US Army Corps
of Engineers ®
Portland District

Crims Island
Section 536 Habitat Restoration Project
Lower Columbia River and Estuary

Draft Integrated Feasibility Report and Environmental Assessment

Project Partners:

U.S. Army Corps of Engineers
U.S. Fish and Wildlife Service
Bonneville Power Administration
U.S. Geological Survey
Columbia Land Trust

April 2004

ABBREVIATIONS AND ACRONYMS

BPA	Bonneville Power Administration
Corps	U.S. Army Corps of Engineers
CRM	Columbia River mile(s)
cfs	cubic feet per second
DEQ	Oregon Department of Environmental Quality
DMEF	Dredge Material Evaluation Framework
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
FY	fiscal year
IDC	interest during construction
LCREP	Lower Columbia River Estuary Program
NEPA	National Environmental Policy Act
NPCC	Northwest Power and Conservation Council
O&M	operations and maintenance
ODFW	Oregon Department of Fish and Wildlife
PCBs	polychlorinated biphenyls
PAHs	polynuclear aromatic hydrocarbons
RPA	Reasonable and Prudent Alternative
SHPO	State Historic Preservation Officer
ug/kg	micrograms per kilogram
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
USFWS	U.S. Fish and Wildlife Service
WDFW	Washington Department of Fish and Wildlife

EXECUTIVE SUMMARY

Over the past 100 years, dike and levee building, hydrosystem operations, and other activities have reduced the amount of available wetland habitat in the lower Columbia River and estuary by about 75% over historical levels. The U.S. Army Corps of Engineers, Portland District, and the U.S. Fish and Wildlife Service propose to restore 92 acres of native tidal emergent marsh, mudflat, and side channel habitats; restore tidal flow to 88 acres of forested swamp/freshwater marsh; and reestablish 115 acres of native riparian forest habitat on Crims Island, located at Columbia River miles 54-57 on the Oregon side of the navigation channel.

The proposed project will benefit many fish and wildlife species, including federally listed salmonids, the endangered Columbian white-tailed deer, and the threatened bald eagle, as well as waterfowl and Neotropical migratory birds. Proposed restoration of tidal emergent marsh, forested swamp/freshwater marsh, riparian forest; connection of restored wetlands and tidal channels to the mainstem Columbia River; management of non-native invasive plant species; and increased export of detrital nutrients will mimic the more natural riparian forest/tidal marsh habitats that were historically abundant in the Columbia River estuary. A monitoring program will measure the response of fish, especially juvenile salmonids, and vegetation to the restoration measures.

Project partners include the U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, Bonneville Power Administration, U.S. Geological Survey, and the Columbia Land Trust. The Columbia Land Trust acquired fee title ownership to 473 acres on Crims Island, and will transfer ownership of those acres to the U.S. Fish and Wildlife Service for inclusion into the Julia Butler Hansen National Wildlife Refuge. The Service also has made an offer to the current landowner for the purchase of an additional 90 acres on the island, which are contiguous and west of the new acquisition. The Oregon Division of State Lands and another private holding (about 36 acres) comprise the remaining ownership of the island. The costs for Columbian white-tailed deer reintroduction would be shared between the Bonneville Power Administration, U.S. Fish and Wildlife Service, Oregon Department of Fish and Wildlife, and the Washington Department of Fish and Wildlife.

Restoration of habitat for juvenile salmonids migrating through the lower Columbia River and the estuary is an important component of regional recovery plans. The proposed project addresses numerous limiting factors and fish and wildlife needs identified in the 2001 *Lower Columbia River and Columbia River Subbasin Summary*. It is consistent with and will help achieve the Northwest Power and Conservation Council's biological objectives outlined in their 2000 *Columbia Basin Fish and Wildlife Program*. The proposed project addresses the 2000 *Federal Columbia River Power System Biological Opinion* Reasonable and Prudent Alternatives for listed salmonids and will aid in U.S. Fish and Wildlife Service's recovery efforts for the endangered Columbian white-tailed deer.

This integrated Feasibility Report and Environmental Assessment examines existing conditions in the Crims Island study area, proposes alternatives for restoring important habitat functions on Crims Island, evaluates the potential environmental impacts of the proposed alternatives in accordance with the National Environmental Policy Act, and recommends a preferred restoration alternative.

Crims Island Section 536 Habitat Restoration Project Draft Integrated Feasibility Report and Environmental Assessment

Table of Contents

Note: * Indicates information required for National Environmental Policy Act compliance.

Table of Contents (continued)

Note: * Indicates information required for National Environmental Policy Act compliance.

Table of Contents (continued)

Plate 1. Crims Island Section 536 Ecosystem Restoration Project

LIST OF TABLES

LIST OF FIGURES

APPENDICES

Note: * Indicates information required for National Environmental Policy Act compliance.

1. INTRODUCTION

1.1. Purpose and Need*

The purpose of the Crims Island Section 536 Habitat Restoration project is to restore tidal emergent marsh, tidal channel, and riparian forest habitats on the island to benefit many fish and wildlife species in the lower Columbia River and estuary (Figure 1). The proposed project specifically provides juvenile salmonid rearing/foraging habitat for threatened fall chinook (*Oncorhynchus tshawytscha*) sub-yearlings and threatened chum salmon (*Oncorhynchus keta*), both Endangered Species Act (ESA) listed Evolutionarily Significant Units (ESUs), as well as coho salmon (*Oncorhynchus kisutch*), a candidate species for listing. Other salmonids including endangered Snake River sockeye salmon (*Oncorhynchus nerka*), threatened steelhead trout (*Oncorhynchus mykiss*), and coastal cutthroat trout (*Oncorhynchus clarki*), are expected to benefit from the restoration of historic linkages in the estuarine food web on Crims Island through the reestablishment of tidal wetland emergent vegetation, increases in detrital export to the river and estuary, and associated benefits from increases in benthic invertebrate populations. The proposed project also provides habitat for waterfowl, bald eagles (*Haliaeetus leucocephalus*), and neotropical migratory birds, and contributes to the recovery of the endangered Columbian white-tailed deer (*Odocoileus virginianus leucurus*). A monitoring program will measure the response of fish, especially juvenile salmon, and waterfowl, Columbian white-tailed deer, and vegetation to the restoration measures.

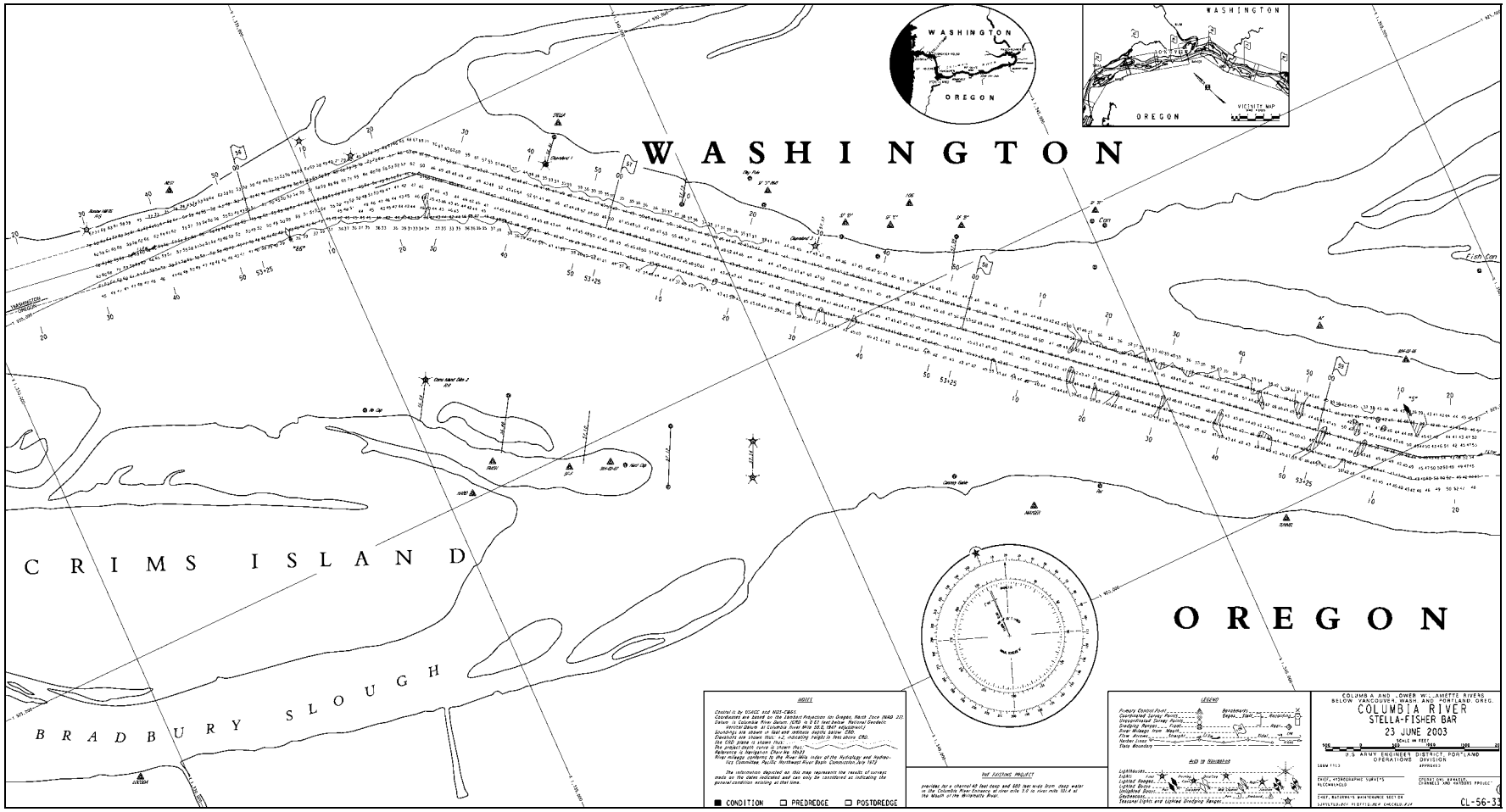
The need for habitat restoration at Crims Island is predicated upon the significant historic losses of tidal marsh and riparian forest habitat along the lower Columbia River. Over the last century, the amount of available wetland habitat in this region has decreased by about 75% over historical levels because of dike and levee building, hydrosystem operations, and other activities (NPCC 2001). A recent finding of the LCREP Science Working Group identified a number of priority projects that would provide significant benefits to fish and wildlife. The conservation of mainstem channel islands, particularly those providing opportunities for restoration, was identified as an important objective. Restoration and conservation of these islands and associated shallow water habitat would benefit estuary condition and salmonid populations throughout the Columbia River system.

Also, riparian plant communities dominated by Oregon ash and cottonwood forest have declined approximately 86% from historical levels, and forested swamp dominated by Sitka spruce has declined 70% (Graves et al. 1995, Corps 1996). Restoration of riparian habitat for juvenile salmonids migrating through the lower Columbia River and estuary is an important component of regional recovery plans and the successful reestablishment of healthy, self-sustaining populations. The lower river and estuary are critical areas for migrating juveniles, especially anadromous salmonids federally listed as threatened or endangered, because these areas provide refugia from predators, feeding grounds, and areas to transition physiologically from freshwater to saltwater.

Additional Columbian white-tailed deer would be reintroduced to the island to help establish three viable subpopulations on secure habitat in upper estuary and meet the goals of the *Revised Columbian White-tailed Deer Recovery Plan* (USFWS 1983). The costs for white-tailed deer reintroduction would be shared between the BPA, USFWS, Oregon Department of Fish and Wildlife (ODFW), and the Washington Department of Fish and Wildlife (WDFW).

Project partners include the U.S. Army Corps of Engineers (Corps), Bonneville Power Administration (BPA), U.S. Fish and Wildlife Service (USFWS), U.S. Geological Survey (USGS), and the Columbia Land Trust. The USFWS is the sponsor for the proposed project.

Figure 1. Crims Island Vicinity Map



This integrated Feasibility Report and Environmental Assessment examines existing conditions in the Crims Island study area, proposes alternatives for restoring important habitat functions on Crims Island, evaluates the potential environmental impacts of the proposed alternatives, and recommends a preferred restoration alternative. The Environmental Assessment integrated into the Feasibility Report satisfies the requirements of the National Environmental Policy Act.

1.2. Study Authority

Section 536 of the Water Resources Development Act of 2000 (Public Law 106-541) authorized the Lower Columbia River Ecosystem Restoration Study to bring together and implement current efforts by a number of governmental and private organizations to identify and cost share restoration projects. These organizations include the National Estuary Program, six state agencies from Oregon and Washington, four federal agencies, recreation, ports, industry, agriculture, labor, commercial fishing, environmental interests and private citizens. The purpose of the Section 536 study is to carry out ecosystem restoration projects necessary to protect, monitor and restore fish and wildlife habitat based on recommendations made by the Lower Columbia River Estuary Program (LCREP). Section 536 is principally focused on fish and wildlife habitat needs as outlined by LCREP, and allows for immediate identification and construction of restoration projects.

1.3. Study Area Description*

The proposed project is located on Crims Island within the Columbia River estuary. Crims and Gull Islands form a small island complex on the Oregon side of the navigation channel between river miles (CRM) 54-57 in Columbia County. Crims Island is approximately 2.5 miles long and 0.5 miles wide at its widest point. Longview, Washington, is the nearest major city lying upstream of Crims Island at CRM 65. Clatskanie, Oregon, lies approximately 5 miles south and inland of Crims Island.

The islands are approximately 743 acres in size, including claimable tide lands, with land holdings belonging to Oregon Division of State Lands, USFWS, RSG Products, and two private landowners. The Columbia Land Trust has acquired fee title ownership to 393 acres on Crims Island, plus 80 acres of claimable tidal lands, which were previously owned by Jefferson Poplar (Figure 2). Ownership of those acres will be transferred to the USFWS at the end of May 2004 and will become an addition to the Julia Butler Hansen National Wildlife Refuge. The USFWS may also acquire additional acres at Gull and Crims Islands in the future.

Crims Island is bordered by the Columbia River to the north and Bradbury Slough to the south and has several acres of open water that vary in depth throughout the year. According to the National Wetland Inventory, the island is comprised largely of palustrine tidal emergent, scrub-shrub, and forested wetlands. The island is beyond the salinity gradient, but is still subject to tidal fluctuations. Smaller areas of riparian and upland habitat are present typically along the outside edge of the island, with the largest expanse of upland at the upstream end of Crims Island. Over time, the island has been altered through homesteading, wetland drainage, agricultural production, berm construction, and grazing by cattle. Landowners do not reside on the island. A small herd of cattle still graze on the island, principally in the high marsh and the pasture at the upstream end.

The potential project area footprint is composed of forested wetlands on the west end and high tidal marsh and upland pasture on the east end. An inlet channel enters the island from Bradbury Slough at the south end of the island. It extends north for approximately 1,000 feet and divides into a channel that is perpendicular to the inlet channel, extending both west and east for approximately 2,000 feet along each leg, forming a ‘T.’ The T-channel was constructed for drainage purposes and at one time included a tidegate that has subsequently failed, allowing for tidal inundation to reoccur.

This T-channel provides the only significant conveyance of tidal inundation into the study area. Several small dendritic tidal channels have formed off the T-channel.

Figure 2. Crims Island Property Ownerships

Ownership Key:
1. RSG Forest Products (proposed for acquisition by USFWS)
2. Jefferson Poplar (acquired by Columbia Land Trust; will be transferred to USFWS)
3. Clifford Family (currently not for sale)
4. Oregon Division of State Lands
5. Tennant Family (currently not for sale)

Few mature riparian trees are present around the high tidal marsh area, although an extensive forested wetland occurs on the west side of the island. The main inlet to the forested wetland has been closed with an earthen plug, blocking interchange of tidal waters. Overall, tidal inundation into the island has been significantly reduced by construction of low berms, impairment of flows by the T-channel, and placement of inlet plugs, one now lost due to erosion. Vegetation in the high tidal marsh and pastureland has been extensively grazed and trampled. Riparian buffers around the high tidal marsh are narrow or nonexistent. There area few immature trees present for successional replacement of riparian forests. Several non-native plant species have become established, including reed canarygrass *(Phalaris arundinacea)*, Himalayan blackberry *(Rubus discolor)*, and purple loosestrife *(Lythrum salicaria)*.

1.4. Problems and Opportunities

The loss of riparian forest and wetland habitats in the lower Columbia River and estuary has been well documented (Graves et al. 1995, Corps 1996). The Northwest Power and Conservation Council's *Lower Columbia River and Columbia River Estuary Subbasin Summary* (NPCC 2001) states that, "Extensive losses of habitat have occurred in the lower Columbia River and Estuary provinces as a result of dredging, filling, diking, and channelization. Estimates from 1870 to 1970 indicate that 20,000 acres of tidal swamps (with woody vegetation; 78% of estuary littoral area), 10,000 acres of tidal marshes (with nonwoody vegetation) and 3,000 acres of tidal flats have been lost." The original extent of tidal marsh and swamp in the estuary has been reduced by more than half (LCREP 1999). The LCREP Management Committee identified habitat loss and modification as one of seven priority issues of concern to the estuary. Also, one of the technical recommendations of *Wy-Kan-Ush-Mi Wa-Kish-Wit Spirit of the Salmon* (Nez Perce et al. 1995) is to protect and restore critical estuary habitat. The estuary wetlands provide habitat for all Columbia Basin salmon stocks at some period in their life cycle. The Independent Scientific Advisory Board report, *The Columbia River Estuary and the Columbia River Basin Fish and Wildlife Program* (November 2000) hypothesized that the significant loss of peripheral wetlands and tidal channels in the estuary has been detrimental to salmonids.

Crims Island's natural concave shape and drainage patterns were altered by construction of low dikes at the island's edges. As a result, the island is bowl-shaped, with lower areas in the interior. Drainage ditches were excavated through tidal habitats and tide gates were added to prevent tidal inundation. The failure of the tide gates led to the abandonment of the island for agricultural purposes. The remaining ditches and dikes continue to alter the island's hydrology. The plug at the downstream end precludes tidal interchange with the interior marshes and forested swamp habitat.

Historic tidal channels on Crims Island have been degraded by direct fill, siltation, tillage, and trampling by cattle. Restoration of tidal channels to a functional state is critical to restoring the proper functioning of tidal wetlands, including the nature and extent of their use by fish and wildlife. The remnant tidal wetlands downriver from Crims Island are typically permeated with conspicuous dendritic and meandering tidal channels tapering in size toward the higher ground at the upstream end. Floodplains upstream display linear shallow troughs with adjacent low ridges formed by high-energy flows that occurred prior to flood control (Christy and Putera 1993). Crims Island displays features of both channel types. The historic tidal channels have been heavily impacted by the practices mentioned above. Reintroduction of dendritic and meandering tidal channels will allow for more efficient tidal ebb and flow, increased topographic heterogeneity, and more efficient export of detrital material (Callaway 2001). Also, fish ingress and egress would be improved with tidal channel and marsh restoration.

Currently, fish habitat (tidal channels and marsh) on Crims Island is in a degraded condition and consists of an excavated, steep-banked, ditched waterway (T-channel), a reed canarygrass-dominated high tidal marsh area, and a forested swamp/freshwater marsh blocked from tidal flow by an earthen plug. Tidal circulation is limited by the natural and artificial berms surrounding much of the proposed restoration area, configuration of the T-channel ditch, and the plug blocking the former tidal channel. The tidal marsh restoration area is presently a dead-end channel that is only open to the Columbia River through the narrow T-channel ditch. Currently, fish use is primarily limited to the ditched T-channel on the island.

Losses of estuarine and tidal riverine wetland habitat have affected all salmonid species using the Columbia River system. Juvenile salmon are known to use tidal habitats in the vicinity of Crims Island (personal communication, W. Van der Naald, ODFW). Studies have shown that both yearling

and subyearling chinook salmon use shallow, intertidal areas (Durkin 1982, McCabe et al. 1986). Subyearling chinook salmon, which use the mainstem Columbia River and estuaries extensively for rearing, have been most affected by losses of shallow, intertidal areas caused by activities such as diking and draining. Other species, such as chum and some coho salmon that use estuarine areas and migrate to the lower Columbia River as fry and fingerling, also are likely to have been impacted by these activities. Coastal cutthroat trout also makes extensive use of the lower Columbia River and the estuary for feeding and migration.

The Lower Columbia River Estuary Partnership Science Working Group identified a number of priority projects that provide significant benefits to fish and wildlife. The conservation of mainstem channel islands, particularly those that provide opportunities for restoration, is identified as an important objective for restoration. Restoration and conservation of these islands and associated shallow water habitat would benefit estuary condition and salmonid populations throughout the Columbia River system. Also, a 1993 survey of lower Columbia River wetland communities completed by The Nature Conservancy identified the importance of conserving the remaining channel wetland habitats.

Currently, reed canarygrass dominates the proposed tidal marsh restoration area on Crims Island. The current tidal prism provides insufficient flooding to discourage reed canarygrass growth at current site elevations. Excavation, in conjunction with inundation, is generally effective for eliminating large, monotypic stands of reed canarygrass (personal communication, R. Stockhouse, Pacific University). Reestablishing the tidal prism would be expected to restore functional habitat to those areas that are relatively free of reed canarygrass, and significantly improve those areas dominated by this wetland invasive. Also, purple loosestrife threatens the native biodiversity of the remaining emergent tidal marsh in the estuary. Purple loosestrife is well established in the Columbia River and its capacity to dominate wetlands and displace native vegetation is well documented (Thompson et al. 1987). The conversion of diverse marsh plant assemblages to monoculture stands of purple loosestrife degrades the estuary ecosystem and has negative effects on juvenile salmonid rearing habitat. Restoration of existing tidal marsh on Crims Island by managing invasive exotic plants would increase native biodiversity for fish. Wetland enhancement by restoring a tidal regime on the island would convert degraded canarygrass wetland to tidal emergent marsh composed of a higher percentage of native plant species and more complex channel configurations (dendritic channels) for salmonid rearing and foraging use.

Since 1968, the lower Columbia River population of Columbian white-tailed deer has been federally listed as endangered. The *Subbasin Summary* contains the following needs as identified in the *Revised Columbian White-tailed Deer Recovery Plan* (USFWS 1983):

- Secure habitat for one additional subpopulation of Columbian white-tailed deer so that there are three secure and viable subpopulations.
- Acquire habitat (fee title or easement) or long-term agreements with private organizations, such as the Columbia Land Trust and The Nature Conservancy, which own habitat.
- Develop a monitoring/management plan that will ensure the population remains recovered.

In summary, Crims Island provides a significant opportunity to restore tidal marsh and riparian forest habitats for federally listed salmonids and Columbian white-tailed deer, plus many other fish and wildlife species present in the lower Columbia River and estuary. Options to restore historic habitat function include excavating the canarygrass-dominated marsh to substantially improve tidal marsh habitat and establish native tidal marsh vegetation, restoring marsh habitat, restoring tidal flow to interior habitats, constructing tidal channels in the marsh, and constructing a side channel(s) that would provide flow through the island. These option(s) are expected to improve flow, circulation,

temperatures, fish ingress and egress for juvenile salmonids, and detrital export to Bradbury Slough and the estuary. The upland pasturelands at the upstream end of the island could be developed as riparian forest habitat, principally a black cottonwood (*Populus trichocarpa*)–Oregon white ash (*Fraxinus latifolia*) forest. Soil excavated to restore tidal marsh habitat and channels would be disposed on adjacent pasturelands and then utilized for establishment of riparian forest habitat. Riparian forest establishment would benefit Columbian white-tailed deer, bald eagles, and Neotropical migratory birds, plus provide for future detrital, insect, and large woody debris export into the estuary.

1.5. Planning Criteria

The overall purpose of the study is to investigate and recommend habitat restoration alternatives for Crims Island that would be applicable for restoring tidal emergent marsh, mudflat, side channel, riparian forest, and forested swamp/freshwater marsh habitats in the lower Columbia River and estuary.

1.5.1. General Criteria

- Compatibility with other habitat restoration efforts in the lower Columbia River and estuary by federal, state and local agencies, and private organizations.
- Conduct analyses of environmental benefits and costs in accordance with Corps regulations to ensure that any plan is viable and cost effective.
- Protect public health, safety, and well being.

1.5.2. Technical Criteria

- The target elevation of the restored tidal marsh habitat will be based upon a nearby reference tidal marsh (Gull Island) subject to comparable tidal and river stage water levels.
- Size and capacity of tidal channels will be based upon volume of water present in the tidal marsh based upon acreage, depth of excavation, and flood tide elevation.

1.5.3. Environmental Criteria

- Restore native tidal emergent marsh, mudflat, side channel, and riparian forest habitats.
- Restore tidal flow and circulation to an existing forested swamp/freshwater marsh.
- Restore off-channel rearing/foraging habitat and ingress/egress for listed salmonids and other native fish species.
- Improve habitat conditions for Columbian white-tailed deer, waterfowl, bald eagles, and Neotropical migratory birds.
- Improve water quality conditions.

1.6. Relationship to Regional Studies and Projects

The overall vision for the *2000 Columbia Basin Fish and Wildlife Program* (NPCC 2000) states, "Wherever feasible, this program will be accomplished by protecting and restoring the natural ecological functions, habitats, and biological diversity of the Columbia River Basin." The habitat strategies section of the *Program* emphasizes the importance of protection and restoration of mainstem habitat conditions. Strategies include restoring ecosystems, not just single species (Crims Island would restore tidal emergent marsh and riparian forest, which are vital components of the estuary ecosystem); use native species wherever feasible (recovery of Columbian white-tailed deer, establishment of native tidal marsh and riparian forest vegetation); and include the estuary. The

basin-level biological objectives in the *Program* call for coordinating wildlife mitigation activities with fish mitigation and restoration efforts by combining wildlife habitat restoration and acquisition with aquatic habitats. The restoration objectives for Crims Island link the recovery of the Columbian white-tailed deer with protection and restoration of aquatic and riparian habitat for fish and other wildlife. Crims Island provides important perching and foraging habitat for bald eagles; there also is a bald eagle nest site on the island. Riparian forest habitat will provide nesting and foraging habitat for Neotropical migratory birds.

The habitat restoration objectives for Crims Island are consistent with the *Provisional Statement of Biological Objectives for Environmental Characteristics at the Basin Level* (Appendix D of the *Program*). For example, Biological Objective 2 aims to: (1) increase the connections between rivers and their floodplains, side channels and riparian zones; and (2) manage riparian areas to protect aquatic conditions and form a transition to floodplain terrestrial areas and side channels. Biological Objective 4 aims to increase energy and nutrient connections within the system to increase productivity and expand biological communities. The restoration objectives for Crims Island would address these needs by reconnecting tidal flow to a forested swamp/freshwater marsh, providing side channels to improve flow and fisheries ingress/egress, enhancing productivity and connectivity in a tidal marsh, and establishing riparian forest to provide detrital nutrients. A monoculture of reed canarygrass on the island would be replaced with a more diverse assemblage of vegetation native to the Columbia River floodplain.

The *Lower Columbia River and Columbia River Estuary Subbasin Summary* (NPCC 2001) contains a recommendation by the Independent Scientific Advisory Board to, "Remove dikes in the lower river and upper estuary to restore connections between peripheral floodplains and the river…." The report, *Salmon at River's End: The Role of the Estuary in the Decline and Recovery of Columbia River Salmon* (Bottom et al. 2001) recommends a management action to, "Protect and restore opportunities for salmon to access emergent and forested wetlands in the estuary and riparian wetlands in the tidal floodplain."

The *Subbasin Summary* incorporates the technical recommendations of *Wy-Kan-Ush-Mi Wa-Kish-Wit Spirit of the Salmon* (Nez Perce et al. 1995) including, "Begin improving in-channel stream conditions for anadromous fish by improving or eliminating land-use practices that degrade watershed quality." The principal land use on Crims Island is year-round cattle grazing. Cattle have access to the entire island and grazing is degrading the vegetative structure and composition and the water quality of the tidal marsh and swamp habitat. In addition, cattle grazing preclude restoration of riparian forest habitat via natural regeneration. The restoration objective for the island is to end cattle grazing, improve water quality, restore riparian forest habitat and increase the value of the wetlands as salmonid rearing and foraging habitat.

The *2000 Federal Columbia River Power System Biological Opinion*, Section 9.6.2.2, supports the actions of the *Comprehensive Conservation and Management Plan* (LCREP 1999). A goal of Action 2 of the *Plan* is to, "Protect, conserve, and enhance identified habitats, particularly wetlands, on the mainstem of the lower Columbia River." The environmental measurement for this action is to permanently enhance, protect, or reclaim 10,000 acres of wetland habitat and 3,000 acres of upland habitat by 2010. Similarly, in order to rebuild productivity in the lower 46 river miles, Reasonable and Prudent Alternative (RPA) 160 in the *Biological Opinion* calls for protecting and enhancing 10,000 acres of tidal wetlands and other key habitats over the next 10 years. To help achieve these goals, LCREP and NOAA Fisheries developed a list of proposed habitat restoration projects that included the acquisition and restoration of Crims Island. The restoration objectives for lands purchased (473 acres) on Crims Island will contribute more than 115 acres of riparian forest, 75 acres of tidal marsh habitat, and 17 acres of tidal channel habitat toward achievement of the goals of

Action 2 and RPA 160, as well as other RPA actions. An additional 4 acres of channel habitat is being considered for development. Acquisition of another parcel of land on Crims Island could lead to the restoration of tidal flow to an additional 88 acres.

The restoration objectives for Crims Island also would complement the following projects that restore tidal wetlands and other key habitats, and monitor salmonid use in the lower Columbia River and estuary.

- The Grays Bay Estuary Project. The Columbia Land Trust, Ducks Unlimited, USFWS, WDFW, Natural Resources Conservation Service, National Fish and Wildlife Foundation, and Lower Columbia Fish Recovery Board are cooperating to acquire, restore, and enhance 350 acres of tidally influenced palustrine forested wetland (the total of approved and highly ranked projects is over 800 acres). Monitoring of fish use is a critical element of this project.

- Lord Island Protection. The Columbia Land Trust purchased Lord Island (CRM 63.5) to preserve the habitat values of more than 200 acres of tidal wetland and riparian forest. The Oregon Watershed Enhancement Board and the National Fish and Wildlife Foundation funded the project. This conservation project was strongly supported by the local community.

- The Klaskanine River Estuary Project. The Columbia Land Trust and Ducks Unlimited are restoring tidal wetlands to this estuary, located in the North Coast Basin.

- The Chinook River Section 536 Project. The Corps, WDFW, Sea Resources, Columbia Land Trust, Ducks Unlimited, USFWS, and other agencies are proposing to restore tidal influence to the Chinook River and estuary, located near the mouth of the Columbia River in Washington.

- Estuarine habitat and juvenile salmon, current and historic linkages in the lower Columbia River and estuary. Project EST-P-02 of the Corps Anadromous Fish Evaluation Program. This project specifically examines a broad range of ecosystem functions that relate to juvenile salmonid habitat use of estuarine habitats.

2. AFFECTED ENVIRONMENT*

2.1. Physical Characteristics

2.1.1. Geology and Soils

The island is formed of floodplain soils, such as Locoda and Wauna-Locoda silt loams, and Udipsamments (NRCS 1985). Areas less than 10 feet in elevation are comprised of the silt loams, which are deep poorly drained soils with slopes of 0 to 3%. Permeability of these soils is moderately slow and available water capacity is about 10 to 14 inches. Most areas of these units are used for habitat for wetland wildlife. Elevations from 5-20 feet are composed of the udipsamments, which are very deep, excessively drained soils on slopes of 0 to 3%. These sandy soils have permeability that is rapid or very rapid and are used mainly for recreation and wildlife habitat (NRCS 1985).

2.1.2. Sediment Quality

As part of the Columbia River Channel Improvement Project, three sediment samples were collected in the navigation channel adjacent to Crims Island in 1997. Physical analyses were conducted on all three samples, with chemical analyses conducted on one of the samples. The mean grain size for all samples was 0.48 mm, with 99.5% sand and 0.3% fines. Chemical data for the sample analyzed showed that no metals, pesticides, polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs), phthalates, or phenols were above the screening levels of the *Dredge Material Evaluation Framework for the Lower Columbia River Management Area* (DMEF; November 1998). In 1999 and 2000, the U.S. Environmental Protection Agency (USEPA) collected three sediment samples in the vicinity of Crims Island and Bradbury Slough. Chemical analyses showed that none of the compounds analyzed exceeded the DMEF guidelines.

Five sediment samples were collected from the project site on July 15, 2003. All samples were submitted for physical analyses, including total volatile solids. Chemical analyses were run for metals (9 inorganic), total organic carbon, pesticides, PCBs, phenols, phthalates, miscellaneous extractables, and PAHs (see Appendix B for additional information). Three samples were classified as ‘silty sand’ and two samples as ‘sandy silt.’ Mean grain size for all the samples is 0.05 mm, with 0.05% gravel, 40.67% sand (57.78%-32.38% range), 59.27% silt/clay (75.33%-42.22% range) and 4.60% volatile solids (2.74%-8.78% range).

The chemical analyses indicated low levels of metals, low levels of several phenol and phthalate compounds, and very low levels of PAHs. The benzyl alcohol level in one sample was at 68.9 micrograms per kilogram (ug/kg), which exceeded the DMEF screening guideline of 57 ug/kg. Sixty percent of the benzyl alcohol produced is used in the textile industry as a dye assistant. Other uses include lacquer solvent, plasticizer, photographic developer, a preservative in medication, and ballpoint pen inks. It can enter the environment from the exhaust of motor vehicles and effluent from Kraft mills. There also are natural sources of benzyl alcohol in the environment; it is contained in the oils of several plants (for example, hyacinth and jasmine). While the level of benzyl alcohol exceeded the DMEF screening level, it was detected in only one sample, which possibly picked up an isolated piece of debris containing benzyl alcohol, or was a laboratory artifact.

2.1.3. Hydrology

Crims Island is located at CRM 54 to 56.5 on the lower Columbia River, upstream of saltwater estuary, but still subject to tidal action. The Corps' Northwestern Division produced combined probability flood profiles for the lower Columbia River (June 1, 1994) based on the unsteady flow model results. Table 1 shows the flood frequency elevations at the upstream and downstream ends of Crims Island.

Table 1. Columbia River Combined Probability Flood Elevations

Location	Water Surface Elevations for Given Flood Frequency in feet NGVD (feet NAVD88)				
	2-year	10-year	50-year	100-year	500-year
CRM 54.0, downstream end of Crims Island	10.2 (13.4)	12.1 (15.3)	13.7 (16.9)	14.3 (17.5)	16.1 (19.3)
CRM 56.6, upstream end of Crims Island	10.4 (13.6)	12.6 (15.8)	14.3 (17.5)	15.0 (18.2)	16.9 (20.1)

Source: CENPP-PE-HY

To gain perspective on the magnitude of mean flow during flood events, flood frequency flows above the tidal zone at The Dalles Dam (CRM 191.5) are shown in Table 2. Several rivers join the Columbia River below The Dalles Dam, including the Willamette, Lewis, and Cowlitz Rivers. Regulated discharge flow frequency values are taken from a Corps' analysis dated June 1987.

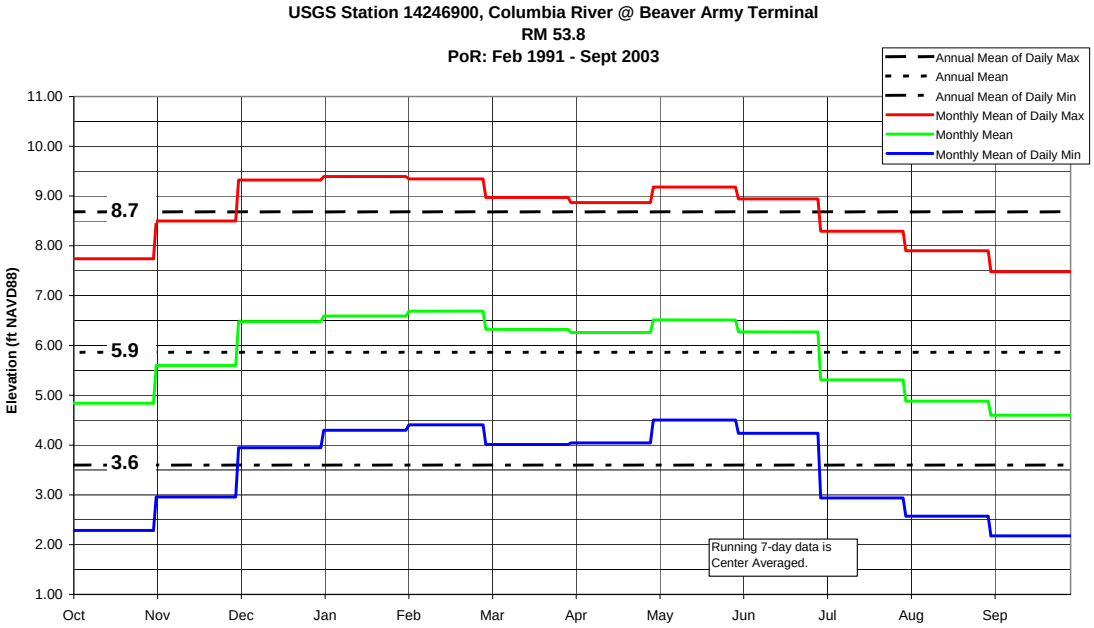
Table 2. Columbia River Regulated Flood Frequency Flows at The Dalles Dam (CRM 191.5)

Maximum Annual Daily Regulated Discharge for Given Frequency x 1000 cfs				
2-year	10-year	50-year	100-year	500-year
360	515	635	680	800

An analysis of USGS station 14246900 Columbia River at Beaver Army Terminal, located at CRM 53.8, was performed in order to gain understanding of the tidal effects at Crims Island. This station has been recording instantaneous stage data at 15-minute intervals since February 1991. Review of the Columbia River flood profiles show that the difference in water surface between Beaver Army Terminal and Crims Island is 0.2 feet at 2-year flood frequency flows. During extreme conditions, low river flow and high tides, negative flows are observed in the Columbia River at Beaver Army Terminal. Therefore, a constant shift cannot be applied to the observed stage data. Stages at Crims Island will be considered as equivalent to Beaver Army Terminal for this study.

Mean values over the period of record for each Julian day are calculated for maximum, minimum and mean stages. Monthly and annual means are calculated from each of these daily values (Figure 3). The average daily tidal range at CRM 53.8 is 5.1 feet. The seasonal variation ranges from a low monthly mean of 4.6 feet in September to a high monthly mean of 6.7 feet in February.

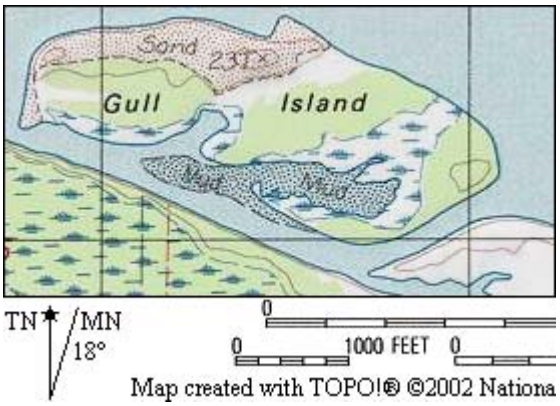
Figure 3. Stage-frequency at Columbia River Mile 53.8



Reference Marsh

The reference marsh for development of design elevations is located on Gull Island, near the western end of Crims Island (Figure 4). This marsh is sufficiently close to the project area to consider the driving river stages equivalent between the two areas.

Figure 4. Gull Island Reference Marsh



The downstream boundary of the reference marsh on Gull Island is a channel off of the Columbia River that separates Crims Island from Gull Island. This channel is subtidal and large (4 to 5 times in width) compared to the largest channel in the reference marsh. The downstream interface between this channel and the reference marsh is a gently sloping unvegetated mudflat. The highest elevations in this mudflat are 6.0-6.5 feet (NAVD88). This mudflat yields to a vegetated marsh plain at elevations 7.2-8.0 feet in a narrow zone of steep grade. A single channel passes through this lower marsh plain and then bifurcates into two distinct zones. One branch of the bifurcated channel

connects the downstream water source to an interior quasi-mudflat (lightly vegetated, very soft soils similar to non-vegetated mudflat). This channel bisects the interior mudflat and is distinguishable throughout the length of the mudflat. This interior quasi-mudflat exists at an elevation of 6.5-7.0 feet. This interior mudflat yields to vegetated marsh plain on either side.

The second branch of the bifurcated main channel bisects a marsh plain. The steep banks of the channel yield to vegetated marsh plain at elevation 7.5-8.0 feet. This channel can be follow to the upstream boundary of the reference marsh. The marsh plain on either side of this channel is the highest non-lands in the intertidal area and has the highest elevation at 9.5 feet.

Elevation of the reference marsh plain corresponds well with the stage-frequency analysis of Beaver Army Terminal USGS station 14246900 (Figure 3). The daily maximum stage averaged per month for the period of record varies from a low of 7.5 feet in September to a high of 9.4 feet in December (NAVD88). This is the same range of elevations seen in the vegetated marsh plain in the reference marsh. This relationship between daily maximum stage elevations and marsh plain elevations follows marsh development theory (Callaway 2001) and will serve as a design elevation range for excavations in the project area.

Tronson Island, located at CRM 30, provides an analog for the wetland channel system (Figures 5 and 6). Several factors make this particular site appealing as a reference:

- The soil types on Tronson Island are similar to those found in the project area.
- The inland intertidal marsh is supplied water from two main channels, one downstream and one mid island, similar to the channel system proposed on Crims Island.
- The two main wetland channels on Tronson Island are connected to a side slough and not the main stem of the Columbia River.
- The marsh area on Tronson Island is roughly equivalent to the project area on Crims Island.

Figure 5. Tronson Island from USGS 7.5' Quadrangle Map

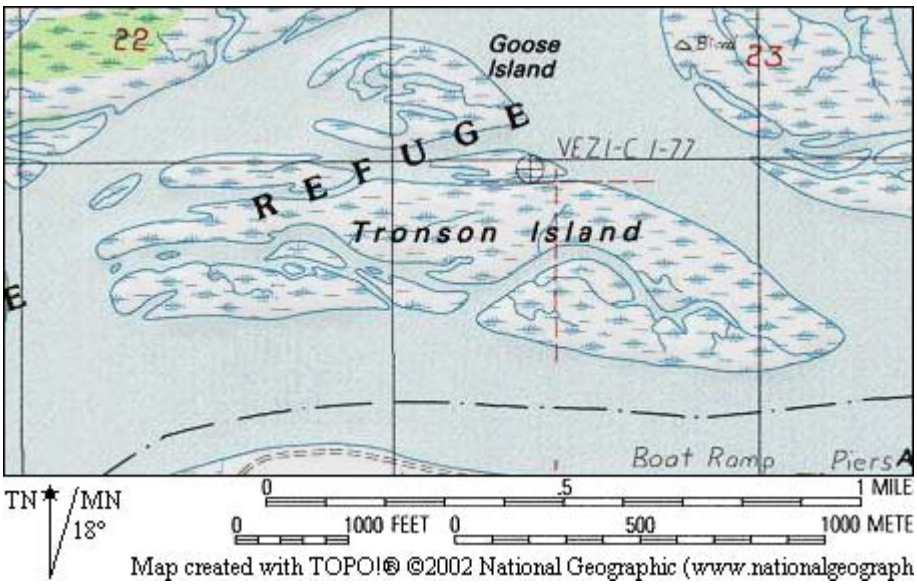


Figure 6. Tronson Island 2001

2.1.4. Floodplains

The majority of Crims Island is located within the 2-year flood elevation of the Columbia River. Few berms exist on the island that would not be overtopped during a 2-year flood event. The Island is upstream of the saline gradient, but still subject to tidal action. The presence of large dams upstream from Crims Island and development of floodplains has had a significant influence on the frequency and duration of large scale flood events.

Flood flows of a 2-year event in the area have elevations ranging from 13.4 to 13.6 feet. Average tidal fluctuation ranges between a mean lower low water of 3.6 feet and mean higher high water of 8.7 feet. As a result, many portions of the study area are currently inundated by normal tidal fluctuations, but only during wet seasons or extreme high tides. The majority of the area would be overtopped by a 2-year flood although some areas of the island are above the 100-year flows.

Much of the island is tidal marsh and several tidal channels are present within and between Crims and other surrounding islands. Gull Island, to the northwest, and several other smaller unnamed islands, are separated from Crims by channels. Within Crims, two main channels are present, including the T-channel that enters the island from Bradbury Slough and the channel leading from the north end of the island into the forested wetlands. The T-channel is artificially steep, although several smaller natural tidal channels have formed and radiate outward from it.

The T-channel was artificially created to allow drainage of the island for agricultural and grazing uses and at one time included a tidegate which has been subsequently lost to erosion. In addition, a low berm was constructed around the island and the inlet to the forested wetland was closed off with an earthen plug. These measures provided further reduction in tidal inundation or flooding of interior portions of the island in order to protect agricultural use. Floodplain interactions within Crims Island are constrained by the presence of artificial channels, the remaining inlet plug, and low berms.

2.1.5. Water Quality and Quantity

The lower Columbia River Basin extends from Bonneville Dam to the mouth of the river, a length of over 146 miles, and drains 18,000 square miles west of the Cascade Range crest (Fuhrer et al. 1996). Crims Island is within the Columbia River estuary, the area influenced by daily tidal fluctuations. The Columbia River has an altered hydrograph, resulting from the construction and operation of numerous dams on the mainstem and tributaries. The median annual streamflow was 260,000 cfs for the years 1928-1984 (Fuhrer et al. 1996). Annual peak flows primarily occur in the spring as a result of snowmelt.

Construction of low dikes around the edge of Crims Island has altered the connectivity of the inland wetlands and tidal channels to the Columbia River. Historic tidal channels on the island have been degraded by direct fill, siltation, tilling for crops, and trampling by cattle. The plug on the west end of the island reduces tidal connectivity to a large interior forested wetland.

The water quality of the Columbia and lower Willamette Rivers was previously addressed in two studies (Tetra Tech 1995, 1996). The conclusion of these studies relative to the health of the rivers characterize them as 'marginally healthy' based on levels of dissolved oxygen, toxins, and habitat conditions. The primary unregulated sources of pollutants include non-point sources such as urban and agricultural runoff.

The 303(d) list of water quality-limited streams shows the Columbia River, including the study area, as exceeding several parameters, including dissolved oxygen, temperature, total dissolved gas, and fecal coliform, and has been found to have exceedences for several pollutants, including 4,4'-DDE, arsenic, bis (2-ethylhexyl) phthalate, Dieldrin, PCB-1248, PCB-1254, and PCB-1260. Cattle are currently grazing the island and contribute to poor water quality conditions through temporary sediment disturbance and increased contribution of fecal coliforms to the wetlands and Columbia River. The preparation of a TMDL is underway for total dissolved gas and temperatures within the lower Columbia River and should be completed in 2004.

2.1.6. Hazardous, Toxic, and Radioactive Waste

A Level I Contaminant Survey (Environmental Site Assessment) for the Jefferson Poplar property on Crims Island (#2 on Figure 2) was conducted by environmental contaminant specialists with the USFWS on March 20 and April 1, 2003. A variety of old, rusty farm equipment was near the house, including several rusted 55-gallon drums, a watering trough, and an aerosol can. Household debris consisted primarily of two refrigerators. Since there was no information on when the house was constructed, it is possible that lead-based paints and asbestos are present. Also, an old 500-gallon propane tank was located near the shore about 0.25 miles away from the house. The tank was rusty and the gauge broken; it was unknown whether any gas remained in the tank. Proper disposal of the debris, structures, tank, and lead-based paints/asbestos, if present, were a condition of acquisition and transfer of property to the USFWS. No evidence of asbestos was found and the presence of any lead-based paints in the abandoned residence (circa 1910) was remediated when the house was burned in the autumn of 2003. Removal/disposal of remaining debris will be accomplished during project construction.

There was an elevated area of sandy fill material about 2-3 acres in size along the western border of the property. The material appeared to have been in place for a long time based on the moss layer and vegetation fringing the fill area. The observations made during the site visit indicated that the fill did not likely contain contaminated material due to the sandy nature of the fill, the healthy appearance of mosses growing on the sand, and the absence of staining in drainages.

A search for federal hazardous waste facilities listed on the USEPA's Comprehensive Environmental Response, Compensation, and Liability Act Information System database revealed no active sites within 1 mile of the Jefferson Poplar property. However, one archived site was located on the island (see discussion for Oregon).

A search for Washington hazardous waste facilities listed on the Confirmed and Suspected Contaminated Sites Report database at the Washington Department of Ecology revealed no facilities within 1 mile of the property.

A search of Oregon hazardous waste facilities listed on the Environmental Cleanup Site Information database at the Department of Environmental Quality (DEQ) showed two facilities within 1 mile of the property. A removal site on the south side of Crims Island and on the property itself was designated as an archived site by the USEPA, which means that to the best of their knowledge, assessment was completed and no further steps needed to be taken to list the site. A preliminary assessment was conducted in 1989 and the removal occurred during the same year. The site was archived in 1996. Additional information regarding the removal history could not be obtained during interviews and record searches. During site visits, no signs of abandoned or active structures or evidence of a removal action were observed at the removal action coordinates. Also, there was no evidence of disrupted soil or discolored/dying vegetation at or near the removal action coordinates. Based on the site history and conditions observed during the site visits, the USFWS concluded that this site did not appear to pose a contaminant threat to fish and wildlife resources.

The second site, Portland General Electric's Beaver Generating Plant, is located across Bradbury Slough on the Oregon shore. The site was listed due to a 200-gallon spill of turbine lube oil in 1999. Oil migrated to the underlying soil and into a dry well. Contaminated soil was removed. Although PCBs were detected in the waste soil, they were suspected to have originated from historical releases. The database indicated that the wetlands adjacent to the site may have been impacted by the spill due to overland runoff and possibly from discharge of impacted shallow groundwater. The DEQ information stated that the PCBs detected were below the level for industrial cleanup and relatively insoluble. Given that the contaminated soil was removed, the USFWS concluded that the site did not appear to pose a threat to fish and wildlife resources.

2.2. Aquatic and Riparian Habitat

According to the National Wetland Inventory (USFWS 2002), approximately 70% of Crims Island is composed of wetlands. The island can be separated into two major vegetation types, with emergent wetland primarily present on the east half (high tidal marsh), and scrub-shrub or forested wetland primarily present on the west half. The eastern wetlands are dominated by reed canarygrass, with few native sedges and rushes. The scrub-shrub and forested wetlands are dominated by black cottonwood, Oregon ash, willow (*Salix* ssp.), elderberry (*Sambucus* ssp.), red osier dogwood (*Cornus stolonifera*), and spirea.

Portions of Crims Island are subject to tidal inundation. Gull Island lies at the western end of Crims Island and the two islands form a complex of riparian forest, tidal marsh, forested swamp/freshwater marsh, side channel, dredged material disposal, and upland pasture habitats. A side channel separates the dredged material disposal location at the upstream end of Crims Island (Site O-57.0) from the main portion of the island. Another side channel dead ends along the northern side of the main portion of Crims Island. The plug near the downstream end of the island prevents tidal inundation of an 88-acre area characterized as forested swamp/freshwater marsh except during high river stages. Tidal marsh vegetation associated with the T-channel and proposed for restoration is dominated by

reed canarygrass. Other tidal marsh communities in the Crims-Gull Island complex vary from low to high marsh. Plant species that compose tidal marsh vegetation include tufted hairgrass (*Deschampsia caespitosa*), sedges, and common spikerush, and introduced species such as yellow flag (*Iris pseudacorus*) and purple loosestrife.

Riparian forest is present in areas where elevations are slightly higher than in forested wetlands, typically including the outer edge of the island, but also including a large area in the central north portion. Dominant riparian species are black cottonwood and willow. Cottonwoods are approximately 50 to 100 years old. Understory species within riparian zones include thick stands of roses, willows, non-native blackberry, and dogwood species. Emergent wetlands are dominated by the non-native reed canarygrass, and have few areas of native forbs, such as rushes and bulrushes Much of the east half of the island has been mowed or grazed for cattle, resulting in a reed canary grass monoculture. Scrub-shrub wetland species also include roses, willows, and dogwoods, with fewer areas of blackberry. All habitats within Crims Island have a non-native component. Reed canarygrass grows in all habitat types, while Himalayan blackberry is present in scrub-shrub and forested areas, and purple loosestrife has become established throughout the island.

Overall, the scrub-shrub and forested wetlands and riparian forests on Crims Island currently provide good cover and nesting habitat for a variety of species. However, emergent wetlands have degraded significantly as a result of reed canary grass invasion, mowing, and grazing by cattle. A vegetation study is scheduled for the spring of 2004 to compare the Crims Island communities to reference sites.

2.3. Fish and Wildlife

2.3.1. Fish

Upriver migrating adult salmonids are present in the Columbia River and estuary throughout the year. Their residence time in the estuary is usually short, and they normally do not feed to any extent. However, some migrating adult salmonids may hold in the lower river or estuary for some period of time before entering their spawning streams. Their presence in the Crims Island area would be expected to be transitory because there are no nearby natal streams.

Juvenile salmonids are present in the lower river in the early spring and summer during their migration to the ocean. Actively migrating year-old juvenile spring chinook, coho, and steelhead smolts migrate principally at the surface over the deeper water portion of the river, and move through the lower river and estuary without stopping. Chum and fall chinook have life stages that include migrating downstream, but do not become smolts at this time and are referred to as subyearling fish. These subyearling fish migrate downstream at a slower rate and can be present in the lower Columbia River and Estuary for extended periods of time. They rear in the shallow water areas and bays such as Cathlamet, Youngs and Grays Bays before becoming smolts and migrating to the ocean. Most remain in the estuary throughout the summer, while some may over-winter in the estuary before smolting and migrating to the ocean. These subyearling fish will likely make direct use of the channels and tidal marsh restoration areas proposed at Crims Island.

Northern pikeminnow, peamouth, banded killifish, and large-scale suckers likely occur in the mainstem Columbia River, side channel, and tidal marsh channels in the Crims Island area. Common carp are abundant in tidal marsh and side channel habitats. Three-spine stickleback also occurs in these habitats. Warmwater gamefish are expected to occur in side channel habitat.

2.3.2. Wildlife

Various species of birds and mammals compose the wildlife community on Crims Island. These species are associated with the principal habitat types on the island, which are riparian forest, tidal marsh, and pastureland. Although loons, grebes, cormorants, gulls, and terns are present in the open water habitat surrounding the island, they are not a common component of the avifauna occurring on the island or in the areas proposed for habitat restoration.

Waterfowl, particularly puddle ducks and Canada geese, are seasonally very abundant on Crims Island, which provides waterfowl nesting and foraging habitat (marshes, pastureland for Canada geese and American wigeon) and supports good concentrations of ducks and geese during migration periods and winter. Mallards, northern pintails, American wigeon, green-winged teal, and Canada geese (several subspecies) are probably the most abundant wintering species. Mallards and Canada geese are the principal nesting species on the island.

Raptors (hawks, owls) occur throughout the Crims Island area with a number of species present either as residents and/or wintering birds. Bald eagles, a federally threatened species, are relatively abundant and represented by resident and wintering birds; a nesting pair occurs on Crims Island. Peregrine falcons also are present and occur as resident, migrant and/or wintering birds. The abundance of shorebirds, waterfowl, and non-game birds in the area are attractive to peregrine falcons. Red-tailed hawks nest on the island and wintering birds would be expected on the island. Northern harriers are present as residents, migrants, and wintering birds, particularly in the tidal marsh habitat, which provides good foraging habitat. Cooper's and sharp-shinned hawks probably nest in the riparian forest stands on the island. American kestrels are present and ospreys occur throughout the general area. Osprey will nest on navigation aids, dolphins, range markers, and natural locations such as snags. The existing riparian forest stands on the island currently or in the future will provide nesting platforms for osprey. Great horned and western screech owls are the most abundant owl species, particularly in riparian forest habitat. Barn owls are likely present although abundance is unknown. Short-eared, pygmy, and saw-whet owls may occur as migrants and wintering birds, and some nesting effort by these species may occur on the island.

Upland gamebirds, with the possible exception of ruffed grouse, are not expected to occur on Crims Island. Band-tailed pigeons and mourning doves may occur. Rails and coots are present, with sora and Virginia rail primarily associated with wetlands. American coots use the tidal marsh habitat, sloughs, and backwater channels associated with the island. Shorebird use of the proposed restoration area is minimal given the lack of tidal mudflat habitat.

Numerous bird species frequent Crims Island in abundance and include species such as Vaux's swifts, rufous hummingbirds, belted kingfishers, downy and hairy woodpeckers, northern flickers, six species of swallows, black-capped chickadees, Bewick's wrens, kinglets, Swainson's thrushes, warbling vireos, several warbler species, black-headed grosbeaks, and song sparrows, among others. Riparian and tidal marsh habitats at Crims Island are important to many of these species. Tidal marsh does not support many nesting songbirds due to tidal inundation. Common yellowthroats and song sparrows nest in some of the higher marshes where bulrushes, willows, or other vegetation provides elevated nesting sites. Blackbirds forage in marsh vegetation and swallows forage on insects over the marshes, pastureland, and open-water habitats.

Columbian white-tailed deer, a federally endangered species, are the mammal of most concern in the study area. They principally are located on the Julia Butler Hansen National Wildlife Refuge, Puget Island, and in the Clatskanie bottomlands near Westport. Columbian white-tailed deer are at the upstream end of their recent distribution on the Columbia River at Crims Island. The USFWS

reintroduced 60 Columbian white-tailed deer to the island from 1999-2000 in an effort to establish another secure and viable population of this listed species. In 2003, an estimated 20-30 deer remain on the island (personal communication, J. David, USFWS, 2003). These deer do not generally occur in the proposed tidal marsh, channel, and riparian forest restoration areas due to the presence of cattle grazing at these locations.

Black-tailed deer also may occur on Crims Island, inhabiting riparian forest and upland habitat. They are present on the Oregon mainland across Bradbury Slough from Crims Island. Roosevelt elk also occur in the general area but are probably absent from Crims Island. Black bears would be expected to share a distribution similar to Roosevelt elk.

Beaver, nutria, raccoon, muskrat, mink, and river otter represent furbearers in the study area. The introduced nutria is very abundant, inhabiting dredged material islands, tidal marshes and swamps, sloughs, ponds, backwaters, and diked agricultural and wetland habitat. Beavers are abundant and are associated with wetlands and bodies of water with adjacent riparian forest habitat as are the other furbearers noted. River otter are abundant and well distributed throughout the lower Columbia River (Henney et al. 1996). Mink populations in the lower Columbia River were very low with only one family group and 4 individuals noted during summer surveys and only two animals reported by trappers (Henney et al. 1996). Red foxes, striped skunks, opossums, and coyotes occur throughout the study area, typically on the mainland and infrequently on island habitats. Coyotes are present on Crims Island based on scat observations.

About 32 small mammal species may occur in the study area, excluding bats. Vagrant shrews and deer mice are expected to be the most abundant species (Hinchberger 1978). Vole species would be most abundant in agricultural croplands, particularly pasturelands and grain stubble left standing over winter. Nine or more species of bats may occur throughout the general area using riparian and coniferous forest habitat, buildings, bridges, and other structures for roost and maternity sites.

2.4. Threatened and Endangered Species

The USFWS provided a letter dated May 30, 2003 listing the federally threatened and endangered species that may be present in the Crims Island area (Table 3).

2.4.1. Listed Fish Species

Twelve ESUs of Columbia River salmonids occur in the area (Table 3). Coho salmon (*Oncorhynchus kisutch*; Lower Columbia River/Southwest Washington Evolutionarily Significant Unit) is a candidate species for listing.

Juvenile salmonids are present in the lower Columbia River in the early spring and summer during their migration to the ocean. Year-old juvenile spring chinook, coho, and steelhead smolts (that are actively migrating to the ocean) are migrating principally at the surface over the deeper water portion of the river, and move through the lower river and estuary without stopping. Chum and fall chinook subyearlings and smolts also migrate through the estuary. The subyearling fish migrate downstream at a slower rate and can be present in the lower river and estuary for extended periods of time. They rear in the shallow water areas and bays such as Cathlamet, Youngs and Grays Bays before migrating out to the ocean. Most remain in the estuary throughout the summer, while some may over-winter in the estuary. These subyearling fish will likely make direct use of the channels and tidal marsh restoration areas proposed at Crims Island.

Table 3. Threatened and Endangered Species and Status in the Crims Island Area

ESU (fish) or Common Name (wildlife/plants)	Scientific Name	Federal Status
Chum Salmon – Lower Columbia River	*Oncorhynchus keta*	Threatened
Steelhead Trout	*Oncorhynchus mykiss*	
Lower Columbia River		Threatened
Middle Columbia River		Threatened
Upper Willamette River		Threatened
Upper Columbia River		Endangered
Snake River Basin		Threatened
Chinook Salmon	*Oncorhynchus tshawytscha*	
Lower Columbia River		Threatened
Upper Willamette River		Threatened
Upper Columbia River		Endangered
Fall runs; Snake River		Threatened; Critical Habitat
Spring/summer runs; Snake River		Threatened; Critical Habitat
Snake River Sockeye Salmon	*Oncorhynchus nerka*	Endangered; Critical Habitat
Columbian White-tailed Deer	*Odocoileus virginianus leucurus*	Endangered
Bald Eagle	*Haliaeetus leucocephalus*	Threatened
Howellia	*Howellia aquatilis*	Threatened
Bradshaw's Lomatium	*Lomatium bradshawii*	Endangered
Nelson's Checkermallow	*Sidalcea nelsoniana*	Threatened

Lower Columbia River chum salmon (threatened) are distributed from Bonneville Dam to the mouth of the Columbia River. Adults migrate from early October through November and spawning occurs in November and December. A majority of spawning habitat is in lower portions of rivers just above tidewater (Grays River, Washington) and in the side channel near Hamilton Island below Bonneville Dam. Spawning occurs in the mainstem Columbia River in areas where substrate is gravel. Juveniles outmigrate during spring. Most juveniles rear extensively in estuaries. Historically, Blind Slough and its tributaries supported small number of chum salmon. Currently, limited documentation exists on juvenile chum salmon use of the study area.

Steelhead that may be present include the following ESUs: the threatened Middle Columbia River, endangered Upper Columbia River, threatened Upper Willamette River, threatened Lower Columbia River, and threatened Snake River Basin. Steelhead populations in the Columbia River Basin include two spawning migrations: winter-run and summer-run. Spawning habitat for steelhead include upper reaches of tributaries. Juveniles spend from 1-7 years (average 2) in freshwater and outmigrate during the spring and early summer, primarily in the main channel. Steelhead would not be expected to occur in the study area.

Sockeye salmon (endangered) occurs in the Salmon River, a tributary of the Snake River. This population migrates in spring and summer and spawning occurs in February and March. Spawning occurs in inlets or outlets of lakes or in river systems. Juveniles rear in freshwater for one year and outmigrate in spring and early summer as yearlings. Sockeye would not be expected to occur in the study area.

Adult Snake River fall chinook salmon (threatened) enter the Columbia River in July and August and reach the mouth of the Snake River from the middle of August through October. Spawning occurs in the Snake River and lower reaches of tributaries to the Snake River in October and November. Juvenile Snake River fall chinook salmon move seaward slowly as subyearlings or 'ocean-type.'

Studies of the downstream migration of chinook salmon in the lower Columbia River concluded that they were present from June to October. Chinook salmon tend to linger in the lower Columbia River and may spend a considerable portion of their first year in the estuary. Adults return to the Snake River at ages 2-5, with age 4 the most common spawning age. While no documentation exists on the use of this species in the study area, their life cycle suggests use of backwater habitat like that of the Crims Island area for rearing prior to ocean entry.

Adult Snake River spring and summer chinook salmon (threatened) migrate upstream past Bonneville Dam from March through May and June through July, respectively. Spring and summer runs of chinook salmon in the Snake River prefer smaller, higher elevation streams and tend to migrate quickly to sea as yearling or 'stream-type' smolts. Snake River spring/summer salmon would not be expected to occur in the study area.

Fall run Lower Columbia River chinook salmon (threatened) are predominant in this region, and return to the river in late August to spawn within a few weeks. Spring-run chinook salmon on the lower Columbia River enter freshwater in March and April well in advance of spawning in August and September. Spawning occurs from late August to November. Juveniles outmigrate from early spring to fall depending upon run type. While no documentation exists on the use of this species in the study area, their life cycle suggests use of use of backwater habitat like that of the Crims Island area for rearing prior to ocean entry.

Upper Columbia River chinook salmon (endangered) occur in Columbia River tributaries upstream of the Rock Island Dam and downstream of Chief Joseph Dam in Washington, excluding the Okanogan River. Adults migrate from late winter to spring and spawn from late August to November. Spawning occurs in the mainstem Columbia River to upper reaches of tributaries. Juveniles outmigrate from early spring to summer. Sub-yearling chinook salmon are most likely to use the study area only for rearing during migration downstream. Sub-yearling chinook enter the estuary in late May and again between July and August. Some sub-yearling salmon reside in the estuary for as long as several months and rear in backwaters and other shallow water habitats. The lack of systematic surveys of juvenile salmonids in estuarine, shallow water habitats limits the interpretation of current habitat use of the study area.

Upper Willamette River chinook salmon (threatened) occurs above Willamette Falls in three major tributaries, the McKenzie River and South and North Forks of the Santiam River. Adult spring-run chinook enter the Columbia River in March and April, but they do not ascend Willamette Falls until May or June, and spawn from late August to early October. Juveniles outmigrate from early spring to summer. They are not expected to occur in the study area.

2.4.2. Listed Wildlife and Plants

At Crims Island, Columbian white-tailed deer are at the upstream end of their recent distribution on the Columbia River. As discussed previously, the USFWS reintroduced 60 Columbian white-tailed deer to the island in 1999-2000, and are generally not found in the proposed tidal marsh, channel, and riparian forest restoration areas because of cattle grazing. Riparian forest, old fields, agricultural pasturelands and croplands, Sitka spruce swamp, wetlands, and hybrid popular plantations are habitats inhabited by this subspecies within the Columbia River estuary. The current vegetative cover of the upland portions of the proposed restoration areas is primarily a grass-forb (pasture) community while the tidally influenced areas are dominated by reed canarygrass.

Bald eagles that constitute nesting pairs in the Columbia River estuary are considered year-around residents; the area also supports wintering eagles. Garrett et al. (1988) estimated a maximum

wintering population of 170 bald eagles downstream of Longview, Washington. Wintering birds are most abundant in the estuary and at the Sauvie Island-Vancouver Lowlands. The number of wintering bald eagles fluctuates annually, probably in response to local and external weather patterns and prey availability. Regardless, the lower Columbia River downstream of Portland represents an important wintering area for bald eagles. Migrant bald eagles also are expected to occur as transients in the study area although their number cannot be determined.

Bald eagles occur at Crims Island as resident nesting adults and wintering/transient birds. They use the riparian trees around the island and project perimeter for hunting and loafing perches. Crims Island lies within the Abernathy, Washington – Crims Island, Oregon bald eagle territory. This territory has been occupied since 1983 (Isaacs and Anthony 2002). Three of five nests previously located in this pair's territory no longer exist. An alternate nest (656-2) at Abernathy is still present for use (Isaacs and Anthony 2002). Since 1996, the resident pair has occupied nest 701 on Crims Island, which is approximately 1,000 feet distant from the nearest edge of the proposed restoration action. Nest 701 lies north of the north side channel and is located on the far side of the northern arm of Crims Island adjacent to the mainstem Columbia River. Mature cottonwood trees provide a visual screen between nest 701 and the project site.

Scientific Resources, Inc. (1990) investigated the nesting pair and identified breeding and post-breeding home ranges plus foraging areas. They determined that the highest centers of activity for both seasons were focused around the original Crims Island nest site (300). Gull Island was outside the high use contours but within the 95% contour. Most perch (hunting, loafing) locations for this pair also were centered upon the Crims Island nest site (300). Two perch locations were noted on Gull Island. Foraging activities for this pair were centered upon Bradbury Slough; this is at least partially an artifact of sampling. Observation conditions were optimum for the Bradbury Slough area and more difficult for other locations within their territory. One predation attempt immediately upstream of Gull Island and four attempts in the Columbia River between Gull Island and the mouth of Abernathy Creek were observed.

Howellia grows in firm, consolidated clay and organic sediments occurring in wetlands associated with ephemeral glacial pothole ponds and former river oxbows (USFWS 1998). This plant's microhabitats include shallow water and the edges of deep ponds that are partially surrounded by deciduous trees (USFWS 1998). Although the historic type locality for this species is Sauvie Island, no populations are currently found there. Howellia is apparently extirpated from Oregon (USFWS 1998). Virtually all of the remaining populations of this species are clustered in two metapopulations. One occurs near Spokane, Washington and the second is in the Swan River drainage of northwestern Montana (USFWS 1998). The only known populations in the general area occur at Ridgefield National Wildlife Refuge. Two small populations are located there in close proximity (USFWS 1998). Suitable habitat for Howellia does not occur on Crims Island. The tidal marsh restoration area is currently subject to tidal inundation and is dominated by reed canarygrass.

Bradshaw's lomatium is found in low, seasonally wet, native prairies dominated by tufted hairgrass and sedge species in the Willamette Valley. The species was once widespread throughout the Willamette Valley but is now restricted to a few sites in Lane, Marion and Benton Counties, Oregon and one population in Clark County, Washington. Land development for agricultural, industrial, and housing purposes has resulted in loss of habitat for this species. The encroachment of woody vegetation, a result of fire suppression, also represents a threat to the habitat conditions required by this species. Suitable habitat for this species does not occur on Crims Island.

Nelson's checkermallow is scattered throughout the Willamette Valley and occurs at other locations in Oregon and Washington (CH2M Hill 1993). The majority of sites where this species presently

occurs are located in the Willamette Valley and several sites are in the Oregon Coast Range (USFWS 1998). One site occurs in Cowlitz County, Washington in the Coast Range (USFWS 1998). The species was once very occasional in the Willamette Valley, from Linn and Benton Counties north to near Portland and westward to eastern Tillamook County (USFWS 1998).

Nelson's checkermallow primarily occurs in open, sunny areas with little or no shade; the species does not tolerate encroachment of woody species (USFWS 1994). This plant occurs in a variety of habitats, including relatively undisturbed seasonal wetlands, annually mowed roadside ditches, margins of cultivated fields in the Willamette Valley, and high meadows in the Coast Range (CH2M Hill 1993). It most frequently occurs in ash swales and meadows with wet depressions (USFWS 1998). This species may tolerate a limited amount of disturbance, but it is unlikely to tolerate frequent or excessive ground disturbance over consecutive years. Suitable habitat for this species does not occur on Crims Island.

2.5. Cultural and Historic Resources

An initial review of the cultural resources studies and histories of the area reveal that the Chelwits Indian village at Oaks Point on the Oregon mainland was the closest known prehistoric village in the area. However, no prehistoric cultural resources have been identified on Crims Island. From what we presently know about prehistoric settlement patterns along this area of the Columbia River, it seems unlikely that Crims Island would have been the location of a village, but the area could certainly have been used for the procurement of resources. The interior could have provided hunting and edible or medicinal plants, and fishing activities may have been based along the shores. Areas along natural levee remnants near the shoreline would probably provide the highest potential for presence of archaeological remains. No excavation work is proposed for the high ground or natural levees.

The island was likely forested in the past and it is not known when much of it was cleared. Local informant Warren Nakalla, who currently grazes cattle on the island, related that a dairy began operating there in the early 1900s, and the structures seen in aerial photographs on the eastern end of the island belonged to this endeavor. There was a house, a bunkhouse and attached shed, a well house, and a metal roofed barn. Only the barn remains as the other structures have burned. The T-channels were purportedly excavated to enhance drainage of the interior of the island and improve pasturage, but exactly when the channels were dug and by what means is uncertain. It is not apparent where materials from this earlier excavation were distributed over the landscape, although the banks along the channels are somewhat higher than the surrounding terrain.

2.6. Socioeconomics and Land Uses

Crims Island has been inhabited by humans at least since the 1800s. Homesteaders settled on the island, drained the wetlands as much as possible, and used the land primarily for cattle grazing and agricultural purposes. A group of structures were formerly present at the east end of the island, including a house and barn; only the pole barn remains. No commercial development has occurred on the island. Cattle grazing occurs and is centralized at the east end of the island where the principal upland pasture is located. However, cattle do graze throughout the island area.

There is no commercial development on Crims Island and it has only a small role in the determination of socioeconomics of the region, primarily as a result of cattle ranching. However, relocation of cattle off the island will occur within the year. Agricultural production was abandoned when it became too difficult to completely restrict tidal and flooding inundation on the island.

Ownership of the island is divided between two private landowners, RSG Forest Products, the USFWS, and Oregon Division of State Lands. Lands owned by USFWS and the state have been designated for wildlife habitat, while lands owned by RSG may be, or may have previously been, harvested for timber. Lands recently acquired by Columbia Land Trust from Jefferson Poplar will be turned over to the USFWS in late May 2004 and will become an extension of the Julia Butler Hansen Wildlife Refuge.

There is no public access to Crims Island and no transportation infrastructure is present in any form. The nearest towns include Locoda, Quincy, Inglis, Mayger, and Clatskanie, which is the largest of the towns. Port Westward, near Locoda, is home to the Beaver Generating Plant, which supplies large areas of the Pacific Northwest with natural gas. Larson Marine Services, located on the mainland near Port Westward, provides boat transportation to Crims Island.

There are no essential public services on Crims Island. Utility lines are present leading to the residential structures on the east end of the island, and it is likely that a buried cable extends from the mainland to the island. No visible phone or power lines are on the island.

Recreation opportunities at Crims Island include hunting, fishing, birdwatching, and boating. Abundant waterfowl populations and fish habitats draw duck hunters, birdwatchers, and anglers to the area via boat. There are at least two structures on the island that may serve as shelter for hunters. A beach area is present at the easternmost end of the island, which most likely draws anglers, campers, picnickers and sunbathers to its shore during summer. There are no officially established recreational features on the island, such as picnic tables or camping facilities, although the forthcoming acquisition by USFWS may result in increased visitation.

Crims Island is part of the Lower Columbia River Estuary, one of the most diverse and expansive estuaries on the west coast. Cutting through the Cascade and Coast Ranges, the Columbia River can be viewed from the surrounding foothills, where mountain and waterway meet in dramatic uninterrupted vistas. Islands are an integral part of the widely and beautifully braided lower river estuary. The undeveloped beauty of Crims Island contributes to the overall aesthetic resource of the Columbia River.

2.7. Air Quality/Noise/Light

The Washington State Department of Ecology Air Quality Program website reports that Cowlitz County has good air quality (https://fortress.wa.gov/ecy/aqp/Public/databyarea.shtml). The Oregon Department of Environmental Quality's nearest air quality monitor station is in Portland, which does not provide information regarding the Crims Island area. Although there are no onsite sources of pollution, the Longview, Washington industrial complex influences air quality at Crims Island when wind carries emissions downriver.

Although Crims Island is undeveloped and only used for cattle grazing, it is near the Beaver Generating Plant in Port Westward, which emits a significant level of noise to the study area. Noise from gas turbine generators within the Beaver Plant were tested and found to be within acceptable legal limits (Oregon Office of Energy 2002). Other sources of noise include recreational and commercial river traffic and mainland traffic near Port Westward. Also, no artificial lighting is present at Crims Island and no practices in the area currently affect natural light conditions.

3. FUTURE WITHOUT-PROJECT CONDITIONS*

If no action is taken, the existing conditions on the restoration portion of Crims Island will continue to provide poor fish and wildlife habitat, and will fail to achieve the objectives of the LCREP. The tidal marsh, forested swamp/freshwater marsh, and riparian forest habitats on the island will remain degraded. Currently, fish habitat on the island has been significantly altered through land use practices which have created steep banked, ditched waterways (T-channel), non-native plant-dominated high tidal marsh (reed canarygrass), and forested swamp/freshwater marsh disconnected from tidal flow. Tidal circulation would continue to be limited by the natural and artificial berms surrounding much of the restoration area, the configuration of the T-channel, and the plug blocking the former tidal channel. The tidal marsh restoration area is presently a dead-end channel that is only open to the Columbia River through the narrow T-channel. Tidal inundation flows through the existing tidal T-channel but does not overtop existing wetlands on a regular basis, except during higher tides. The high tidal marsh is composed of freshwater plant species. Fish use is primarily limited to the T-channel on the island. The downstream emergent and forested wetland habitats would continue to be isolated from the river, preventing juvenile salmonid and other fish access to productive feeding areas. Over time, additional tidal channel formation would occur. However, it is likely that non-native vegetation would become further established and begin encroaching in areas that are increasingly cut off from tidal influence.

Also, the lack of riparian forest has limited detritus production and export, as well as the use of the island by many species of wildlife, including the endangered Columbian white-tailed deer. Because of the land acquisition by the USFWS, it is anticipated that cattle grazing on the island would cease within the first six months of 2004. Once cattle and grazing disturbance are removed, the absence of any management actions (such as a weed control strategy and native planting plan) would result in the rapid colonization of aggressive, non-native plants such as Himalayan blackberry, Canada thistle, and tansy ragwort in the non-forested, upland areas. In addition, the pastureland adjacent to the marsh and slough habitat would remain in its current unmanaged condition, which severely limits riparian forest recruitment.

If no action is taken, the capacity of Crims Island to support the variety and abundance of fish and wildlife, as it did historically, will not occur. The tidal marsh and swamp habitats would remain partially isolated from the river, and unable to fully contribute to the productivity of the lower Columbia River and estuary. The regional goal to restore and protect 10,000 acres of wetland and riparian habitats in the lower Columbia River and estuary for the conservation and recovery of listed salmonid populations would take longer to accomplish, and the 473 acres of protected, restorable habitat on Crims Island would remain underutilized.

4. ALTERNATIVES*

4.1. Initial Screening

For Crims Island, the initial screening of potential restoration measures was based on interagency meetings with the USFWS and the Corps, including site visits, to assess management objectives for the island and potential restoration measures to accomplish them. The primary management objectives include improving riparian forest habitat for Columbian white-tailed deer, restoring tidal marsh habitat for fish and wildlife resources, and improving fisheries (juvenile salmonid) ingress and egress to tidal marsh habitat. Development of riparian forest habitat on lands currently used for cattle pasture was identified as a measure that would benefit Columbian white-tailed deer. Tidal marsh restoration measures include removing reed canarygrass, altering the site elevation to extend the tidal inundation period, and improving site physical characteristics to favor native tidal marsh vegetation establishment and persistence. The provision and/or improvement of side channel habitats to the tidal marsh area were identified as a possible means to improve use by juvenile salmonids and allow for greater export of detrital material into the estuary. Borrow material generated from tidal marsh and side channel excavation could be used for riparian forest establishment on the adjacent upland habitats. Removal of a soil plug near the downstream end of the island was identified as a measure to restore tidal flow and circulation to a forested swamp/freshwater marsh.

4.2. Proposed Restoration Measures

Several possible conceptual restoration measures were identified for the Crims Island habitat restoration project (see Plate 1). The initial concept for habitat restoration centered on development of tidal marsh and riparian habitat on the upstream portion of the island. This area corresponded roughly to the reed canarygrass marsh and pastureland upstream of the T-channel intersection. The restoration options for this area were discussed at various interagency meetings and site visits. As information on land acquisition and ownership became available, consideration was also given to restoration of the reed canarygrass marsh downstream of the T-channel intersection and the provision of connector/through channels. The plug, near the downstream end of the island, also was an initial restoration concept. However, while removal of the plug is given full consideration in this study, implementation of the particular action remains contingent upon acquisition of that parcel of land or securing a conservation easement from the current landowner.

Restoration of Tidal Marsh Habitat. Two distinct elements, the upstream and downstream tidal marsh restoration elements, were considered for restoration purposes. The entrance channel for the T-channel serves to mark the boundary between these two elements. Restoration of the upstream tidal marsh was initially considered because of its larger size, its proximity to the upland disposal site to be used for riparian forest restoration purposes, and its lesser complexity and greater economy of scale relative to both costs and habitat outputs (acreage, benefits to fish and wildlife resources).

The downstream tidal marsh restoration element is a smaller area with fewer outputs for fish and wildlife resources, and has a greater construction complexity. Also, it does not contribute additional acreage to riparian forest restoration because it does not have an adjacent, upland disposal site; material must be transported to the upland disposal site associated with the upland tidal marsh restoration. The downstream area also is dependent upon the larger entrance channel and plug construction features associated with the upstream element for implementation. Therefore, the downstream tidal marsh restoration element was not considered a stand-alone alternative because of its dependence upon features associated with the upstream tidal marsh development. Also, the

downstream tidal marsh development is included as an element of the upstream tidal marsh development due to the regional focus on restoration of lower Columbia River tidal habitat.

Tidal marsh restoration was predicated upon removal of the canarygrass-dominant vegetation and development of a more natural, native plant-dominated tidal marsh habitat. It was assumed that lowering the present elevation of the existing tidal marsh habitat would favor development of a native plant dominated tidal marsh. A nearby reference marsh on Gull Island was identified on the premise that the site elevation at that location, with virtually identical exposure to tidal inundation and river stage, would provide elevation information to attain the objective. This reference marsh differs from the location on Tronson Island (CRM 30), which was selected as a reference site for tidal channels. Surveys conducted at the reference marsh and the tidal marsh restoration site on Crims Island demonstrates that there is an approximately 2-foot difference in elevation. Consequently, the tidal marsh restoration at Crims Island is targeted to remove approximately 2 feet of soil, including the vegetative overburden, to attain the proper conditions. Micro-topography on the site would be followed during the construction process to diversify site conditions.

Excavation of the marsh plain to a lower elevation would allow for more frequent and longer duration tidal inundation. Excavation also would allow for a larger volume of water to enter and exit marsh during each tidal cycle. This volume of water is termed the tidal prism. Tidal channels form to accommodate this transfer of water and to dissipate its energy. The size and shape of the channel network is dependant on several factors including hydrodynamics, substrate, and vegetation.

Tidal channel sizing is based on empirical relationships derived from several west coast tidal marshes (Williams et al. 2002). Applicability of these empirical relationships to the Columbia River was verified to the extent possible with aerial photos of a reference marsh. An intertidal marsh on Tronson Island was used as a reference site for channel geometry for the Crims Island project. Channel placement is designed to move water into and out of areas that are currently low. The selected geometry of the tidal channel system is designed to make best use of the micro-topography of the existing wetland area. A one-dimensional unsteady state model was used to size the entrance channels.

Only the larger order channels will be excavated to full capacity during construction. By creating full capacity in the larger channels, sufficient volumes of tidal water will be immediately available to improve water quality, tidal circulation and habitat. Smaller channels further upstream from the entrance will be excavated as pilot channels. The smallest channels will form naturally. This approach will promote development of the complex channel system and help to control potential negative effects from mass erosion during channel formation if the system were allowed to develop naturally.

The larger order channels to be excavated include an enlargement of the T-channel entrance and construction of a new inlet-outlet channel that connects to the downstream arm of the T-channel. The T-channel entrance also will be realigned from its present linear form to a gradually curved, branched channel. As the constructed tidal channels progress further into the tidal marsh restoration area, they will become more sinuous and branched.

The tidal channel area under consideration for implementation substantially exceeds that initially envisioned. This is indicative of more intensive investigation and an attempt to more accurately mimic the natural tidal marsh conditions.

Bottom dwelling invertebrates, including *Corophium* and chironomids, are major food items in the diets of juvenile chinook salmon in the lower Columbia River (Craddock et al. 1976) and estuary

(McCabe et al. 1983). Sinuous, shallow tidal channels would be constructed through the restored tidal marsh to mimic naturally occurring channels. The channels would improve tidal circulation, allow for greater ingress and egress of juvenile salmonids, and increase detrital export. The channels would connect to an existing subtidal channel. Invertebrate production would increase over time and made more available to rearing fish that access the restored tidal marsh area.

The riparian forest component of the restoration effort, a sub-feature of the upstream tidal marsh/riparian forest restoration, remains comparable to the initial concept. There are approximately 115 acres of existing cattle pasture that would be restored to riparian forest. Initially, this pastureland would be to serve as a disposal site for the material excavated during channel and tidal marsh restoration. It is estimated that a 2-foot lift of soil would be added to the acreage involved. Stand establishment of riparian forest trees and shrubs will be accomplished through a combination of natural regeneration through seed dispersal from adjacent forest stands (65 acres) and the planting of seedlings and cuttings (50 acres). Ground preparation (tillage) would be implemented immediately prior to seed dispersal and active planting of root stock seedlings and cuttings to provide the proper substrate conditions for germination and growth of seedlings.

Connector/Through Channels. A connector channel was proposed early on in the development of restoration measures to connect the existing northern through channel with the dead end backwater channel that also occurs on the north side of the island. The connector channel concept was considered to provide through flow into the dead-end channel, thereby increasing access by juvenile salmonids and providing more suitable (cooler) water temperatures during the summer. These connector channels also were considered as pathways to improve detrital export from the tidal marsh habitat to the Columbia River. Based upon discussions with fisheries biologists, the connector channel concept was expanded to cover: (1) connection to the tidal marsh restoration from the dead end channel; (2) addition of a second channel from the current dead end slough to the tidal marsh restoration; and (3) provision of a through channel via construction of a channel from the upstream end of the island that connected to both the tidal marsh and the dead-end side channel and that utilized the existing T-channel outlet and a new channel located at the end of the downstream arm of the T-channel as outlets to Bradbury Slough.

The connector channels were discussed among project partners based upon their relative value to fish resources and tidal marsh habitat, similarity to natural tidal marsh islands, and cost. No specific net gain in value for fisheries resources could be delineated. Juvenile use of the area is primarily during the spring season, this period is not generally significantly impacted by elevated water temperatures. Flood and ebb tides currently provide a good, twice daily, exchange of water in the dead end side channel. Consequently, improvements in water quality and temperature and fisheries access/egress were considered very limited relative to the costs.

While fisheries resource access and egress may be improved with the construction of connector channels, properly designed and sized channels to allow tidal flows to readily access the restored tidal marsh habitat would provide comparable results. Natural tidal islands typically have relatively linear through-flow channels, if they are present. Typically, tidal marsh islands have inlet-outlet channels that originate near the downstream end and extend upstream. These channels branch and fimbriate as they extend into the interior of the island, with numerous, sinuous and small side channels dead ending against higher-elevation ground that compose the upstream portion of the tidal marsh island. Therefore, construction of the through channel or connector channels that extend into the tidal marsh habitat would not mimic the natural situation observed in the lower Columbia River.

Cost is a significant factor with respect to the connector/through channels. Each channel would have to come through relatively high ground, thus requiring substantial excavation to attain depth to pass

flows and resulting in a relatively large breadth given 1:3 or gentler slopes. This translates into large volumes of material to be removed and a substantial cost factor.

Based on the assessment of the various factors relative to the proposed through or connector channels, it was decided to retain one connector channel in the analysis. The connector channel from the northern through channel to the northern dead end channel will be analyzed further. The results of the incremental cost analysis and cost efficiency analysis will be used to determine if this measure should be selected or dropped from consideration.

Due to the greater water storage volume of the tidal marsh habitat post-construction, a connection between Bradbury Slough and the downstream arm of the T-channel will be constructed. Construction of this channel will allow for two ingress-egress points for tidal waters to the tidal marsh restoration area. Absent development of a second ingress-egress channel, the existing T-channel inlet would have to be substantially enlarged to allow for ingress-egress of tidal waters in order to prevent the river eroding the inlet-outlet channel to the appropriate size and configuration to handle the volume present. Construction of this downstream inlet-outlet channel should allow for better fish access and egress from the restoration area. The downstream inlet-outlet channel also mimics natural marshes in the lower Columbia River.

Plug Removal. A plug that presently blocks a former tidal channel would be removed to restore tidal flow to interior marshes and a forested swamp/freshwater marsh located in the downstream portion of Crims Island. The measure would allow greater ingress and egress of juvenile salmonids and increase detrital export from these marshes.

4.3. Array of Alternatives

The conceptual restoration measures were further developed, and in some cases combined, in order to meet some or all of the planning criteria and restoration objectives (Sections 1.5 and 1.6) for Crims Island to varying degrees. The resulting alternatives are described below.

1. *No Action Alternative*. Under the No Action Alternative, no habitat restoration actions would be implemented at Crims Island.

2. *Upstream Tidal Marsh/Riparian Forest Habitat*. Portions of the upstream end of Crims Island (upstream of the T-channel leg that connects to Bradbury Slough) would be excavated approximately 2 feet to restore suitable elevations for tidal marsh development. The excavation depth is predicated upon site elevation information obtained from an elevation survey of the reference marsh. A survey of the tidal marsh habitat, dominated by reed canarygrass on Crims Island, revealed that it was approximately 2 feet higher in elevation than the reference marsh, hence the establishment of the excavation depth. The existing reed canarygrass vegetation would be removed to develop naturally vegetated tidal marsh habitat. Site elevation would be reduced uniformly by 2 feet via excavation throughout the tidal marsh area. Seeds in the soil bank and the tidal import of propagules would be the sources for establishment of these native tidal marsh plant species.

Sinuous, shallow tidal channels would be constructed throughout the restored tidal marsh. These constructed tidal channels are based upon the hydraulic engineering analyses of water volume, tidal elevation, river stage, a reference marsh at Tronson Island, and empirical relationships based upon a literature review from several west coast tidal marshes.

Disposal of material excavated from the tidal marsh restoration would occur on adjacent upland currently used for cattle pasture. Physical characteristics of these pasturelands would be altered

primarily via an estimated 2-foot increase is site elevation where disposal occurs. The subsequent development of riparian forest vegetation will lead to a more diverse height structure for the vegetation on the pasturelands, including the disposal areas.

3. *Plug Removal*. The plug that currently blocks tidal waters from entering and exiting a freshwater marsh/forested swamp near the downstream end of Crims Island will be removed. The material would be excavated and sidecast onto an open area on the existing berm. Riparian forest vegetation would likely develop on the disposal site. The ingress and egress of tidal waters may alter the composition of the wetland vegetation in the freshwater marsh habitat. Fisheries ingress and egress will occur after plug removal, as will detrital export.

4. *Connector Channel*. A connecting channel would be constructed from the northern through channel to the northern dead end channel. It would result in substantial excavation of an upland area, resulting in the conversion of approximately 4 acres of present pastureland to a channel habitat, including banks. This alternative would allow through flow of water in the current dead end channel, affecting approximately 33 acres of backwater habitat.

5. *Upstream Tidal Marsh/Riparian Forest Habitat and Downstream Tidal Marsh Habitat Development*. The reader should note that the downstream tidal marsh habitat development is considered in this and some of the subsequent alternatives as an added restoration element. The rationale for considering the downstream tidal marsh habitat development as a restoration element rather than a stand-alone alternative is further discussed in Section 4.2 under the subsection *Restoration of Tidal Marsh Habitat*.

6. *Upstream Tidal Marsh/Riparian Forest Habitat and Plug Removal.*

7. *Upstream Tidal Marsh/Riparian Forest Habitat and Connector Channel.*

8. *Plug Removal and Connector Channel.*

9. *Upstream Tidal Marsh/Riparian Forest Habitat, Downstream Tidal Marsh, and Plug Removal*.

10. *Upstream Tidal Marsh/Riparian Forest Habitat, Downstream Tidal Marsh, and Connector Channel.*

11. *Upstream Tidal Marsh/Riparian Forest Habitat, Plug Removal, and Connector Channel.*

12. *Upstream Tidal Marsh/Riparian Forest Habitat, Downstream Tidal Marsh, Plug Removal, and Connector Channel.*

4.4. Evaluation of the Restoration Benefits by Alternative

1. *No Action Alternative*. For the No Action Alternative, the tidal marsh, forested swamp/freshwater marsh, and riparian forest habitats on Crims Island will remain degraded. Tidal circulation would continue to be limited by the partially constructed and natural berms surrounding much of the restoration area, configuration of the ditch, and the plug blocking the former tidal channel to the forested wetland. The tidal marsh and forested wetland habitats would continue to be isolated from the river, preventing juvenile salmonid and other fish access to productive feeding areas. Also, the pasturelands adjacent to the marsh and slough habitat will remain degraded. The lack of riparian forest would limit detritus production and export, and the use of the island by many species of wildlife, including the endangered Columbian white-tailed deer.

This alternative does not meet the planning criteria and restoration objectives discussed in Sections 1.5 and 1.6 of this document. However, the No Action Alternative is included in the output and economic evaluations as a baseline against which the restoration alternatives are compared.

2. *Upstream Tidal Marsh/Riparian Forest Habitat.* The reduced site elevation associated with implementation of this alternative would lead to greater tidal inundation (depth and time period) and would favor the development of a native tidal marsh plant community. An estimated 52 acres of tidal marsh and 11 acres of tidal channel habitat would be developed and/or improved with implementation of this alternative. Seeds in the soil bank and the tidal import of propagules would be the sources for establishment of these native tidal marsh plant species. It is anticipated that plant species diversity and structural complexity would increase compared to the pre-project condition of a dense reed canarygrass marsh subject to grazing by cattle, which would be discontinued prior to project implementation. This physical alteration of the substrate would lead to establishment of native tidal marsh vegetation and is expected to result in changes in vegetation density and physical height. Forage resources for waterfowl would be substantially improved over the existing condition given a greater plant species composition, increased availability of seeds, tubers and shoots, and elimination of cattle grazing in the tidal marsh habitat.

Tidal channels would be constructed throughout the restored tidal marsh to mimic naturally occurring tidal channels and would provide for improved ingress/egress of tidal waters and salmonids, and improve detrital export capability to the adjoining side channels and the Columbia River.

Disposal of material excavated from the tidal marsh restoration would occur on adjacent upland currently used for cattle pasture. Physical characteristics of these pasturelands would be altered primarily via an estimated 2-foot increase in site elevation where disposal occurs. The subsequent development of riparian forest vegetation would lead to a more diverse height structure for the vegetation on the pasturelands, including the disposal areas. An estimated 115 acres of riparian forest habitat would be developed on the disposal area for the project.

Riparian forest restoration via plantings and natural seeding would convert the former grazed pasturelands and project disposal areas into a black cottonwood-Oregon white ash riparian forest with an understory of red-osier dogwood, willow species, elderberry, snowberry and other tree, shrub and grass/forb species. It is anticipated that restoration of riparian forest would substantially increase use of the area by Neotropical migrants and resident songbirds. With forest maturation in the future, the species composition of birds should increase. Amphibians on the island, such as red-legged frogs, would be expected to benefit from the restoration of riparian forest habitat. Insect production and detrital export would increase, principally leaves, but also trees under a mature forest condition, post-project implementation. The level of these riparian outputs would be expected to increase with maturation of the riparian forest habitat.

For wildlife, the net qualitative increases for each habitat component (tidal marsh and channel, riparian forest) were estimated at 0.9 on a scale of 0 to 1. The net gain in wildlife habitat units for the 178-acre restoration effort under this alternative was 160. The restoration effort should result in a more natural and diverse tidal marsh plant community than the present virtual monoculture and benefit many species of wildlife through provision of an improved forage resource. Restoration of the historic riparian forest plant community, once established, will have substantial value for many wildlife species through provision of habitat for cover, forage, and nesting, amongst other values. The site for riparian forest restoration is currently cattle pasture/grassland and was given a low existing value.

For fisheries resources, the net qualitative increases for tidal marsh and channel was estimated at 0.8; riparian forest was estimated at 0.4 on a scale of 0 to 1. The existing T-channel was considered to provide a low existing value for fisheries and substantial improvements in fisheries use and value were forecast with post-project implementation. Ingress and egress of fish, including juvenile salmonids, and export of detrital material would be greatly improved through provision of properly sized channels. Fisheries use for foraging would be improved. The existing value of the tidal marsh habitat was estimated to be low due to site dominance by reed canarygrass and limited wildlife forage value, fisheries access and detrital export.

Riparian forest restoration was considered to provide a low moderate net value (0.4) to fisheries resources over time. Value would be attained through detrital export of leaves, insect production, and eventually large woody debris input to the river. Also, the net increase in fisheries habitat units was estimated at 96 units. The combined wildlife and fisheries habitat unit gain with implementation of this alternative is 256 habitat units.

3. *Plug Removal*. This alternative would improve the ingress and egress of tidal waters to 88 acres of forested swamp habitat. Fisheries ingress and egress will occur after plug removal, as will detrital export in contrast to the present situation. Riparian forest vegetation would likely develop on the disposal site, although the extent is very minor. A net quality gain of 0.8 units was forecast for fisheries resources resulting in the gain of 70 fisheries habitat units. Wildlife gains in net quality relating to this alternative were low as habitat conditions in the current forested swamp were considered very good. The net gain (0.2 units) for wildlife was attributed to better fisheries forage availability post-implementation. The estimated value for wildlife was 18 habitat units for an alternative total of 87.9 habitat units.

4. *Connector Channel*. This alternative would result in the development of approximately 4 acres of channel habitat, including banks. The alternative also allows flow through of water to the current dead end channel, affecting approximately 33 acres of backwater habitat. A minor improvement to fisheries habitat conditions in the former dead end channel, because of through flow, would be anticipated. The net quality gain for fisheries and wildlife resources was estimated at 0.1 resulting in a net gain in habitat units of 3.6 for each resource group for a total gain of 7.2 habitat units.

5. *Upstream Tidal Marsh/Riparian Forest and Downstream Tidal Marsh Habitat Development*. This alternative incorporates Alternative 2 and downstream tidal marsh habitat development, which is a habitat development element dependent upon features associated with Alternative 2 and not a stand-alone alternative. Tidal marsh improvements would increase to 75 acres. Channel acreage would increase from 11 to 17 acres. Combining these two components would not increase in acreage for riparian forest above the 115 acres reported for Alternative 2 alternatives.Net gains in habitat values are as described for Alternatives 2 and 3. This alternative would produce an estimated gain of 186 wildlife and 119 fisheries habitat units for a total gain of 305 habitat units.

6. *Upstream Tidal Marsh/Riparian Forest Habitats and Plug Removal*. This alternative incorporates the features of Alternatives 2 and 3. Habitat improvements and acreage are as discussed for the individual alternatives in the previous text. Estimated gains for wildlife are 178 habitat units and 166 habitat units for fisheries resources for a total gain of 343.9 habitat units.

7. *Upstream Tidal Marsh/Riparian Forest Habitats and Connector Channel*. This alternative incorporates the features of Alternatives 2 and 4. Habitat improvements and acreage are as discussed for the individual alternatives in the previous text. Estimated gains for wildlife are 164 habitat units and 100 habitat units for fisheries resources for a total gain of 263.2 habitat units.

8. *Plug Removal and Connector Channel*. This alternative combines Alternatives 3 and 4. Habitat improvements and acreage are as discussed for the individual alternatives in the previous text. Estimated gains for wildlife are 21 habitat units and 74 habitat units for fisheries resources for a total gain of 95.1 habitat units.

9. *Upstream Tidal Marsh/Riparian Forest Habitats, Downstream Tidal Marsh, and Plug Removal*. This alternative combines Alternatives 2 and 3, and the downstream tidal marsh habitat development, which is a habitat development element dependent upon features associated with Alternative 2 and not a stand-alone alternative. Habitat improvements and acreage are as discussed for the individual alternatives in the previous text. Estimated gains for wildlife are 204 habitat units and 189 habitat units for fisheries resources for a total gain of 392.9 habitat units.

10. *Upstream Tidal Marsh/Riparian Forest Habitats, Downstream Tidal Marsh, and Connector Channel*. This alternative combines Alternatives 2 and 4, and the downstream tidal marsh habitat development, which is a habitat development element dependent upon features associated with Alternative 2 and not a stand-alone alternative. Habitat improvements and acreage are as discussed for the individual alternatives in the previous text. Estimated gains for wildlife are 190 habitat units and 123 habitat units for fisheries resources for a total gain of 312.2 habitat units.

11 *Upstream Tidal Marsh/Riparian Forest Habitats, Plug Removal, and Connector Channel*. This alternative combines Alternatives 2, 3, and 4. Habitat improvements and acreage are as discussed for the individual alternatives in the previous text. Estimated gains for wildlife are 181 habitat units and 170 habitat units for fisheries resources for a total gain of 351.1 habitat units.

12. *Upstream Tidal Marsh/Riparian Forest Habitat, Downstream Tidal Marsh, Plug Removal, and Connector Channel*. This alternative combines Alternatives 2, 3, and 4, and the downstream tidal marsh habitat development, which is a habitat development element dependent upon features associated with Alternative 2 and not a stand-alone alternative. Habitat improvements and acreage are as discussed for the individual alternatives in the previous text. Estimated gains for wildlife are 207 habitat units and 193 habitat units for fisheries resources for a total gain of 400.1 habitat units.

4.5. Cost Effectiveness and Incremental Cost Analyses

In conjunction with the environmental analysis of potential projects, cost effectiveness and incremental cost analyses of potential alternatives are required. The following explanations clarify the difference between cost effectiveness and incremental cost analyses, and the purposes for each.

- *Cost effectiveness analysis* is conducted to ensure that the least cost solution is identified for various levels of environmental output. Its purpose is to eliminate inefficient alternatives, based on comparing environmental outputs with *average cost* of an alternative.
- *Incremental cost analysis* is conducted to show changes in costs for increasing levels of environmental outputs. It provides data for decision-makers to address the question "Is the next level worth it?" It measures the incremental or *additional cost* of the next additional level of environmental output.

The without-project condition (No Action Alternative) represents the current conditions at Crims Island. It serves as the basis for comparison of the alternatives or with-project conditions. There are four elements being considered in this restoration study. Each of the elements and potential combinations of elements were discussed in Section 4.2, resulting in the list of workable alternatives shown in Section 4.3.

The non-monetary benefits of the environmental restoration alternatives are measured in average annual environmental outputs (see Appendix C for more information on development of the environmental outputs). It should be noted that the average annual environmental outputs listed represent the net increase in output above and beyond the without-project condition.

The implementation costs for the project include the costs associated with the project, including development costs and operations and maintenance (O&M) costs. In order to compare costs with average annual environmental outputs, it is necessary to convert implementation costs to average annual costs. The stream of costs associated with the project occurs at various points in time. Therefore, all costs were present-valued (or future-valued) to the beginning of the period of analysis, and amortized at the FY 2004 Federal discount rate of 5.625% over the 50-year project life, to develop equivalent average annual costs (see Appendix D for information on project costs).

For determining the economic cost of the project and its various components, a calculation is made to determine the cost of interest during construction (IDC). This interest is added to the other costs of the project and is included as part of the average annual cost. The IDC is included as an economic cost, but it is not included as a financial cost. The IDC is calculated using the FY 2004 discount rate of 5.625% for costs incurred during construction of the project.

The O&M costs for the project are estimated at $31,990 per year for the first 3 years for the riparian forest component, plus an additional $9,550 for the first year for equipment purchase. Using the FY 2004 discount rate of 5.625% to convert to equivalent average annual costs over the project life, the O&M costs are estimated at $5,718 on an annual basis. The project costs are expressed in terms of average annual dollars per average annual environmental output.

Table 4 summarizes the net gains in average annual environmental outputs, the average annual costs, and the average annual cost per environmental output for each alternative. As Table 1 shows, the average annual cost per environmental output is directly associated with the number of environmental outputs gained by development of each alternative. Note that the No Action Alternative is listed first and the average annual environmental outputs represent the net gain over the No Action Alternative.

Table 4. Average Annual Environmental Outputs, Average Annual Costs, and Average Annual Cost per Environmental Output

Alternatives	Average Annual Output	Average Annual Cost ($)	Average Annual Cost per Output ($)
Alternative 1 (No Action)	0	0	0
Alternative 2	256.0	99,944	390
Alternative 3	87.9	1,032	12
Alternative 4	7.2	18,771	2,607
Alternative 5	305.0	159,636	523
Alternative 6	343.9	100,976	294
Alternative 7	263.2	118,715	451
Alternative 8	95.1	19,803	208
Alternative 9	392.9	160,668	409
Alternative 10	312.2	178,407	571
Alternative 11	351.1	119,747	341
Alternative 12	400.1	179,439	448

Table 5 displays the cost-effective, least-cost alternatives listed in ascending order of average annual environmental outputs. Alternatives that had a higher cost for a given level of environmental output were not cost-effective and were dropped from further consideration (Alternatives 4, 5, 7, 10).

Table 5. Cost-effective Least-cost Combinations, Average Annual Environmental Outputs, and Average Annual Cost

Alternatives	Average Annual Output	Average Annual Cost ($)
Alternative 1 (No Action)	0	0
Alternative 3	87.9	1,032
Alternative 8	95.1	19,803
Alternative 2	256.0	99,944
Alternative 6	343.9	100,976
Alternative 11	351.1	119,747
Alternative 9	392.9	160,668
Alternative 12	400.1	179,439

The preceding table displays the supply schedule of the average annual cost for each level of output, which serves as the basis from which to derive the incremental cost analysis. Incremental cost analysis is required to address whether the incremental or additional cost of the next level of output is worth it. In environmental studies, the comparison is between dollar incremental costs and non-dollar incremental units of output. In order to facilitate the required calculations, the IWR "Cost Effectiveness and Incremental Cost Analysis" (Eco-Easy) software program was used to do the calculations necessary to eliminate the irregular, non-continuously increasing cost changes that occur in the incremental average annual cost per output calculations.

For the final incremental cost analysis, it was necessary to do a series of calculations to determine the lowest average cost for additional output from amongst the remaining levels of output. Each of the recalculations begins with the previous step's lowest average cost level of output set as the new 'zero level.' The calculation in this step uses the additional cost and additional outputs above those of the previously identified level of output with the lowest average cost (for further details on this process, please refer to *Cost Effectiveness Analysis for Environmental Planning: Nine Easy Steps*, IWR Report 94-PS-2, October 1994). Table 6 summarizes the results of the final incremental cost analysis.

Table 6. Summary of Final Incremental Cost Analysis

Alternative	Total Average Annual Cost ($)	Total Average Annual Output	Added Average Annual Output	Added Average Annual Cost ($)	Incremental Average Annual Cost per Output ($)
No Action	0	0	0	0	0
Alternative 3	1,032	87.9	87.9	1,032	12
Alternative 6	100,976	343.9	256.0	99,944	390
Alternative 9	160,668	392.9	49.0	59,692	1,218
Alternative 12	179,439	400.1	7.2	18,771	2,607

Table 6 shows the change from one combination to the next. For instance, moving from Alternative 9 to Alternative 12 shows a change of 7.2 additional average annual environmental outputs (400.1 outputs for Alternative 12 minus 392.9 outputs for Alternative 9); an additional average annual cost of $18,771 ($179,439 cost for Alternative 12 minus $160,668 cost for Alternative 9); and, an additional or incremental $2,607 average annual cost per average annual environmental outputs ($18,771 incremental cost divided by 7.2 incremental environmental output).

The column on the right summarizes the incremental average annual cost per output; its purpose is to show potential breakpoints where gaining the next level of output shows a significant increase in costs. In this case, there is a significant break between Alternative 9 (upstream tidal marsh/riparian forest, downstream tidal marsh, and plug removal) and Alternative 12 (upstream tidal marsh/riparian forest, downstream tidal marsh, plug removal, and connector channel). Therefore, Alternative 9 would be the cost-effective and incrementally justified alternative.

After the above cost effectiveness and incremental cost analysis was prepared, a revised baseline cost estimate was completed that exhibited a fairly substantial increase in cost. This cost increase was associated with increased fuel costs and an updated construction scenario. An additional iteration of the Eco-Easy program was run to determine whether cost changes had an impact on plan selection. Alternative 9 remained the cost effective and incrementally justified alternative. The cost data in the cost effectiveness and incremental cost analysis discussed above have not been adjusted to reflect the increased project cost.

4.6. Selection of Preferred Alternative

Based on the results of the cost effectiveness and incremental cost analyses, Alternative 9 would be the most cost effective alternative and is selected as the Preferred Alternative. Alternative 9 is composed of upstream tidal marsh/riparian forest, downstream tidal marsh, and plug removal (see Plate 1). The upstream tidal marsh/riparian forest and downstream tidal marsh elements of this alternative lie within lands purchased for project purposes. The plug removal element will only be implemented if those lands are acquired by the USFWS through fee-title, easement, or agreement for project purposes.

5. PREFERRED ALTERNATIVE*

5.1. Plan Features

The Preferred Alternative is Alternative 9 (upstream tidal marsh/riparian forest habitats, downstream tidal marsh, and plug removal). Implementation of the plug removal element is contingent upon acquisition of the land affected by this element. All elements of the Preferred Alternative can be constructed concurrently, except riparian forest restoration, which would occur in the subsequent winter and spring period.

Excavation will occur between July 15 and October 15 of the first and second construction years, depending upon funding availability, while herbicide application, tillage and plantings will occur between February 1 and May 15 in the following years. Consequently, mobilization and demobilization of equipment will occur at least twice; for riparian restoration, minimal equipment will be required; for planting of cuttings and seedlings, materials and crew will be required (no heavy equipment is forecast for use). Initially, a plug would be constructed across the mouth of the T-channel at low tide to stop tidal flow into the construction area and allow for the area to dry. This plug would have a 24-inch corrugated metal pipe with a tidegate and/or a pumping system placed to handle interior drainage in order to facilitate construction.

Construction access to Crims Island would be by landing barge. The best access point appears to be on the Bradbury Slough shoreline upstream of the constructed channel (T-channel) that penetrates into the interior of the island. Agricultural interests used this location to land animals, equipment and fodder. The landing location features a good bankline with immediate access to an elevated upland with stable soil and apparent deep-water access to the bankline. Landing barges would possess ramps of sufficient width and weight bearing capability to handle a relatively large tracked excavator, tracked or off-road trucks, a D-4 sized Cat, and fuel trucks.

Specific features of the project to be constructed by the Corps are shown on Plate 1 and described below. It is expected that one summer/fall construction period will be required to complete construction efforts for excavation and disposal of soil, although an additional season may be necessary to accommodate any contingencies or funding shortfalls. Tillage operations would occur the next spring. Plantings of tree seedlings and cuttings would occur on 50 acres the winter after construction involving excavation and disposal of soil.

5.1.1. Restoration of Upstream Tidal Marsh Habitat/Riparian Forest and Downstream Tidal Marsh Habitat

Tidal marsh restoration would occur in the late summer/early fall. Tracked excavators and tracked trucks would be used to excavate the site to the appropriate depths. A temporary dam of in situ soil would be used to block the mouth of the T-channel to prevent tidal flow from entering the site and allow for construction under dry conditions. A pump or culvert fitted with a tidegate would be used to dewater the T-channel and tidal marsh sites. The temporary dam would be removed immediately upon completion of the tidal marsh habitat restoration.

Excavated soils from the tidal marsh and channel construction measures would be placed on adjacent pasturelands and subsequently treated aerially with herbicide to control reed canarygrass and then tilled. Natural seed dispersal from adjacent cottonwoods and willows would be relied upon for riparian forest establishment on approximately 65 acres. Plantings of cuttings and/or seedlings to establish riparian forest would be implemented on approximately 50 acres, and also would be

implemented if natural stand establishment was unsatisfactory on the site. Plantings also would be used to increase plant species diversity throughout the restored riparian tract.

5.1.2. Plug Removal

Plug removal would be accomplished by a tracked excavator with borrow material sidecast onto an open area on the existing berm. Borrow material would be roughly leveled with a small cat. Equipment access would be by barge. No restoration actions are planned for the wetland; tidal circulation attains the objective. Either natural seeding or planting of cuttings and seedlings would be used to restore the small disposal area where borrow materials are placed.

5.2. Operations and Maintenance

Operations and maintenance (O&M) activities at Crims Island pertain to the riparian forest habitat to be developed on approximately 115 acres. Minimal O&M activities are forecast for the tidal marsh and channel components of the overall restoration project. Tidal channels are anticipated to be self-maintaining and no intervention would be required. Size of tidal channels was based on empirical formulas, volume of water associated with the tidal cycle, and site elevation. Where tidal channels are too small, the Columbia River will carve them out to the appropriate size. If channels are too large, sediment infill would modify them over time to the appropriate size. The excavation of the current high tidal marsh habitat is intended to allow native tidal marsh vegetation to establish and due to more frequent and prolonged inundation attributable to the lower site elevation, limit establishment of reed canarygrass. Purple loosestrife will establish in the restored tidal marsh habitat given its extensive presence in the lower Columbia River. Biological control actions implemented on a minor scale at present but forecast to increase in intensity and distribution in the near future will aid control of this species at Crims Island.

Riparian forest establishment on the site is predicated on natural seeding (65 acres) and planting of cutting and seedlings (50 acres). It is estimated that a 3-year O&M effort will be required to support establishment of riparian forest vegetation. Riparian trees and shrubs would have sufficient growth to tolerate residual weeds and continue to thrive after 3 years of O&M. The O&M effort will primarily involve weed management and supplemental plantings of trees and shrubs.

Hand cultivation and herbicide treatment, typically hand application, will be used to control herbaceous weeds and blackberries which are expected to readily pioneer onto the 115 acres given that the surface soil will be disturbed from placement of material excavated to restore the tidal marsh and subsequent tillage. Supplemental planting of trees and shrubs will use seedlings obtained on site from natural established plants and cuttings and commercial seedlings obtained locally to fill gaps in the stand.

A five-person labor crew would be used to accomplish the O&M activity. They would collect and plant supplemental trees and shrubs during February to March. Hand cultivation and herbicide treatment of herbaceous weeds (e.g., Canada thistle, tansy ragwort, reed canarygrass, etc.) would occur in June. Hand-spraying of herbicide (possibly Rodeo©), would be used to minimize drift onto desired vegetation and to allow direct targeting of unwanted species.

The O&M costs for the project are estimated at $31,990 per year for the first 3 years of O&M for the Preferred Alternative, plus an additional $9,550 for the first year of O&M for equipment purchase. These O&M costs are related to the riparian forest habitat. No specific O&M measures for tidal marsh habitat are forecast.

5.3. Pre- and Post-construction Monitoring

A pre- and post-construction monitoring effort will measure the response of juvenile salmonids, tidal marsh vegetation, and Columbian white-tailed deer to the Crims Island restoration actions. The monitoring will provide needed information regarding the use of shallow, tidal waters by juvenile salmonids, and also will be an initial effort to determine the success of tidal wetland restoration in the lower Columbia River and estuary. To date, relatively few studies have been conducted on the use of shallow waters in the estuary by juvenile salmonids. Juvenile salmon are known to use tidal habitats in the vicinity of Crims Island (personal communication, W. Van der Naald, ODFW). The studies that have been conducted have shown that both yearling and subyearling chinook salmon use shallow, intertidal areas (Durkin 1982, McCabe et al. 1986).

The USGS Columbia River Research Laboratory will monitor and evaluate the fish response to tidal marsh and channel restoration on Crims Island. The objectives of the monitoring include:

- Describe the seasonal use by juvenile salmon and other fishes of existing backwater and tidal marsh habitats at Crims Island.
- Describe juvenile salmon feeding preferences in mainstem and backwater habitats of the lower Columbia River.
- Compare the relative productivity of the mainstem Columbia River to Crims Island backwaters.
- Determine the effects of soil removal on productive capacity of restored aquatic habitats.

Tidal marsh plant production would be assessed in a manner generally comparable to the methodology used for the Columbia River Estuary Data Development Program (1984). Sampling would occur in late July and early August. Plant cover and species composition will be determined from five sample locations each at the Gull Island reference and the Crims Island restoration tidal marsh areas. These sampling locations will be permanently staked plus their Global Positioning System location will be recorded to ensure that sample sites are reoccupied in subsequent years. Plant cover data will be recorded from five replicate 0.5 square meter quadrants randomly placed around each sampling location. Percent live biomass would be determined from nine randomly placed 0.1 square meter clip-quadrants at each sampling location. The simple harvest method utilizing peak total standing crop measurements, including both live shoots and attached standing dead material of the same season's growth will be used to estimate primary production.

Transects (100 meter) will be established at sites in the riparian forest areas. Species composition and individual species cover will be determined at 10-meter intervals via 1 x 1 meter square sampling quadrants. Vegetative response to tidal marsh and riparian forest restoration efforts would be monitored in fiscal years 2005 and 2007. Photographs will be obtained at each sampling location to document control and ecosystem restoration feature conditions.

Juvenile salmonid use will be measured in the restored tidal marsh and channel habitats plus at the baseline locations represented by the three interior channel locations on Crims Island plus in a tidal marsh habitat at Gull Island to establish a baseline condition. Due to their intertidal location and vegetative cover, trap nets would likely be used. The sampling timeframe would be May, July and September. Monitoring efforts for juvenile salmonid usage of tidal wetlands would occur in fiscal years 2006 and 2007.

The USFWS will monitor the status and reproduction of reintroduced Columbian white-tailed deer on Crims Island (and adjacent islands).

6. ENVIRONMENTAL CONSEQUENCES*

6.1. Physical Characteristics

6.1.1. Geology and Soils

Soil elevations at the project location will be altered via excavation and deposition for the individual restoration measures of the Preferred Alternative. Throughout the upstream tidal marsh habitat, the top 2 feet of soils will be excavated to allow increased tidal inundation. This excavated material will then be evenly redistributed at a depth of 2 feet throughout areas to be planted with riparian vegetation. Although soils will be disturbed, there will be no overall shift in soil type, and soils are expected to continue to provide a suitable growing medium for native species. Excavation of the existing T-channel to provide sufficient capacity for tidal flows associated with the restored tidal marsh habitat will provide reduced erosion of banks. No geological features are present. Geology and soils would not be significantly affected by the proposed restoration project.

For the No Action Alternative, soils would continue to erode throughout the T-channel, although little change would be expected in geology or soil condition over time.

6.1.2. Sediment Quality

It is possible to manage the sediment in question for benzyl alcohol without further characterization by avoiding disturbance of the area or by excavating and placing the material upland, without potential exposure to the water column. The restoration plan for Crims Island calls for upland disposal of soils and sediments excavated for tidal marsh and channel development. Therefore, no further action regarding benzyl alcohol is required and the proposed disposal and management actions would have no adverse affect on sediments. All of the other sediment tested was determined to be suitable for unconfined, in-water disposal, or could be exposed to water after excavation without further characterization.

The construction plan calls for blocking the T-channel inlet at low tide and then using tidegates and/or pumps to maintain a dry environment in the construction area. Construction in the dry will minimize sediment escape from restoration actions into the waters of the Columbia River. Day-lighting the T-channel and downstream inlet/outlet locations would occur at low tide to minimize sediment output to the waters of the Columbia River.

Some sediment discharge from the tidal marsh and channel restoration area would be expected once tidal flows are restored to the area. These discharges would lessen over time as tidal channels reach equilibrium relative to the volume of water on the area and velocities associated with tidal flood and ebb. Some sediment discharge from the disposal area also would be expected, particularly during the first winter when vegetative cover is minimal. However, because the disposal site is relatively level, sediment laden runoff should be minimal. Riparian restoration actions plus pioneering vegetation should minimize the potential for sediment runoff in subsequent years.

6.1.3. Hydrology

Excavation of the marsh plain to a lower elevation would allow for more frequent and longer duration tidal inundation. Excavation also would allow space for a larger volume of water to enter and exit the marsh restoration area during each tidal cycle. This volume of water is termed the tidal prism. Tidal channels form to accommodate this transfer of water and to dissipate its energy. The

size and shape of the channel network is dependant on several factors including hydrodynamics, substrate, and vegetation and is necessarily unique to each system.

Tidal channel sizing is based on empirical relationships derived from several west coast tidal marshes (Williams et al. 2002). Applicability of these empirical relationships to the Columbia River is verified to the extent possible with aerial photos. An intertidal marsh on Tronson Island (CRM 30) has been utilized as a reference site in terms of channel geometry for this project. The geometry for design of the tidal channel system in the tidal marsh restoration area was selected to make best use of the micro-topography of the existing wetland area. Channel placement was designed to move water into and out of areas that are currently low. A one-dimensional unsteady state model was also used to properly size the inlet/outlet channels to the marsh restoration area.

Only the larger order channels would be excavated to full capacity during construction. By creating full capacity in the larger tidal channels during the construction process, sufficient volumes of tidal water will be immediately available to improve water quality, tidal circulation and habitat. Smaller channels, further upstream from the entrance, would be excavated primarily as pilot channels. The smallest channels would be allowed to form naturally. This approach would promote development of the complex channel system and help to control any potential negative effects of mass erosion during channel formation due to marsh excavation.

6.1.4. Floodplains

Proposed restoration measures are intended to reconnect the floodplain habitats of Crims Island to more frequent tidal inundation. First, the T-channel will be expanded to allow increased channel area. Second, 75 acres of high tidal marsh at the upstream end of Crims Island will be excavated by approximately 2 feet to facilitate native tidal marsh vegetation establishment. The construction of sinuous tidal channels would be implemented to allow a more natural tidal cycle for the restored tidal marsh habitat. Lastly, the earthen plug may be removed from the north inlet to the forested wetland, if the appropriate lands are acquired. Removal of this plug will allow daily fluctuation of tidal waters in and out of the forested wetland on the west end of the island.

During construction, the existing T-channel will be disconnected from tidal inundation, resulting in a temporary loss of off-channel habitats. However, the disconnection will be brief and will not contribute to significant changes in floodplain conditions. The Preferred Alternative is not expected to have significant adverse effects to floodplain conditions. Instead, the proposed restoration measures are intended to increase frequency of tidal inundation in the tidal marsh, which will significantly improve native marsh plant establishment, floodplain connectivity and habitat accessibility and condition. Excavation of tidal marsh habitat and channels was engineered based on reference sites and/or information on tidal channel restoration. The objective is to improve tidal inundation, floodplain connectivity, and facilitate growth of natural floodplain fish, wildlife, and plant communities.

For the No Action Alternative, floodplain habitats on the island will remain poorly connected to tidal inundation and flood flows. Formation of tidal channels will continue at a slow pace and will comprise less overall channel habitat.

6.1.5. Water Quality and Quantity

Construction activities that require use of heavy equipment and excavation of substrate in the project area may affect water quality. An increase in turbidity may result from additional input of sediment into the T-channel during construction or input of sediment into the Columbia River during pumping

of the T-channel. However, since all excavation work will be constructed in the dry, introduction of sediment into the T-channel is expected to be minor and settlement should occur prior to releasing the water into Bradbury Slough. Bare ground exposed during construction and throughout the revegetation period may contribute turbidity to the surrounding waters through runoff. Water quantity (tidal flow) will be temporarily restricted in the project area by the earthen dam during the construction period, but will be restored following completion of construction activities. The project will return more natural tidal fluctuations to the island than presently occurs. The channel to connect the current downstream arm of the T-Channel to Bradbury Slough will occur as one of the last construction actions. This channel would be daylighted to Bradbury Slough during a low tide to limit sediment movement to the Columbia River.

Best management practices will be employed to reduce the pollutant emissions from heavy equipment, such as oils, fuels or grease. The primary erosion control measure will be dewatering of the T-channel and placement of the earthen plug at the outlet. Additional erosion control measures may be employed, if necessary.

The construction measures associated with implementation of the selected alternative may result in temporary reductions in water quality. However, it is unlikely that water quality conditions in the Columbia River would be measurably degraded. Water quality or quantity is not expected to experience significant, adverse effects as a result of the proposed project.

For the No Action Alternative, water quality would likely incrementally improve, if cattle are removed from the island. No net changes would be expected for water quantity.

6.1.6. Hazardous, Toxic, and Radioactive Waste

As discussed in Section 2.1.5, a Level I Contaminant Survey (Environmental Site Assessment) for the Jefferson Poplar property on Crims Island (#2 on Figure 2) was conducted by environmental contaminant specialists with the USFWS. Based on the site history and conditions observed during the site visits, the USFWS concluded that there were no apparent contaminant threats to fish and wildlife resources on or near the property.

6.2. Aquatic and Riparian Habitat

During construction, tidal marsh wetlands will be disconnected from their hydrologic source (Bradbury Slough and the Columbia River) to allow reshaping of channels and excavation of 2 feet of high tidal marsh habitat in the dry. During this time, the area will be denuded of vegetation where excavation is proposed. Lack of water and vegetation will temporarily degrade wetland conditions on the island, preventing fish from accessing the tidal marsh habitat and discouraging use by wildlife species. Conversely, the Preferred Alternative includes several components that are intended to improve tidal marsh conditions. Following the construction phase, conditions are expected to greatly improve in tidal marsh habitats. Improvement of tidal inundation, enlargement and contouring of the T-channel, and removal of the earthen plug will result in a more natural tidal inundation of the tidal marsh. Excavation that results in denuding of vegetation allows large scale removal of non-native reed canarygrass and provides a suitable substrate for natural propagation of tidal marsh vegetation from seeds in the soil seed bank and propagules that enter on the tide. Revegetation of the tidal marsh will improve native diversity of plants, which will attract a greater diversity of fish and wildlife species to the wetland. Overall, the selected alternative is expected to have beneficial effects. Temporary dewatering and vegetation removal is not expected to have significant, adverse effects on wetlands in the area.

The Preferred Alternative would restore 75 acres of tidal marsh, 17 acres of tidal channels, and 115 acres of riparian forest habitat on Crims Island. Tidal exchange would be restored to an additional 88 acres of forested swamp/wetland habitat if one inholding is acquired prior to project construction.

The upstream wetland habitat, dominated by reed canarygrass, would be lowered in elevation, which would introduce daily tidal inundation of the area and restore native tidal marsh vegetation. Excavation will occur down to 2 feet to mimic elevations surveyed at a reference tidal marsh at the adjacent Gull Island, where more frequent tidal inundation facilitates growth of native wetland plant communities. The change in elevation should favor the establishment of native tidal marsh vegetation and restore vegetative species richness and diversity. The removal of cattle from the island would improve the structural diversity of the vegetation. An increase in vegetative material, seed production and tubers foraged on by wildlife species would be expected with the restoration of the marsh habitat. Detrital export linked to tidal marsh habitat would be expected to result in a minor improvement to organic production reaching the estuary.

Tidal channels would increase flow into and out of the area and will be sized to match the increase in volume of water on site that would occur with creation of the tidal marsh restoration. The amount of subtidal habitat at Crims Island would increase slightly with construction of tidal channels. Water exchange via tidal action could be greatly increased if the downstream inlet plug is removed.

Increased area of riparian habitat would result in increased detrital input and insect production that is anticipated to benefit fisheries resources. Increases in detrital input and insect production from riparian forest habitat should increase as trees mature over time. Large woody debris input to the river should begin 25 years or more into the future. Restoration of riparian forest would provide for greater species richness and diversity of vegetation, and structural complexity would be increased over the present situation of a pastureland.

During construction, the upper 2 feet of much of the existing emergent wetland would be excavated, removing several acres of primarily non-native vegetation. This area is dominated by reed canary grass and other non-native species that threaten the diversity of the wetland. No large trees are proposed to be removed during construction. Overall, a reduction in non-native species and the proposed native plantings are expected to improve the overall vegetation condition on Crims Island. No significant, adverse effects are expected to vegetation in the project area.

For the No Action Alternative, wetlands will remain in their degraded condition. Non-native species will likely become more dominant over time, potentially reaching monoculture status within the existing high tidal marsh associated with the T-channel. Tidal flows that inundate interior wetlands and allows for increased function, will continue to be largely disconnected from existing wetlands. Also, vegetation may increasingly become dominated by non-native species that threaten the diversity of the emergent, scrub-shrub and forested wetlands on the island.

6.3. Fish and Wildlife

6.3.1. Fish

Bottom dwelling invertebrates including *Corophium* and chironomids are major food items in the diets of juvenile chinook salmon in the lower Columbia River (Craddock et al. 1976) and Columbia River Estuary (McCabe et al. 1983). Sinuous, shallow tidal channels would be constructed through the restored tidal marsh to mimic naturally occurring channels. The channels would improve tidal circulation, allow for greater ingress and egress of juvenile salmonids, and increase detrital export.

The channels would connect to an existing subtidal channel. Invertebrate production would be increased and made more available to rearing fish that access the restored tidal marsh area.

Restoration of tidal marsh and channel habitat at the upstream end of Crims Island would improve fish access and egress, including juvenile salmonids from listed ESUs. Foraging conditions for fish would be expected to improve with provision of more habitat, better access to the site, and an expected improvement in benthic invertebrate populations in the restored tidal channel habitat. Improvements in detrital export associated with project implementation would be expected to benefit the food chain elsewhere in the estuary, including fish that utilize benthic invertebrates.

6.3.2. Wildlife

Restoration of the tidal marsh habitat, particularly the conversion from a canarygrass-dominated marsh habitat to a more diverse, species rich and structurally complex tidal marsh dominated by native plant species would increase wildlife species use of the area. Waterfowl, particularly puddle duck species and tundra swans, would be expected to substantially benefit from tidal marsh restoration. These species of waterfowl make extensive use of tidal marsh habitat, foraging on seeds, vegetative material and tubers. Fish-eating birds, such as great blue herons, belted kingfishers, osprey and common mergansers would be expected to benefit from improvements to the tidal channel and marsh habitat, and the expected increase in fisheries use.

The restoration of 115 acres of riparian forest habitat would benefit a multitude of wildlife species, particularly as the riparian forest habitat matures. Neotropical migratory birds should substantially benefit from establishment of riparian forest habitat. Their use of this habitat would begin almost immediately as early seral stage species would first take advantage of the seedling trees that are established. As the riparian forest matures, species composition of birds present also would change. Birds would be expected to utilize the riparian forest habitat for nesting, foraging and cover. Mature trees, 50 years or more into the future, would be expected to provide snags and large trees suitable for cavity nesting birds and would be able to support large nest structures built by red-tailed hawks, osprey, and perhaps bald eagles.

Mammalian use would be expected to increase in terms of number of species and overall numbers with the restoration of riparian forest habitat. These include small mammals, such as mice, voles, moles and bats. The development of understory vegetation and the formation of a surface duff layer would favor mice, voles and moles. Development of an overstory, and subsequent cavity bearing trees, would favor bats through provision of forage (insects), cover, and eventually maternal dens.

Larger mammals, such as raccoons, mink, otter, beaver and Columbian white-tailed deer, should attain habitat gains with restoration of tidal marsh and riparian forest habitat. Riparian forest habitat would provide forage resources, cover and/or den locations for these species. Increased fisheries and wildlife use of tidal marsh habitat would benefit raccoons, mink and river otter which prey on some of the species comprising these species complexes.

6.4. Threatened and Endangered Species

Biological Assessments (one for fish and one for wildlife/plants) for the proposed restoration project were prepared and is included in Appendix C. Provided below is a summary of the impact assessment and conclusions from the Biological Assessments.

6.4.1. Fish Species

The restoration actions on Crims Island would target development of approximately 92 acres of tidal emergent marsh, mudflat, and channel habitat plus 115 acres of riparian forest habitat. The benefit from the proposed project is based upon historic losses of off-channel salmonid rearing habitat, their importance to juvenile salmonids, and the need to improve this habitat for 12 Columbia River ESUs that have been listed under the ESA by the NOAA Fisheries (see Table 3). These species will benefit, to varying degrees, from the habitat restoration measures in the Preferred Alternative.

The Preferred Alternative may cause temporary and short-term impacts to anadromous salmonids during construction. The probability for direct mortality to juveniles or adults of listed salmonids during construction would be very low because of their low abundance in the area and the temporary nature of the construction activity. Surface water runoff during construction may increase suspended sediment levels in the slough. Elevated turbidity levels have the potential to disrupt feeding and growth patterns of juveniles. Since no spawning occurs on Crims Island, no direct impacts to redds, eggs or alevins would be anticipated. Because of the erosion and sedimentation control measures that will be used during construction and the duration of the impact, any potential impacts would be expected to be small. Construction activities would cause noise and vibration that may be detected by fish and could alter fish behavior in the area. However, since these construction activities would be intermittent and short-term, they would not be expected to have a significant impact on listed fish. Marginal disruption of rearing habitat would occur in the project area during the construction period. However, this project will ultimately increase available rearing habitat and function. The creation of additional rearing habitat and back channels would not be expected to have overall significant adverse effect on salmonids. Instead, the project has been designed to improve habitat for salmonids in the lower Columbia River and estuary.

Based on the analysis of effects and consideration of conservation measures that would be implemented to avoid and reduce effects, it was determined that the project actions *may affect, but are not likely to adversely affect* the 12 Columbia River ESUs.

Critical habitat was designated for Snake River sockeye salmon, Snake River spring/summer chinook salmon, and Snake River fall chinook salmon on December 28, 1993 (58 *Federal Register* 68543), effective on January 27, 1994. Critical habitat was designated for the remaining 9 ESUs on 16 February 2000, but was withdrawn with NOAA Fisheries consent by the U.S. District Court in 2002. The designation of critical habitat provides notice to federal agencies and the public that these areas and features are vital to the conservation of listed salmon.

The essential features of the critical habitat of Snake River salmon have been further defined to include four components: (1) spawning and juvenile rearing areas, (2) juveniles migration corridors, (3) areas for growth and development to adulthood, and (4) adult migration corridors. Growth and development to adulthood occurs in the Pacific Ocean; therefore, critical habitat on-site would include juvenile migration corridors and rearing habitat, both of which are expected to be improved by the project.

Freshwater essential fish habitat for chinook and coho salmon consists of four major components: (1) spawning and incubation; (2) juvenile rearing; (3) juvenile migration corridors; and (4) adults migration corridors and adult holding habitat. Important features for spawning, rearing and migration include adequate substrate composition, water quality (dissolved oxygen, nutrients, temperature, etc.), space, access and passage, and flood plain and habitat connectivity. The Preferred Alternative will enhance salmonid habitat quality and rearing habitat by restoring and enhancing tidal marsh habitats. Proposed actions will substantially increase tidal marsh habitat and riparian forest habitat.

Based on essential fish habitat requirements of chinook and chum salmon, the potential direct, indirect, and cumulative effects of the habitat restoration project on Crims Island are not likely to adversely affect any identified salmonid essential fish habitat, but will provide additional salmonid essential fish habitat.

The only managed groundfish species in the study area is starry flounder which use the area as rearing and feeding areas for both juveniles and adults. Existing essential fish habitat for starry flounder is limited and likely of poor quality because of the lack circulation and poor water quality. Completion of the restoration actions on Crims Island will improve and increase the essential fish habitat for starry flounder.

6.4.2. Wildlife and Plant Species

Columbian White-tailed Deer. One focus for the proposed restoration project is to improve the overall habitat conditions on Crims Island for the endangered Columbian white-tailed deer. Development of riparian forest habitat on the higher ground at the upstream end of Crims Island will provide cover and forage resources for the species, as this area should seldom be inundated. Much of the rest of the island, outside the pasture lands at the upstream end, are subject to seasonal or tidal flooding which can reduce habitat availability to the species, particularly during the winter and spring months.

The proposed restoration project may result in some localized disturbance to Columbian white-tailed deer. Deer would be expected to avoid the construction area(s) during the day. The area affected by restoration construction actions represents only a small percentage of the island habitat. Cattle grazing on the proposed restoration areas currently preclude most deer use. Cover and forage availability would exceed deer requirements during the construction phase. Further, the proposed restoration actions are not dissimilar from management actions, such as revetment, mowing, weed control, and wetland enhancement that have occurred in recent years on the Julia Butler Hansen National Wildlife Refuge. Those actions have not had a demonstrable adverse affect on the species. Therefore, it is concluded that the proposed restoration project *may affect, but is not likely to adversely affect* Columbian white-tailed deer. Post-construction, the restoration of riparian forest habitat will be beneficial to the species.

Bald Eagles. Nesting bald eagles present on Crims Island area approximately 1,000 feet from the nearest proposed affected area and are well screened from construction activities by mature stands of trees, including cottonwoods. Furthermore, construction of the proposed restoration actions would be scheduled for mid-July into early fall to reduce disturbance to nesting eagles. Tilling in the spring (May) to prepare the proper soil conditions for riparian forest establishment would occur when eagles are incubating eggs or tending young. Given the intervening vegetative screening and distance between the nest location and proposed restoration area, construction related disturbance would be minimal or non-existent to the nesting pair. The Corps' bald eagle monitoring actions for the lower Columbia River also would provide information on nesting status that may be utilized to direct the timing of construction actions. Given the reproductive performance associated with this bald eagle territory, it is most likely that no young approaching fledging would be present during the primary construction start. Foraging eagles may be disturbed by construction activities. However, suitable alternative perching and foraging areas are available on nearby Gull Island, the Washington shoreline, and at the west end of the island. Therefore, it is concluded that the proposed restoration project at Crims Island *may affect, but is not likely to adversely affect* bald eagles.

Listed Plants. There is no suitable habitat for howellia, Bradshaw's lomatium, and Nelson's checkermallow in the project area, and none of these plant species have been observed. Therefore, the proposed restoration project would have *no effect* on these species.

6.5. Cultural and Historic Resources

Known cultural resources in the project area include the ground area encompassing the former structures previously used for dairy farming on Crims Island. This area would be avoided during project construction and a buffer zone established around their former location. These structures were over 50 years old, and though most of them have been burned, they still represent a cultural resource area that should be avoided.

It is unknown if additional cultural resources are presently buried within the affected area. A detailed cultural review is underway and in coordination with the SHPO. Excavation, hauling and redistribution of sediments within the project area would have the most potential to directly impact subsurface cultural deposits if they are present. Heavy equipment may damage artifacts through pressurization or direct excavation damage. However, based on knowledge regarding prehistoric settlement patterns, it is unlikely that Crims Island was the site of a village or settlement. The tidal marsh excavation area would have been a very unlikely location for any settlement but may have provided fishing and hunting areas. The spreading of an additional 5 inches to 2 feet of earth over any buried cultural resources would not seem likely to be deleterious, and might even add to their protection. The added overburden would not seriously restrict the ability of any future researchers to reach potential subsurface deposits.

In order to assess for impacts to unknown cultural resources during excavation of new channels the following recommendations are made. First, sampling should be done via backhoe pits prior to channel excavation. Second, channel excavations should be monitored as they occur. Lastly, record and interpret profiles of exposed of stratigraphy and analyze appropriate pedological and radiometric samples in backhoe pits and along existing channels to identify geomorphological processes and history in the project area.

Further details regarding the potential for cultural resources to be present onsite will be considered by the SHPO. All project construction activities will be in full compliance with regulatory laws and regulations. As a result, no significant, adverse effects on cultural resources would be expected as a result of implementation of the Preferred Alternative.

For the No Action Alternative, cultural resource conditions are not likely to change significantly. However, natural river and climate fluctuations may contribute to the degradation of resources that may be present.

6.6. Socioeconomics and Land Uses

Crims Island provides little socioeconomic input to the local or national community in the form of cattle raised on the island. However, cattle will be relocated whether the Preferred Alternative is implemented or not. There are no public services or operational utilities on the island. No significant adverse effects are expected for public services or utilities as a result of the Preferred Alternative. Also, no adverse effects to land uses would be expected as a result of implementation of the Preferred Alternative or as a result of the No Action Alternative.

Restoration of tidal marsh, forested wetland and riparian habitats within the island will enhance fish and wildlife habitat once construction is complete. This may improve recreational value for

birdwatchers, hunters, and anglers. Access to the restoration portion of the island post-construction will be managed by the USFWS. During construction, recreational value will be temporarily diminished as a result of the noise and activity of heavy equipment and people onsite. Present recreational use is minimal as the site was privately held and used to graze cattle. Many other recreational opportunities exist throughout the area. The Preferred Alternative is not expected to have significant adverse effects to recreation at Crims Island.

The limited current recreational value of the project area may dwindle over time under the No Action Alternative, if continued expansion of reed canary grass, Himalayan blackberry, and purple loosestrife threatens native wildlife diversity. Over time, failure to implement restoration measures throughout the Lower Columbia River estuary may result in further decrease in fish and wildlife populations. This could also reduce the recreation opportunities of the general area.

During construction, the aesthetic value of Crims Island will be temporarily degraded. The restoration area is not visible from the Columbia River and its nearby shores. Following construction, the presence of native tidal wetland habitat and absence of cattle will significantly enhance aesthetic value. The island will once again offer the estuary wetland aesthetic that was historically present. The temporary decline in aesthetic appeal that occurs during construction will be insignificant compared to the beauty that is restored to the island. Adverse effects to aesthetics will not be significant for the Preferred Alternative.

For the No Action Alternative, aesthetic conditions may decline. Continued establishment of reed canarygrass, Himalayan blackberry, and purple loosestrife could result in monocultures of these plants, which severely contradict the natural historic appearance of the lower Columbia River and estuary.

6.7. Air Quality/Noise/Light

Impacts to air quality and noise arising from the Preferred Alternative would occur during initial construction efforts. These impacts would result from use of heavy equipment and would be both minor and temporary in nature. Vegetative buffers and/or distance minimize impacts on wildlife residents of the island and human residents on adjacent shores. Post-construction, there would be no adverse effects expected to air quality and noise. No impacts associated with light would be expected.

For the No Action Alternative, air quality, noise, and light conditions would not change.

6.8. Cumulative Effects

The Preferred Alternative would result in the long-term restoration of 115 acres of riparian forest, 75 acres of tidal marsh and 17 acres of tidal marsh channel habitat. Tidal circulation may be restored to 88 acres of forested swamp/wetland habitat contingent upon purchase of a private inholding near the downstream end of Crims Island. Therefore, a range of 207-295 acres of lower Columbia River habitat would be restored to natural conditions. The Preferred Alternative would result in cumulative benefits for fish and wildlife resources that inhabit the area, including threatened and endangered species.

Although a minor, temporary impact to water quality associated with sediment-related turbidity would be likely; no long-term impairment to water quality would be anticipated for the Preferred Alternative. Temporary increases in turbidity would not have a cumulative effect on water quality in the river due to their temporary nature and the use of best management practices, e.g., emplacing an

earthen dam at the mouth of the T-channel to confine them and construction of the dam and channel opening to Bradbury Slough during low tide in order to be out of the water and thus minimize export offsite of sediments in the water column.

The Preferred Alternative represents one of the initial habitat restoration efforts to reverse actions dating back a century or more that have contributed to the substantial decrease in natural habitats along the lower Columbia River. Although minor in scope compared to the historic habitat losses, the Preferred Alternative represents an incremental gain toward the 10,000 acres of restored habitat proposed in the NOAA Fisheries *Biological Opinion* prepared for operation of the Federal Columbia River Power System.

7. COST ESTIMATE AND SCHEDULE

7.1. Real Estate

The Columbia Land Trust acquired fee title ownership to 473 acres on Crims Island, and will transfer ownership of those acres to the USFWS for inclusion into the Julia Butler Hansen National Wildlife Refuge. The land transfer is expected to be completed in May 2004 prior to initiation of project construction, which is scheduled for August 2004. The USFWS also has made an offer to the current landowner for the purchase of an additional 90 acres on the island, which are contiguous and west of the new acquisition. These additional acres encompass the 'plug removal' element of the Preferred Alternative. Implementation of the plug removal element is contingent upon acquisition of these additional 90 acres. Should this land not be acquired by the USFWS, the plug removal element would not be constructed.

Real Estate actions for implementation of the Preferred Alternative are limited in scope to obtaining a right-of-entry for the Corps' and its contractors to construct the various project features on USFWS property. The right-of-entry will be sought once the USFWS obtains the property from the Columbia Land Trust. There are no concerns regarding obtaining a right-of-entry from the USFWS, which is a project partner with the Corps and other entities.

7.2. Project Cost Estimate

For implementation, the Corps considers the fully funded cost estimate. This cost estimate is inflated to reflect expected inflation to a point midway through the construction of the project (see Appendix D). The fully funded cost estimate for the Preferred Alternative is shown in Table 7.

Table 7. Fully Funded Cost Estimate, Preferred Alternative

Cost Category	Estimated Cost ($1000s)
Total Construction Costs	3,079.4
Feasibility Studies	410.0
Planning, Engineering and Design	213.6
Construction Management	171.9
Total Project Cost	3,874.8

7.3. Operation and Maintenance

Operation and maintenance of the restored habitats on Crims Island will be the responsibility of the USFWS. It is estimated that the USFWS will assume O&M responsibility three years after initial construction. Future actions associated with O&M will likely pertain to control of invasive plants such as purple loosestrife, Canadian thistle, and reed canarygrass. The excavation of the tidal marsh restoration area is intended to lead to a different hydrologic regime than present conditions, favoring native tidal marsh vegetation and precluding invasion by reed canarygrass that prefers a high tidal marsh environment. Purple loosestrife will invade the site due to the extensive infestation in the lower Columbia River. Tidal marsh restoration should benefit from the ongoing and forthcoming efforts by various federal, state and local governments to implement biological controls for purple loosestrife. The initial preparations to restore riparian forest vegetation are intended to provide trees and shrubs a sufficient window (2-5 years) in which to attain sufficient growth to out compete

herbaceous weeds and reed canarygrass. Attainment of a riparian forest stand initially will limit future riparian O&M requirements.

7.4. Design and Construction Schedule

Public Notice, Integrated Feasibility Report and Environmental Assessment	April 20, 2004
Independent Technical Review (ITR)	May 1, 2004
Finding of No Significant Impact	May 28, 2004
Plans and Specifications	May 3, 2004
BCOE Review	May 5-19, 2004
Incorporate BCOE and ITR Review Comments	June 1, 2004
Plans and Specifications to Contracting	June 1, 2004
Contract Advertisement	June 15, 2004
Bid Opening	July 15, 2004
Contract Award	August 1, 2004
Notice to Proceed	August 15, 2004
Phase I Construction (excavation)	August 15-October 29, 2004 and August 15-October 31, 2005
Phase II Construction (riparian plantings)	February 15-May 31, 2005 and February 15-May 31, 2006

7.5. Sponsor Responsibilities

The Section 536 authority allows for projects on federal land. These projects are sponsored by the agency that owns the land, which in the case of Crims Island will be the USFWS. Also, there would be no cost share associated with the restoration. The Corps will fund the restoration action and the USFWS will provide the land and O&M requirements. A draft Memorandum of Agreement between the Corps and the USFWS is located in Appendix E.

8. COORDINATION AND LOCAL SUPPORT

8.1. Public and Agency Coordination

The Crims Island habitat restoration project has received substantial public and agency coordination. The USFWS initially submitted a proposal to the BPA for acquisition of lands and restoration of habitats on Crims Island. The proposal was subsequently presented to the NPCC for review, including their Fiscal Year 2003 Provincial Review process. Governmental and non-governmental entities are included in the Provincial Review process, including the Columbia Basin Fish and Wildlife Authority. Therefore, the Crims Island acquisition and restoration proposal has received considerable public and agency technical review prior to approval for acquisition of lands using BPA funds. The Columbia Land Trust acquired the option to purchase property on Crims Island. Their purchase of the Crims Island property has been concluded and the land will be transferred to the USFWS in May 2004.

The restoration measures for Crims Island have been coordinated with the USFWS, NOAA Fisheries, and the USGS regarding habitat objectives and design. The USGS representatives have collected data on baseline fisheries use in the project area and provided hydro-geomorphological input into the nature and design of tidal channels to be constructed. The Natural Resource Conservation Service also has participated in site visits and provided information on the nature and capability of site soils to support riparian and tidal marsh vegetation.

The Integrated Feasibility Report and Environmental Assessment will receive a 30-day public and agency review. Any comments received from this review will be considered and incorporated into the proposed project, as appropriate.

8.2. Views and Preferences of Project Partners

The USFWS, NPCC, BPA, NOAA Fisheries, USGS and other resource agencies, including non-governmental organizations, are strongly supportive in the restoration of tidal marsh and riparian forest habitat along the lower Columbia River. These habitat elements have incurred substantial historic losses due to diking and conversion of lands to urban and agricultural development. Invasive plants, particularly reed canarygrass and purple loosestrife, also are contributing to the qualitative loss of tidal marsh habitat.

The preferences of project partners regarding the nature and extent of tidal marsh, tidal channel and riparian forest habitat restoration have been vetted through numerous interagency meetings and site visits. Costs and incremental gain in habitat and/or value to species groups were considered in the restoration analysis and were the basis for modification of some restoration actions proposed by participants. Overall, the proposed restoration project at Crims Island attains the general preferences of the project partners. Letters of support are provided in Appendix E.

9. COMPLIANCE WITH APPLICABLE LAWS AND REGULATIONS*

9.1. National Environmental Policy Act of 1969, as Amended

The Environmental Assessment integrated into the Feasibility Report satisfies the requirements of the National Environmental Policy Act (42 USC 4321 et seq.).

9.2. Endangered Species Act of 1973, as Amended

In accordance with Section 7(a)(2) of the Endangered Species Act (ESA) of 1973, as amended, federally funded, constructed, permitted, or licensed projects must take into consideration impacts to federally listed or proposed threatened or endangered species. The USFWS and NOAA Fisheries have been consulted regarding fish, wildlife, and plant species listed or proposed to be listed under the ESA. Biological Assessments (one for fish and one for wildlife/plants) were prepared for the proposed project and are found in Appendix C. The proposed project received a concurrence letter (dated March 8, 2004) from the USFWS for ESA species under their purview. It is currently under review by NOAA Fisheries for ESA compliance for listed species under their purview.

9.3. Clean Water Act of 1977, as Amended

Section 401 of the Clean Water Act requires certification from the state or interstate water control agencies that a proposed water resources project is in compliance with established effluent limitations and water quality standards. The project is in compliance with the Clean Water Act via public review of the project under both Sections 404 and 401 and issuance of the 401 Water Quality Certification under Nationwide Permit #27 (*Federal Register* 67(10): 2082-2083), Oregon Department of Environmental Quality letter dated August 16, 2002. The Section 404(b)(1) Evaluation for the project is located in Appendix A.

9.4. Oregon State Water Quality Standards

Section 401 of the federal Clean Water Act requires states to review projects and federal permits to ensure they will not impact the stream quality or violate surface water quality standards. The restoration action is permitted under Nationwide Permit #27 for which the Oregon Department of Environmental Quality provided water quality certification (letter dated August 16, 2002).

9.5. National Historic Preservation Act

Section 106 of the NHPA requires that a federally assisted or federally permitted projects account for the potential effects on sites, districts, buildings, structures, or objects that are included in or eligible for inclusion in the National Register of Historic Places. A cultural resources review is currently underway and will be reviewed by the SHPO to achieve compliance with the act.

9.6. Native American Graves Protection and Repatriation Act

The Native American Graves Protection and Repatriation Act provides for the protection of Native American and Native Hawaiian cultural items, established ownership and control of Native American cultural items, human remains, and associated funerary objects to Native Americans. It also establishes requirements for the treatment of Native American human remains and sacred or cultural objects found on federal land. This act also provides for the protection, inventory, and repatriation of Native American cultural items, human remains, and associated funerary objects. A

cultural resources review is currently underway and will be reviewed by the SHPO to achieve compliance.

9.7. Fish and Wildlife Coordination Act

The Fish and Wildlife Coordination Act of 1934 states that federal agencies involved in water resource development are to consult with the USFWS and state agency administering wildlife resources concerning proposed actions or plans. Recommendations provided by the USFWS must be specifically addressed in feasibility reports. This proposed project has been jointly undertaken with the USFWS and ODFW and is in compliance with the act.

9.8. Executive Order 11988, Floodplain Management, 24 May 1977

This executive order requires federal agencies to consider how their actions may encourage future development in floodplains, and to minimize such development. The proposed project is in compliance with Executive Order 11988.

9.9. Executive Order 11990, Protection of Wetlands

This executive order requires federal agencies to protect wetland habitats. This proposed project is in compliance with Executive Order 11990.

9.10. Executive Order 12898, Environmental Justice

This executive order requires federal agencies to consider and minimize potential impacts on subsistence, low-income or minority communities. The goal is to ensure that no person or group of people should shoulder a disproportionate share of the negative environmental impacts resulting from the execution of this country's domestic and foreign policy programs. This proposed project is in compliance with Executive Order 12898.

10. CONCLUSIONS AND RECOMMENDATION

10.1. Conclusions

This Integrated Feasibility Study and Environmental Assessment has included an examination of all practicable alternatives for meeting the study purpose to restore tidal emergent marsh, tidal channel, and riparian forest habitats on Crims Island to benefit many fish and wildlife species in the lower Columbia River and estuary. The need for habitat restoration at Crims Island is predicated upon the significant historic losses of tidal marsh and riparian forest habitat along the lower Columbia River.

The Preferred Alternative (Alternative 9) is an incrementally justified and cost-effective alternative that also meets the needs of the sponsor, the U.S. Fish and Wildlife Service. The alternative includes restoration of upstream tidal marsh/riparian forest, downstream tidal marsh, and plug removal to restore tidal flow to interior marshes and a forested freshwater marsh. The upstream tidal marsh/riparian forest and downstream tidal marsh elements of this alternative lie within lands purchased for project purposes. The plug removal element will only be implemented if those lands are acquired by the U.S. Fish and Wildlife Service through fee-title, easement, or agreement for project purposes.

The Preferred Alternative provides substantial benefits to many fish and wildlife species, including federally listed salmonids, the endangered Columbian white-tailed deer, and the threatened bald eagle, as well as waterfowl and Neotropical migratory birds, at a reasonable construction and operation and maintenance cost. A monitoring program will measure the response of fish, especially juvenile salmonids, and vegetation to the restoration measures.

Restoration of habitat for juvenile salmonids migrating through the lower Columbia River and estuary is an important component of regional recovery plans. The proposed project addresses numerous limiting factors and fish and wildlife needs identified in the 2001 *Lower Columbia River and Columbia River Subbasin Summary*. It is consistent with and will help achieve the Northwest Power and Conservation Council's biological objectives outlined in their 2000 *Columbia Basin Fish and Wildlife Program.* The proposed project addresses the 2000 *Federal Columbia River Power System Biological Opinion* Reasonable and Prudent Alternatives for listed salmonids and will aid in U.S. Fish and Wildlife Service's recovery efforts for the endangered Columbian white-tailed deer.

Project partners include the U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, Bonneville Power Administration, U.S. Geological Survey, and the Columbia Land Trust. The proposed project has been reviewed in light of overall public interest, which includes the views of the sponsor and interested agencies. The Portland District has concluded that the total public interest would be served by the implementation of the Preferred Alternative for habitat restoration on Crims Island.

10.2. Recommendation

I have given careful consideration to all significant aspects of this study in the overall public interest, including the environmental, social and economic, and engineering aspects, and the requirements of the sponsor, the U.S. Fish and Wildlife Service. The Preferred Alternative described in this Integrated Feasibility Report and Environmental Assessment provides the optimum solution for restoring critical tidal emergent marsh, tidal channel, and riparian forest habitats to benefit many fish and wildlife species in the lower Columbia River and estuary, including federally listed salmonid species and endangered Columbian white-tailed deer.

I recommend that the Preferred Alternative for the Crims Island Habitat Restoration Project be implemented under Section 536 of the Water Resources Development Act of 2000 (Public Law 106-541). The fully funded cost estimate for the Preferred Alternative is $3,874,800.

The recommendations contained herein reflect the information available at this time and current Departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of national Civil Works construction program nor the perspective of higher review levels within the Executive Branch.

Date: _____

CHARLES S. MARKHAM
Lieutenant Colonel, EN
Acting Commander

11. LITERATURE CITED

Bottom, D.L., C.A. Simenstad, A.M. Baptista, D.A. Jay, J. Burke, K.K. Jones, E. Casillas, and M.H. Schiewe. 2001. Salmon at river's end: The role of the estuary in the decline and recovery of Columbia River salmon. U.S. National Marine Fisheries Service, Seattle WA.

Callaway, J.C. 2001. Hydrology and substrate. Pages 89-117 in J.B. Zedler, ed. Handbook for Restoring Tidal Wetlands. CRC Press, New York.

CH2M Hill. 1993. Technical Memorandum. Biological Assessment of Federal Listed and Candidate Species for the Barney Reservoir Expansion Project. Prepared for U.S. Army Corps of Engineers, Portland OR.

Christy, J.A. and J.A. Putera. 1993. Lower Columbia River natural area inventory. Report to the Nature Conservancy, Washington Field Office, Seattle.

Craddock, D.R., T.H. Blahm, and W.D. Parente. 1976. Occurrence and utilization of zooplankton by juvenile chinook salmon in the lower Columbia River. *Transactions of the American Fisheries Society* 105(1):72-76.

Durkin, J.T. 1982. Migration characteristics of coho salmon (*Oncorhynchus kisutch*) smolts in the Columbia River and its estuary. Pages 365-376 in V.S. Kennedy, ed. Estuarine Comparisons. Academic Press, Inc., New York.

Fuhrer, G.J., D.Q. Tanner, J.L. Morace, S.W. McKenzie, and K.A. Skach. 1996. Water Quality of the Lower Columbia River Basin: Analysis of Current and Historical Water-Quality Data through 1994. U.S. Geological Survey. Water-Resources Investigations Report 95-4294. Prepared in cooperation with the Lower Columbia River Bi-State Water-Quality Programs.

Garrett, M., R.G. Anthony, J.W. Watson, and K. McGarigal. 1988. Ecology of Bald Eagles on the Lower Columbia River. Oregon Cooperative Wildlife Research Unit, Oregon State University, Corvallis. Prepared for the U.S. Army Corps of Engineers, Portland OR.

Graves, J.K., J.A. Christy, and P.J. Clinton. 1995. Historic Habitats of the Lower Columbia River. Columbia River Estuary Study Task Force, Astoria OR.

Henney, C.J., A. Grove, and O.R. Hedstrom. 1996. A Field Evaluation of Mink and River Otter on the Lower Columbia River and the Influence of Environmental Contaminants. Final report for the Lower Columbia River Bi-State Water Quality Program. National Biological Survey, Forest and Rangeland Ecosystem Science Center, Northwest Research Station, Corvallis OR.

Hinchberger, M.S. 1978. Occurrence and Relative Abundance of Small Mammals Associated with Riparian and Upland Habitats Along the Columbia River. Masters Thesis, Oregon State University, Corvallis.

Isaacs, F.B. and R.G. Anthony. 2002. Bald Eagle Nest Locations and History of Use in Oregon and the Washington Portion of the Columbia River Recovery Zone, 1971 through 2002. Oregon Cooperative Fish and Wildlife Research Unit, Oregon State University, Corvallis.

Lower Columbia River Estuary Partnership (LCREP). 1999. Comprehensive Conservation and Management Plan. Available at http://www.lcrep.org/ccmpsummary.htm.

McCabe, G.T., Jr., W.D. Muir, R.E. Emmett, and J.T. Durkin. 1983. Interrelationships between juvenile salmonids and non-salmonid fish in the Columbia River Estuary. *Fishery Bulletin.* 81(4):815-826.

McCabe Jr., G.T., R.L. Emmett, W. D. Muir, and T.H. Blahm. 1986. Utilization of the Columbia River estuary by subyearling chinook salmon. *Northwest Science* 60:113-124.

Natural Resources Conservation Service (NRCS). 1985. Soil Survey of Columbia County. Natural Resources Conservation Service (formerly Soil Conservation Service).

Nez Perce, Umatilla, Warm Springs, and Yakama Tribes. 1995. Wy-Kan-Ush-Mi Wa-Kish-Wit Spirit of the Salmon. Available at http://www.critfc.org/text/techrec.htm.

Northwest Power and Conservation Council (NPCC). 2000 Columbia Basin Fish and Wildlife Program. Available at http://www.nwcouncil.org/library/2000/2000-19/Default.htm.

Northwest Power and Conservation Council (NPCC). 2001. Lower Columbia River and Columbia River Estuary Subbasin Summary. Available at http://www.cbfwa.org/files/province/estuary.

Scientific Resources, Inc. 1990. Biological Assessment Endangered Species and the WTD Site at Port Westward, Near Clatskanie, Oregon. Submitted by WTD Industries, Inc. to the U.S. Army Corps of Engineers, Environmental and Inspection Section, Portland OR.

Tetra Tech. 1995. Willamette River Basin Water Quality Study. Prepared for the Oregon Department of Environmental Quality, Salem OR.

Tetra Tech. 1996. Lower Columbia River Bi-state Program – the Health of the River, 1990-1996. Integrated Technical Report. Prepared for the Oregon Department of Environmental Quality and the Washington Department of Ecology.

Thompson, D.Q., R.L. Stuckey, and E.B. Thompson. 1987. Spread, Impact, and Control of Purple Loosestrife (*Lythrum salicaria*) in North American Wetlands. U.S. Fish and Wildlife Service, Fish and Wildlife Research 2.

U.S. Army Corps of Engineers (Corps). 1996. Lower Columbia River Bi-state Water Quality Program, Fish, Wildlife, and Wetlands GIS Habitat Mapping. Prepared for the Oregon Department of Environmental Quality. Portland District, Portland OR.

U.S. Fish and Wildlife Service (USFWS). 1983. Revised Columbian White-tailed Deer Recovery Plan. Portland OR.

U.S. Fish and Wildlife Service (USFWS). 1994. Formal Consultation Letter for Barney Reservoir Expansion Project. Letter dated June 28, 1994. Portland OR.

U.S. Fish and Wildlife Service (USFWS). 1998. Final Rule: Water Howellia. *Federal Register* July 14, 1994.

U.S. Fish and Wildlife Service (USFWS). 2002. National Wetland Inventory (NWI). Division of Habitat and Resources Conservation. Arlington VA. Website: http://wetlands.fws.gov/.

Williams, P.B., M.K. Orr, and N.J.Garrity. 2002. Hydraulic geometry: A geomorphic design tool for tidal marsh channel evolution in wetland restoration projects. *Restoration Ecology* 10(3):577-590.