Final Report

Dredging Operations Appendix Willamette River Dredge Material Management Plan

Prepared for

U.S. Army Corps of Engineers
Portland District

January 2008

Prepared by

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Printed on Recycled and Recyclable Paper

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Acronyms and Abbreviations

BMPs	best management practices
CAD	contained aquatic disposal
CDF	Confined Disposal Facility
COPC	constituents of potential concern
CRD	Columbia River Datum
CRL	Columbia River Landfill
CWA	Clean Water Act
cy	cubic yards
DMMP	Lower Willamette River Dredge Material Management Plan
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FNC	Federal Navigation Channel
GPS	Global Positioning System
mcy	million cubic yards
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
NEPA	National Environmental Policy Act
NGVD	National Geodetic Vertical Datum
ODFW	Oregon Department of Fish and Wildlife
O&M	operations and maintenance
PAHs	polynuclear aromatic hydrocarbons
PCBs	polychlorinated biphenyls
RCRA	Resource Conservation and Recovery Act
RISG	Ross Island Sand and Gravel
RM	river mile
RTK	real time kinematic
SOD	sediment oxygen demand
TBT	tributyltin
TCLP	toxicity characteristic leaching procedure
TOC	total organic carbon

TSS	total suspended sediment
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WHI	West Hayden Island
WRM	Willamette River Mile

SECTION 1

Introduction

1.1 Appendix Scope

An evaluation of dredging operations is an important part of the development of the Lower Willamette River Dredge Material Management Plan (DMMP). The DMMP will establish a 20-year plan for maintaining the lower Willamette River Federal Navigation Channel (FNC). This appendix describes methods of dredging, methods for transporting dredged material, and methods for management of the dredged material. The methods for management of dredge material are divided into two categories: Beneficial Use and Disposal. Each category is subdivided into upland options and in-water options. Material characterization and acceptability also are discussed in this appendix.

The purpose of the lower Willamette River DMMP and Environmental Impact Statement (EIS) is to:

1. Develop and evaluate alternative plans to maintain the 40-foot FNC in the lower Willamette River for the next 20 years; and
2. Develop and evaluate alternative plans for managing any sediment removed from the FNC, which may include material unsuitable for in-water disposal, in a cost-effective and environmentally acceptable manner.

The DMMP will describe the maintenance of the FNC, from river mile (RM) 0 to 11.6, to a depth of -40 feet Columbia River Datum (CRD) plus 2 feet for advanced maintenance dredging.

1.2 Evaluation Criteria

Each of the methods for dredging operation, transportation, and material management has been evaluated for technical feasibility, environmental acceptability, and cost effectiveness with regard to dredging and dredged material management activities within the Willamette River FNC. The objective of the dredging and dredged material management activities is to maintain the Willamette FNC to a depth of -40 CRD plus 2 feet advanced maintenance dredging. Technical feasibility, environmental acceptability and cost effectiveness are defined as described below:

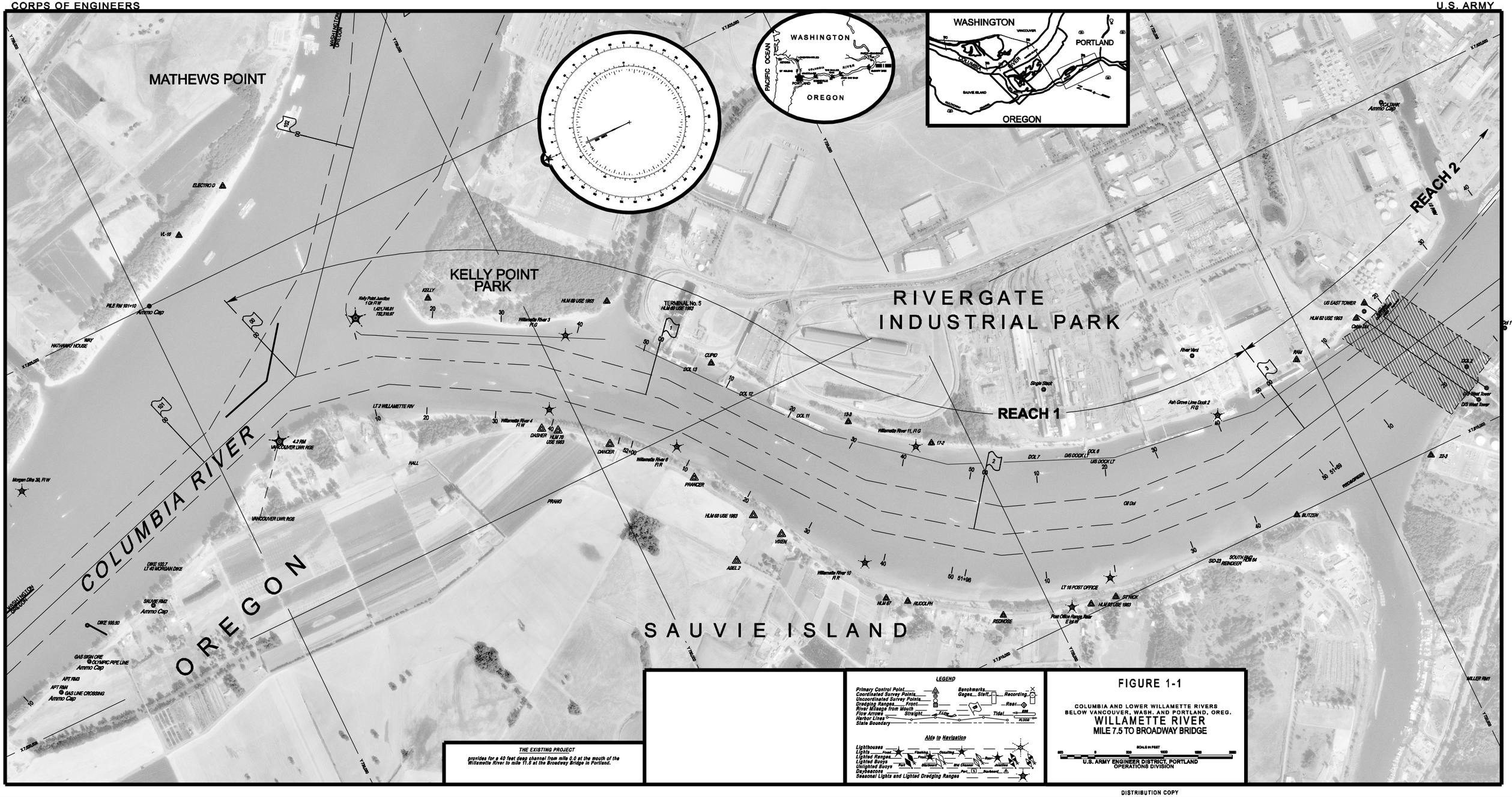
- **Technical Feasibility.** The ability of each method to accomplish the proposed objective. This can include operation, maintenance, technical components and long-term effectiveness of the dredging, transportation, or management methods. Other factors that may be included in the evaluation can include the availability of equipment, operators and technical specialists, as well as the applicability of each method for each river reach.

- **Environmental Acceptability.** The ability of each method to be protective of human health and the environment and to comply with all applicable requirements under the Clean Water Act (CWA) and the National Environmental Policy Act (NEPA). Each method was evaluated on two scales: short-term and long-term. Short-term environmental acceptability will consider the environmental impacts incurred during construction activities such as dredging, transport of dredge material, and deposition of the material at the material management site. Long-term environmental acceptability will consider the environmental impacts incurred by each method after the construction phase is complete.
- **Cost Effectiveness.** The cost of each method by comparison to others using the relative capital plus operations and maintenance (O&M) costs, rather than detailed estimates. The costs for each method are evaluated based on engineering judgment relative to the other methods in the same category.

The evaluation criteria were applied to each method of dredging, material transport and material management independently for each reach of the Willamette River. The methods are compared using a relative system with four categories: 1) Very Favorable, 2) Favorable, 3) Marginal, and 4) Not Recommended. The evaluation is summarized in tables contained in Section 6.

1.3 River Reaches

For the purpose of this evaluation, the Willamette River FNC was divided into three river reaches: Reach 1 (Willamette River Mile [WRM] 0-3); Reach 2 (WRM 3-6.5); and Reach 3 (WRM 6.5-11.6). The reach boundaries were originally defined in the U.S. Army Corps of Engineers (USACE) Portland District Hydrographic survey charts as the chart limits, which are delineated in Figures 1-1, 1-2 and 1-3, respectively.



THE EXISTING PROJECT

provides for a 40 feet deep channel from mile 0.0 at the mouth of the Willamette River to mile 11.5 at the Broadway Bridge in Portland.

LEGEND

Primary Control Point
Coordinated Survey Points
Uncoordinated Survey Points
Dredging Ranges ..... Front
River Mileage from Mouth
Flow Arrows ..... Straight ..... Eddy
Harbor Lines
State Boundary
Benchmarks
Gages ..... Staff ..... Recording
Rear
Tidal ..... Ebb ..... Flood

Aids to Navigation

Lighthouses
Lights ..... Fixed ..... Flashing ..... Occulting
Lighted Ranges ..... Front ..... Rear
Lighted Buoys
Unlighted Buoys ..... Can ..... Stakeboat ..... Mid Channel ..... Junction
Daybeacons ..... Port ..... Starboard
Seasonal Lights and Lighted Dredging Ranges

FIGURE 1-1

COLUMBIA AND LOWER WILLAMETTE RIVERS
BELOW VANCOUVER, WASH. AND PORTLAND, OREG.

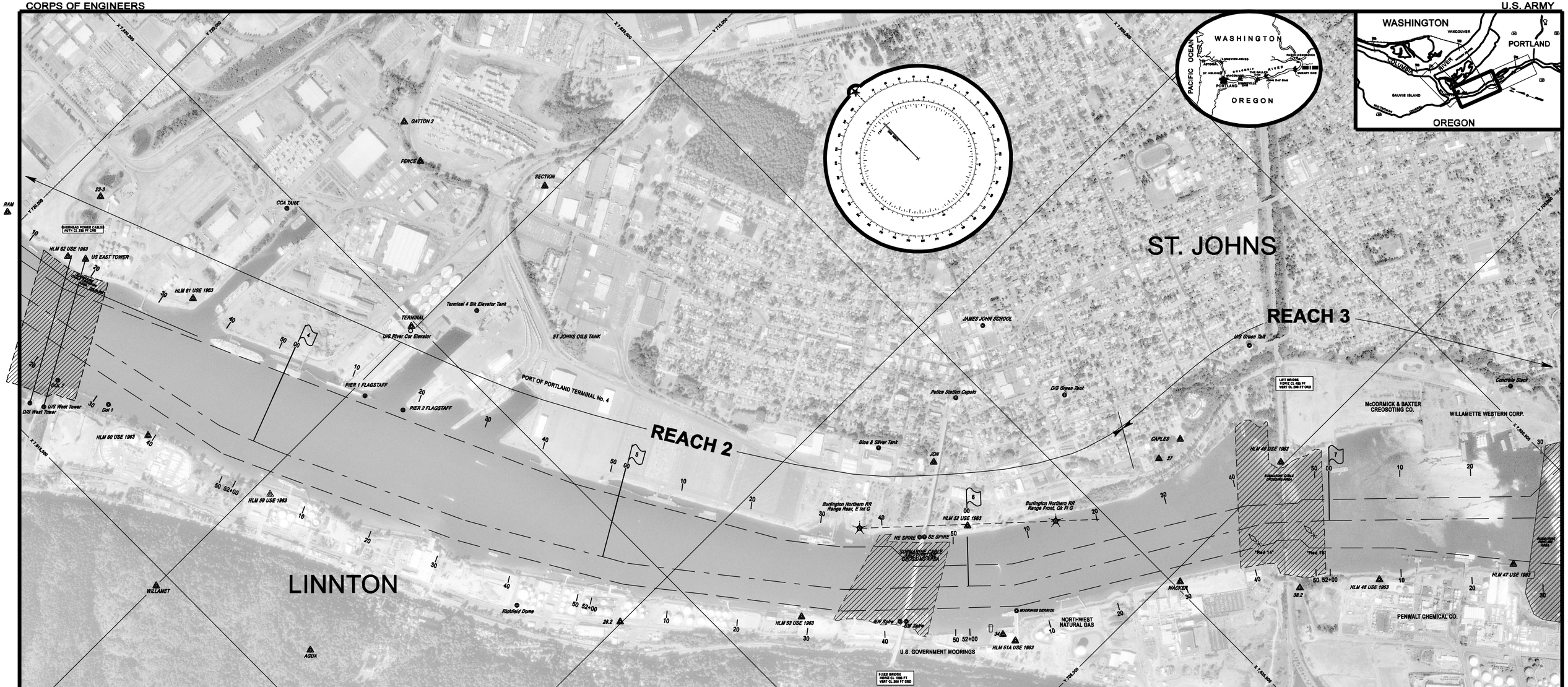
WILLAMETTE RIVER
MILE 7.5 TO BROADWAY BRIDGE

SCALE IN FEET
500 0 500 1000 1500 2000

U.S. ARMY ENGINEER DISTRICT, PORTLAND
OPERATIONS DIVISION

CORPS OF ENGINEERS

U.S. ARMY



THE EXISTING PROJECT

provides for a 40 feet deep channel from mile 0.0 at the mouth of the Willamette River to mile 11.5 at the Broadway Bridge

LEGEND

Primary Control Point
Coordinated Survey Points
Uncoordinated Survey Points
Dredging Ranges — Front
River Mileage from Mouth
Flow Arrows — Straight — FLOW
Harbor Lines
State Boundary

Benchmarks
Gages — Staff — Recording
Rear
Tide! — FLOOD

Aids to Navigation

Lighthouses
Lights — Fixed — Flashing — Occulting
Lighted Ranges — Front — Rear
Lighted Buoys — Port — Starboard — Mid Channel — Junction
Unlighted Buoys
Daybeacons — Port — Starboard
Seasonal Lights and Lighted Dredging Ranges

FIGURE 1-2

COLUMBIA AND LOWER WILLAMETTE RIVERS
BELOW VANCOUVER, WASH. AND PORTLAND, OREG.

WILLAMETTE RIVER
MILE 7.5 TO BROADWAY BRIDGE

SCALE IN FEET
1000 0 500 1000 1500 2000

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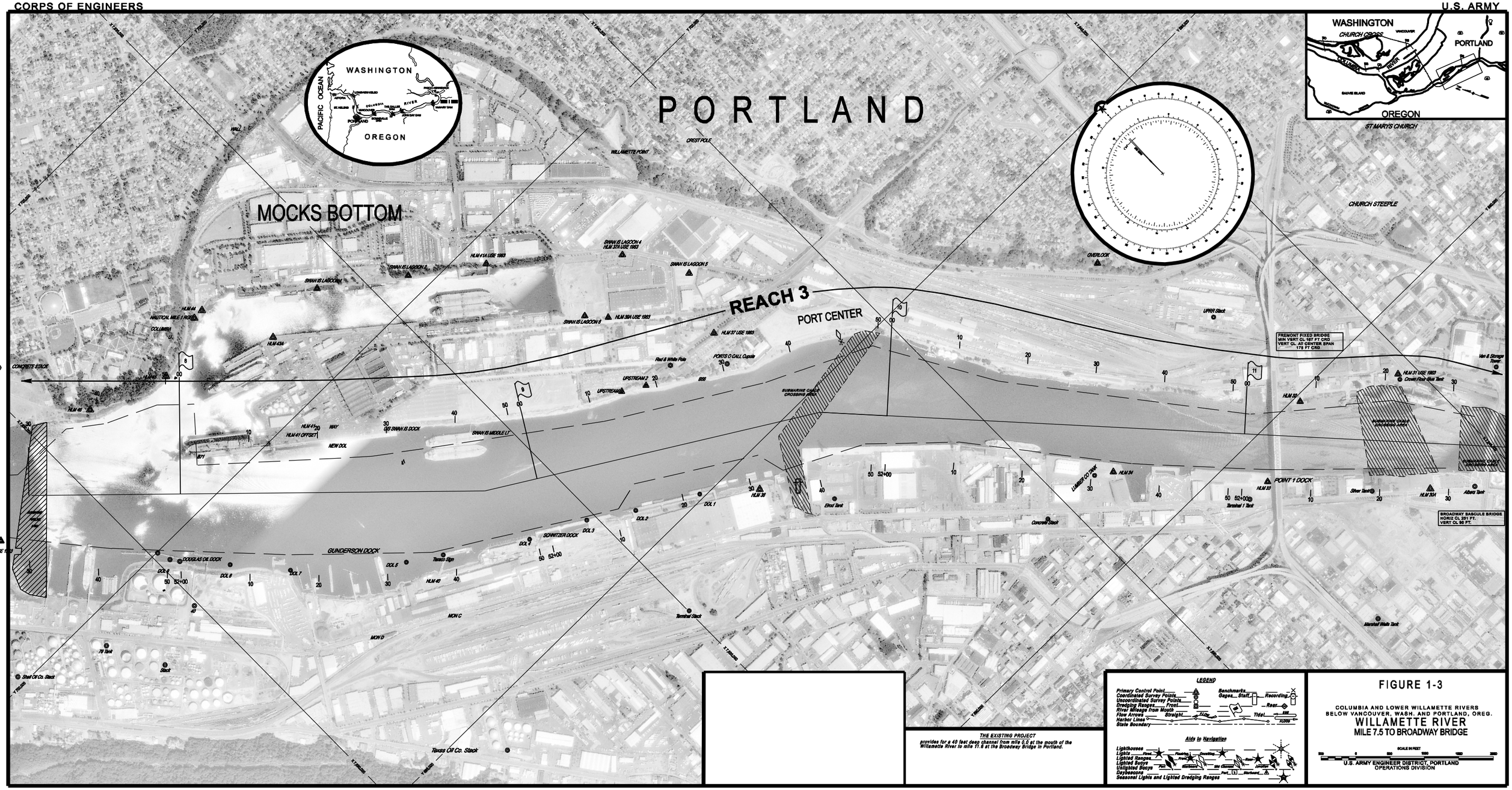

THE EXISTING PROJECT

provides for a 40 feet deep channel from mile 0.0 at the mouth of the Willamette River to mile 11.6 at the Broadway Bridge in Portland.

FIGURE 1-3

COLUMBIA AND LOWER WILLAMETTE RIVERS
BELOW VANCOUVER, WASH. AND PORTLAND, OREG.

WILLAMETTE RIVER

MILE 7.5 TO BROADWAY BRIDGE

SCALE IN FEET

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SECTION 2

Dredging and Transportation Methods

2.1 Dredging Methods

This section includes a description of the dredging equipment and techniques typically used in dredging activities in the United States and, more specifically, on the Willamette River. This section also presents the advantages and limitations of each type of dredge. Each type of dredge has been evaluated for use in each of the three reaches of the Lower Willamette River FNC. Selection of dredging equipment and methods used to perform the dredging will depend on the following factors (USACE and Environmental Protection Agency [EPA] 1992):

- Physical characteristic of material to be dredged
- Quantities of material to be dredged
- Dredging depth
- Distance to disposal area
- Physical environment of the dredging and disposal areas
- Contamination level of sediments
- Method of disposal
- Production required
- Type of dredges available
- Cost

The equipment typically used in dredging projects in the United States, by both the Corps and private industry; principally include mechanical dredges and hydraulic dredges, specifically hopper dredges and hydraulic pipeline dredges (cutter head and plain suction) (USACE, 1983). An evaluation of each dredging method is provided below.

2.1.1 Mechanical Dredging

2.1.1.1 Description of Dredging Method

Mechanical dredges include dipper, clamshell, articulated fixed-arm, and dragline dredges. Mechanical dredges are capable of removing hard-packed material or debris and are well suited for removing fine-grained material, cemented sands, gravels, or well-fractured rock outcrops. Dredging operations using mechanical dredges are relatively accurate and the dredges can be operated in areas where space is limited (USACE, 1983). Most mechanical dredges are not self-propelled and must operate from a barge, and thus require a tugboat to move over long distances. The vessels can move within a limited area using only anchors and spuds to change the position of the dredge. Mechanical dredge bucket capacities range in sizes up to 26 cubic yards. Production rates can vary widely due to variations in depths and materials being excavated; however, between 10 and 30 cycles per hour is typical. Excavated material commonly is put on scows or hopper barges that are towed to the disposal area or material management site (USACE and EPA, 2004). Alternatively, a slurry-

processing unit can be used to fluidize dredged material in a scow or barge and pump it via hydraulic pipeline to the material management site.

Historically, dredging of the lower Willamette River FNC has been performed using a clamshell dredge with in-water disposal in the Columbia River (USACE, 1997). A clamshell dredge is a type of mechanical dredge that removes material by scooping it up with a bucket. Figure 2-1 is a photograph of a typical clamshell dredge with scow. The bucket is suspended from a crane at a point above the sediment and then lowered in the open position. The bucket is lowered into the water column and penetrates into the bottom material. Then, the bucket is closed using wire cables that are operated from the crane. As the sides of the bucket close, material is sheared from the bottom and contained inside the bucket apparatus. The bucket is raised through the water column to the surface and swung to a point over a material barge. The dredged material is then released into the barge by opening the sides of the bucket. Once the desired amount of material is removed from the bottom of the waterway, the dredge is moved to the next nearby location using anchors and spuds. If the next dredging area is a significant distance away, tugs are used to reposition the dredge.

FIGURE 2-1
Typical Mechanical Dredge and Scow Combination *(USACE—Portland District)*

Dewatering of mechanically dredged sediments normally is accomplished by transferring the sediments from the material transport barge to an upland dewatering facility. Sediments can also be transferred from the barge directly into trucks for disposal. The volume of water associated with mechanical dredging is relatively small when compared to the volume of water managed by hopper or other hydraulic dredging.

2.1.1.2 Best Management Practices (BMPs)

Engineering and operational BMPs can be applied to dredging activities to minimize the impacts of dredging and dredge material disposal on water quality. Engineering and operational BMPs are described below.

Engineering BMPs. Engineering BMPs are applied to mechanical dredging by the use of specialized equipment designed to improve the accuracy of dredging and reduce or contain sediment resuspension. Engineering BMPs include environmental buckets and tracking, and positioning software.

Mechanical dredges equipped with environmental buckets are regarded as being particularly useful in fine-grained sediment or contaminated materials where it is necessary to minimize sediment resuspension. Figures 2-2A, 2-2B, and 2-2C are photographs of an environmental bucket and the mechanical dredging process. The bucket has overlapping sides to prevent the release of sediment as the bucket is raised through the water column. Vents on the top of the bucket prevent disturbance of the sediment once in the bucket and allow drainage of excess water once the bucket is raised above the water surface, which allows for a relatively low water content in dredged sediments. Environmental buckets have the additional advantage of minimizing the volume of water in dredged sediments.

Tracking and positioning software is used to monitor dredging progress in both the horizontal and vertical directions. This increases dredging efficiency by preventing over-excavation and improves quality by ensuring that the full, intended dredge cut is achieved. Tracking and positioning software can reduce the environmental impacts of dredging by reducing the number of times the bucket impacts bottom sediments and allowing operators to avoid or target pockets of sediments known to contain constituents of potential concern (COPCs). Figure 2-2D shows a screen from a typical program used to track dredging progress. Positioning systems are discussed in more detail in Section 5.1.

Additional controls, such as using land-based survey equipment and calibrated marks on the cable, can be implemented to further improve vertical accuracy to approximately ±4 inches in calm waters; however, the increase in accuracy is accompanied by a loss in dredging efficiency that must be considered during project design.

Operational BMPs. Operational BMPs are modifications applied to standard work procedures to minimize the adverse affects caused by dredging. Operational BMPs that can be applied to mechanical dredging include in-water work windows and increased cycle time. In-water work windows can be applied to reduce dredging impacts on sensitive species, including anadromous and other game fish and threatened, endangered, or sensitive species, by limiting the work period to avoid the vulnerable life stages of these fish including migration, spawning and rearing. Currently the Oregon Department of Fish and Wildlife (ODFW) has designated two in-water work windows for the Lower Willamette River, the first beginning July 1 and ending October 31, and the second beginning December 1 and ending January 31 (ODFW 2000). In-water work permits are issued using these two work windows as guidelines for restricting the timing of work.

The cycle time of a mechanical dredge is increased when the velocity at which the bucket is raised and lowered is decreased. This reduces the potential for sediment to be washed from the bucket and resuspended during the raising and lowering phases. The loss of dredged

material can also be reduced by limiting the velocity of the bucket as it is raised through the water surface. Additionally, limiting the descent velocity of the bucket reduces the impact energy of the bucket hitting the bottom sediments. This reduces sediment resuspension, but also reduces the volume of material removed with each bite, increasing the total number of cycles that are required to reach the desired bottom elevation. Resuspension caused by descent velocity should be compared to resuspension caused by bottom impact prior to applying this BMP.

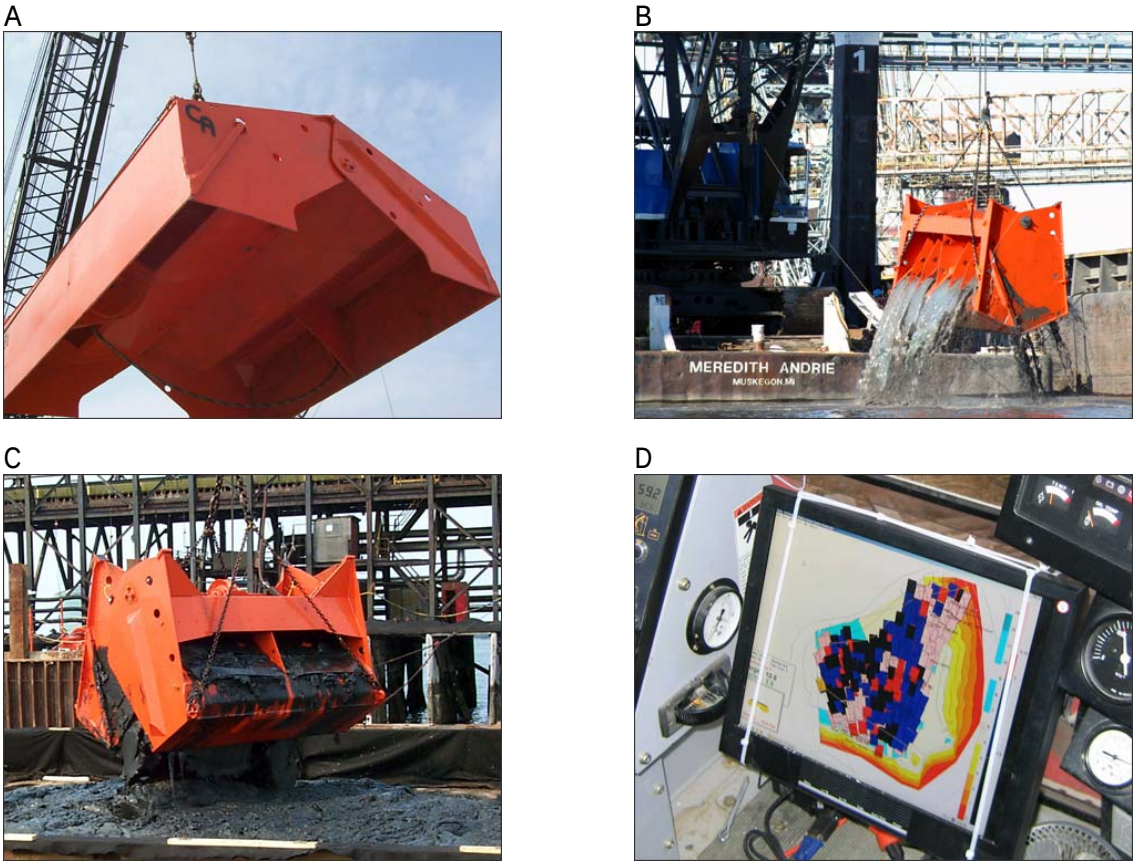

FIGURE 2-2
Environmental Bucket Used To Prevent Resuspension Of Sediments When Dredging At Contaminated Sites Or Under Low Turbidity Requirements.

From top left, A) typical environmental bucket; B) drainage of excess water through vents; C) deposition of dredge material on barge or scow; D) positioning software for tracking dredging progress. *(photos from Cable Arm Web site: www.cablearm.com)*

2.1.1.3 Evaluation of Technical Feasibility

Mechanical dredging with a clamshell is a proven technology that has been the preferred method for the most recent Lower Willamette FNC maintenance dredging projects. Because mechanical dredges commonly are used in the Pacific Northwest, equipment and operators are typically available in the area. Material conveyance/offload methods are mostly limited to barges and scows, which would be readily available in the region. If necessary, multiple barges can be employed to allow for continuous dredging operations. Another material

transport option is a slurry-processing unit, which can be used to transport material from the barge or scow directly to the material management site via hydraulic pipeline.

Material dredged with a mechanical dredge would have lower water content than materials dredged by hopper or other hydraulic dredges. Dredge materials with lower water content may require less time to dewater and may produce less water. Dredged material produced by a mechanical dredge can be transported to both in-water and upland material management sites, as necessary.

A mechanical dredge has a relatively small footprint and shallow draft when compared to a hopper dredge, allowing it to fit into tight spaces near piers and other in-water structures and work in shallow waters near the shore. Computer tracking programs can be used with mechanical dredges to allow for relatively precise dredging in areas where there is concern for damage to property or natural resources. A mechanical dredge may be able to work without impeding river traffic; however, it also requires a barge to transport dredge materials and a tugboat to maneuver the dredge and barge, increasing traffic in the FNC.

The production rate of a mechanical dredge is not as high as that of hopper or other hydraulic dredges.

Evaluation by River Reach. The technical feasibility of a mechanical dredge is rated as Very Favorable for all reaches of the Lower Willamette FNC. Mechanical dredges are capable of removing sediments in all locations of the channel, they are readily available, and they have been proven effective for dredging the FNC.

2.1.1.4 Evaluation of Environmental Acceptability

A mechanical dredge can be equipped with an environmental bucket to reduce resuspension of sediments when it is necessary to reduce turbidity or residual contamination caused by dredging operations. When used in conjunction with a hopper barge, it can reduce discharge of turbid water and/or water containing COPCs to the river during dredging operations. However, not all sediment is suitable for removal by an environmental bucket. An environmental bucket may be, for example, unable to excavate compacted sediment or hardpan. The horizontal and vertical accuracy of a mechanical dredge is similar to that of a hydraulic pipeline dredge and better than a hopper dredge.

Evaluation by River Reach. The environmental acceptability of a mechanical dredge is rated as Very Favorable for all reaches of the Lower Willamette FNC. Application of BMPs can enable a mechanical dredge to minimize sediment resuspension caused by dredging activities on the FNC. In addition, if sediments unsuitable for in-water disposal were encountered, a mechanical dredge would be able to remove the sediments more accurately than a hopper or hydraulic pipeline dredge.

2.1.1.5 Evaluation of Cost Effectiveness

Equipment and mobilization costs for a mechanical dredge are generally lower than for hydraulic dredges of comparable size. However, production rates for a mechanical dredge are lower than that of a comparably sized hydraulic dredge. Thus, a mechanical dredge is less cost effective under circumstances where production rate is the controlling factor of cost (i.e., situations where large volumes of sediments can be dredged without having to transport the dredged materials long distances and without having to remobilize the dredge

within the same project area). In situations where the equipment, mobilization, and production costs are comparable, the cost effectiveness of mechanical dredging will primarily be determined by material transportation and offloading at the material management sites. In-water disposal of dredge material by bottom dumping would be cost effective at any suitable location near the Lower Willamette FNC; however, the rehandling of contaminated material to an upland site for dewatering would significantly increase the cost of transportation and disposal of the dredged material. Rehandle could be necessary if in-water disposal of sediments were not allowed because of turbidity or other concerns. As with other dredging methods, costs would increase due to the implementation of BMPs to reduce sediment resuspension.

Evaluation by River Reach. The cost effectiveness of a mechanical dredge is rated as Favorable for Reach 1 of the Lower Willamette FNC because a relatively small volume of sediment would be dredged from this river reach and it is close to material management sites at Morgan's Bar and Hayden Island.

The cost effectiveness of a mechanical dredge is rated as Favorable for Reach 2 of the Lower Willamette FNC because a relatively small volume of sediment would be dredged from this river reach and it is reasonably close to the material management sites at Morgan's Bar, Hayden Island, and Ross Island. Dredging in Reach 2 may become more cost effective if the Terminal 4 Confined Disposal Facility (CDF) becomes available during maintenance dredging for disposal of material containing COPCs.

The cost effectiveness of a mechanical dredge is rated as Favorable for Reach 3 of the Lower Willamette FNC. This river reach contains a large volume of sediment to be removed. Currently, the only potential material management site identified near Reach 3 is Ross Island Lagoon. Hayden Island and Morgan's Bar is reasonably close and are potential options for management of dredged material dredged by mechanical methods.

2.1.2 Hydraulic Dredging

2.1.2.1 Hopper Dredging

Description of Dredging Method. Hopper dredges are self-propelled seagoing ships with hulls and lines similar to a typical ocean vessel and equipped with propulsion machinery, sediment containers (hoppers), dredge pumps, and other special equipment required to remove material from a channel bottom (USACE, 1983). Hopper dredges have propulsion power adequate for required free-running speed and dredging against strong currents and excellent maneuverability for safe and effective work in rough, open seas. Dredged material is raised by dredge pumps through dragarms that are pulled along the channel in contact with the channel bottom. The material is discharged into hoppers built in the vessel. Hopper dredges are classified according to hopper capacity, which can range from as small as 500 cubic yards to more than 12,000 cubic yards. The USACE Portland District owns and operates the 6,000-cubic-yard hopper dredge "Essayons" that primarily is used to dredge the Columbia River FNC. A picture of the "Essayons" is shown in Figure 2-3. During dredging operations, hopper dredges travel at a ground speed of from 2 to 3 mph and can dredge in depths from about 10 feet to over 80 feet. They are equipped with twin propellers, twin rudders, and bow thrusters to provide the required maneuverability.

FIGURE 2-3
Photograph of the Corps' Hopper Dredge "Essayons" *(USACE—Portland District)*

Dredging is accomplished by progressive traverses over the area to be dredged. Hopper dredges are equipped with large centrifugal pumps similar to those employed by other hydraulic dredges. Suction pipes (dragarms) are hinged on each side of the vessel with the intake (drag) extending downward toward the stern of the vessel. The drag arm is moved along the channel bottom as the vessel moves forward. The dredged material is conveyed up the pipe by suction and deposited and stored in the hoppers of the vessel. Water conveyed into the hopper along with the sediment is decanted using adjustable weirs that can be raised or lowered to provide the necessary water retention time in the hopper. Once fully loaded, hopper dredges move to the disposal site to unload before resuming dredging. Unloading is accomplished either by opening doors in the bottom of the hoppers and allowing the dredged material to be released to an open-water disposal site or by pumping the dredged material to an upland disposal site. Because of the sediment quality restriction that can be placed on open-water disposal, many hopper dredges have direct pump-out capability for dredge material placement in upland confined sites.

Hopper dredging is normally performed under one of two operational methods; (a) pumping to overflow and (b) pumping past overflow. When pumping to overflow, no water or sediment is discharged past the overflow weir. Pumping to overflow can be used when dredging sediments that are not suitable for in-water disposal. Pumping past overflow is used when dredge material is suitable for in-water disposal, such as clean sand, and the percentage of solids in the overflow is low. Water is decanted from the hopper and discharged back to the receiving water body.

The use of these methods is determined by the type of material being dredged and the location where the dredging is taking place. For example, pumping past overflow increases the volume of material that a hopper dredge can dredge in one event, but may not always be acceptable due to water quality concerns over the affects of parameters such as turbidity or contamination on natural resources near the dredging site (USACE and EPA, 2004).

Hopper dredges mainly are used for maintenance dredging in exposed harbors and shipping channels where traffic and operating conditions rule out the use of stationary dredges. The materials excavated by hopper dredges cover a wide range of types, but the hopper dredge is most effective in the removal of material that forms shoals after the initial dredging is completed. Hopper dredges are most efficient in excavating loose, unconsolidated materials; however, specifically designed drags are available for use in raking and breaking up hard materials. One such device in common usage is the water jet, whereby nozzles direct high-pressure jets of water into the in situ sediments. Consolidated material is broken up, allowing it to be removed by the draghead suctions, and sediments are fluidized resulting in more efficient removal of dredge material.

Similar to other hydraulic dredges, hopper dredges produce dredged materials with high water content. Dewatering in the hopper essentially is the operation of the dredge to pump past overflow. Dewatering at upland material management sites is generally accomplished using settling ponds or overland flow. Settling ponds are sized based on the settling characteristics of the dredge material and the rate of dredging. Water decanted from the sediments is discharged to a receiving water body. The characteristics of the decant water will determine if treatment is necessary prior to discharge. Dewatering by overland flow requires that the dredge material and water is suitable for direct discharge to the ground or receiving water body and that the solids have good settling properties. After dewatering, the material can be either left in place at the dewatering site, or rehandled as necessary for reuse or disposal.

Best Management Practices (BMPs). Engineering and operational BMPs can be applied to hopper dredging activities to minimize the impacts of dredging and dredge material disposal on water quality. Operational BMPs applied to hopper dredging procedures include eliminating or reducing hopper overflow and the use of a recirculation system.

As discussed above, eliminating or reducing hopper overflow reduces the amount of fine material that is discharged from the hopper. This control also may significantly reduce the efficiency of dredging operations in fine-grained sediments with poor settling properties.

Some hopper dredges are equipped with a recirculation system that recirculates water from the hopper overflow to the draghead where it is used to convey more material into the hopper. This reduces the volume of water that must be discharged from the hopper. Not all hopper dredges have this capability.

In addition, in-water work windows can be applied to reduce dredging impacts on sensitive species, including anadromous and other game fish and threatened, endangered, or sensitive species, by limiting the work period to avoid the vulnerable life stages of these fish including migration, spawning and rearing. Currently ODFW has designated two in-water work windows for the Lower Willamette River, the first beginning July 1 and ending October 31, and the second beginning December 1 and ending January 31 (ODFW 2000). In-water work permits are issued using these two work windows as guidelines for restricting the timing of work.

Evaluation of Technical Feasibility. Hopper dredges are commonly used in maintenance dredging operations in the Columbia FNC and could be available for maintenance dredging operations in the Lower Willamette FNC. Hopper dredges were last used for dredging

operations on the lower Willamette FNC in 1984 and have not been used since due to restrictions on in-water disposal of dredged materials in the Willamette River that made hopper dredging economically infeasible, though not technically infeasible. Several hopper dredges are available locally; including the USACE owned dredge "Essayons" and dredge crews are available in the Columbia River Basin region. A hopper dredge does not require additional equipment to transport dredge materials to in-water disposal or reuse sites because it stores and transports the materials in its own hopper. However, a hopper dredge can be used in combination with a hydraulic dredge to rehandle the dredged material and convey the material to an upland site. Some hopper dredges have pump-out capabilities that allow them to convey material short distances to an upland site without the aid of additional equipment.

Dewatering of sediments is required for disposal or beneficial reuse at upland material management sites and would require the construction of dewatering cells. The sediment's physical and chemical characteristics will determine if the dredge material can be managed at an in-water site or must be disposed at an upland site.

A hopper dredge would be capable of dredging large volumes of material at the depths required for this maintenance-dredging project. The location of shoaling in the Lower Willamette FNC would be accessible to a hopper dredge. Because several dredging events have been conducted to maintain the FNC at the currently authorized depth for the past 40 years (USACE, 1997), shoaling is composed of materials deposited after initial construction of the channel. A hopper dredge would be suitable for removal of most of the material in the Lower Willamette FNC.

The self-propelled hopper dredge has several advantages on the Lower Willamette FNC over other types of dredges. The hopper dredge is the only type of dredge that can move to the dredging project under its own power. It does not require an in-water conveyance pipe or barge and thus does not interfere with or obstruct channel traffic. The hopper dredge produces usable channel improvements almost as soon as work begins by traversing the entire length of the channel or problem shoal, excavating a shallow cut during each passage and increasing channel depth as work progresses.

The disadvantage of a hopper dredge is that it must periodically move to the dredge material-management site to offload materials once the hopper has reached capacity. Additionally, the hopper dredge excavates with less precision than mechanical dredges or other types of hydraulic dredges, which makes it more difficult to dredge accurately around obstructions or to precision dredge to avoid damage to property or natural resources.

Evaluation by River Reach. The technical feasibility of using a hopper dredge for maintenance dredging of Reach 1 is Favorable. Use of a hopper dredge would be an effective method for removal of sediments from Reach 1. Currently, shoaling in this area is generally in open areas of the channel away from terminals and would be accessible to a hopper dredge. Cycle time for material offloading would be relatively short compared to dredging operations in Reach 2 and Reach 3 because in-water disposal areas are located in closer proximity to Reach 1. This would reduce the transport needed for handling of dredge material. If dredged materials in Reach 1 are found to be unsuitable for in-water disposal, an upland management site at West Hayden Island is located in close proximity.

The technical feasibility of using a hopper dredge for maintenance dredging of Reaches 2 and 3 is Marginal. A hopper dredge may have difficulty dredging sediments in some restrictive areas of Reaches 2 and 3. With the exception of one potential site, Ross Island Lagoon, there are no currently identified dredge material management sites in close proximity to Reaches 2 and 3, increasing the cycle time for transport of materials to the management site and reducing the effective rate of dredging. If Ross Island Lagoon does become available, five lift-span or draw-bridges (Broadway, Steel, Burnside, Morrison, and Hawthorn) crossing the Willamette River south of the FNC between river mile 11.6 and 13.5 will have to be raised to allow a hopper dredge to pass beneath. This could significantly increase the cycle time for material transport using a hopper dredge. In should also be confirmed that the lift-span bridges are able to raise high enough to clear any hopper dredge proposed for use in dredging operations. In addition, the elevation of the sill beneath the inlet to Ross Island Lagoon sits at an elevation of approximately -12.35 feet WRD (Hart Crowser 2000). This translates to a depth of between 15.8 feet and 30.70 feet below water surface at ordinary low and ordinary high water levels, respectively. A hopper dredge would have to cross this sill to offload dredged materials at the lagoon and it may be necessary to restrict the volume of material placed in the hopper to ensure that the vessel draft is shallow enough to pass into the lagoon.

Evaluation of Environmental Acceptability. The environmental acceptability of a hopper dredge will be primarily determined by sediment resuspension during dredging activities and the effects of sediment resuspension on the turbidity of the Lower Willamette FNC. Hopper dredge removal of dredge materials from the channel bottom generally causes a relatively low increase in the turbidity of the surrounding waters; however, water discharged from the hopper overflow could contain a large amount of fine-grained material. This is common when dredging silty sands or sandy silts similar to the material in the Lower Willamette FNC because the retention time in the hopper is often not long enough for fine-grained material to settle out of suspension. Sediment discharged through the hopper overflow will increase turbidity in the waters downstream of dredging operations. The overflow of turbid water could be limited to minimize exceedance of turbidity standards (see Section 3 for discussion of turbidity standards).

The sediment oxygen demand (SOD) of sediments discharged from the hopper overflow may result in reduced water column oxygen concentrations. A U.S. Geological Survey (USGS) study estimated SOD in the Lower Willamette River at 1.8 (±0.3) $g/m^2 \cdot day$ (USGS 1994). During measurement, the observed rate of oxygen depletion was greater during the initial measurement phase. This was attributed to the disturbance and resuspension of bottom sediments caused by placement of the measurement equipment. The results of this study indicate that the role of SOD in the depletion of dissolved oxygen is an important component of the overall oxygen budget in the Willamette River and that the rate of oxygen depletion may be increased when sediments are resuspended. This information may lead to further limitations on the discharge of sediments from a hopper dredge.

A hopper dredge is not designed to dredge with the accuracy often required by environmental dredging. Water discharged to the river from the hopper would be limited in locations where contaminated sediments were encountered by discontinuing dredging operations before the overflow level in the hopper is reached. The dredged material would

then be transported to an in-water confined disposal facility or pumped to an upland dewatering facility. Because the hopper dredge uses hydraulic conveyance to remove sediments from the channel bottom (creating slurry that is potentially more than 90 percent water by volume), a potentially large volume of water would require management if the hopper dredge was not allowed to operate past the overflow.

Evaluation by River Reach. The environmental acceptability of a hopper dredge is rated as Marginal for Reach 1 of the Lower Willamette FNC due to potential concerns with the turbidity of water discharged from the hopper overflow; although a plume would likely be less than the width of the river.

The environmental acceptability of a hopper dredge is rated as Not Recommended for Reaches 2 and 3 of the Lower Willamette FNC due to concerns with the turbidity of water discharged from the hopper overflow and the inability of a hopper dredge to dredge precisely in limited areas of the FNC where sediments may not be suitable for in-water disposal.

Evaluation of Cost Effectiveness. The cost effectiveness of a hopper dredge will be largely driven by the material that is being dredged. Dredging of sediments that are not suitable for in-water disposal or sediments with a high percentage of fines may necessitate restrictions on dredging operations to avoid environmental impacts caused by sediment resuspension through the hopper overflow. These restrictions may prevent or severely limit the volume of water that is permitted to overflow from the hopper. In such cases, the dredge must retain most or all of the water conveyed to the hopper and may not be able to pump for a long enough time to fill the hopper with an economical load of sediment. The result is an increased number of trips to the material management site to offload sediment and water, a large volume of water that must be managed, and an increased percentage of time devoted to material offload. This would increase dredging costs by increasing the amount of time required for dredging operations.

Evaluation by River Reach. The cost effectiveness of a hopper dredge is rated as Favorable for Reach 1 of the Lower Willamette FNC. The time required for a round trip from the dredge site to the in-water disposal site at Morgan's Bar and back is relatively short, and if dredged materials were determined unsuitable for in-water disposal, a hopper dredge with direct pump-out capabilities could convey the material to the upland dewatering site at Hayden Island.

The cost effectiveness of a hopper dredge is rated as Marginal for Reaches 2 and 3 of the Lower Willamette FNC. This reach of the FNC contains the bulk of the sediments to be dredged from the river, indicating that dredging could be economical if the dredge is allowed to operate at optimum conditions (that is, dredge past overflow); however, there are few dredged material management sites currently identified within an economical distance of Reach 3. If the dredge is not allowed to pump past the overflow, the efficiency of the dredging operation will be reduced and the cost of dredging will be increased, with the effects magnified by the lack of nearby material management sites. The cost effectiveness is improved if the material is determined acceptable for placement at Ross Island Lagoon.

2.1.2.2 Pipeline Dredging

Description of Dredging Method. Hydraulic pipeline dredges, specifically the cutter head dredge, are the most widely used dredge type in the United States. The rotating cutter apparatus surrounding the intake end of the suction pipe allows the dredge to efficiently excavate and pump all types of alluvial materials and compacted deposits, such as clay and hardpan (USACE, 1983). The cutter head is not necessary in dredging of materials consisting of clay, silt and fine sand, and may actually be undesirable because rotation of the cutter head produces a turbidity cloud and increases the potential for adverse environmental impacts. Figure 2-4 shows a cutter head from a hydraulic cutter head dredge. This type of dredge has the capability to pump dredged material distances of up to approximately 1 mile without a booster pump, and greater distances with booster pumps, to in-water material management sites. The pumping range to upland sites is significantly reduced due to having to overcome the increase in elevation. Slurries of 10 to 20 percent solids (by dry weight) are typical, depending upon the material being dredged, dredging depth, horsepower of dredge pumps, and pumping distance to the material management site (USACE, 1983). The intake of a hydraulic pipeline suction dredge can range in size from 6 inches to more than 30 inches in diameter.

Hydraulic pipeline dredges generally are equipped with two stern spuds used to hold the dredge in working position and to advance the dredge into the cut or excavating area. Figure 2-5 shows the typical sequence of operation for a hydraulic cutter head dredge. During operation, the dredge swings from side to side alternately using the port and starboard spuds as a pivot. A “cutter head” (if required) on the end of an arm is buried about 3 to 6 feet deep in the river bottom material and swings in a 250- to 300-foot arc in front of the dredge. Cables attached to anchors on each side of the dredge control lateral movement. Forward movement is achieved by lowering the starboard spud after the port swing is made and then raising the port spud. The dredge is then swung back to the starboard side of the cut centerline. The port spud is lowered and the starboard spud lifted to advance the dredge.

FIGURE 2-4
Cutter Head From A Hydraulic Cutter Head Dredge.

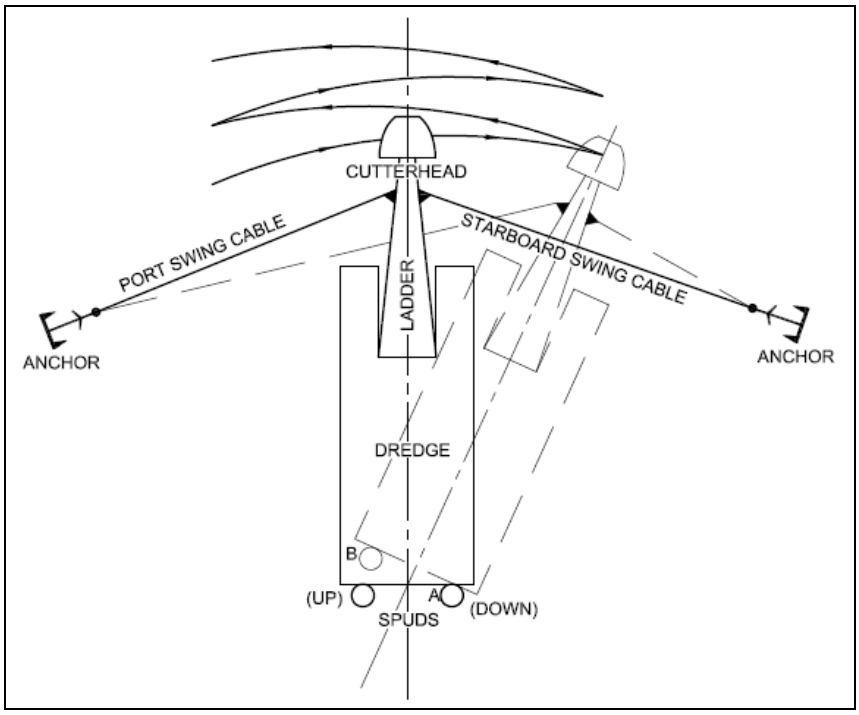

FIGURE 2-5
Typical Sequence Of Operation For A Hydraulic Cutter Head Dredge (USACE, 1983)

The excavated material may be pumped to an open water site or to confined disposal facilities located either upland or in-water. When dredged materials are pumped to an open-water management site, a discharge pipeline, made up of sections of pipe mounted on pontoons and held in place by anchors, is required. Sections of shore pipeline are used when an upland dredge material management site is used.

Hydraulic pipeline dredges produce dredged materials with high water content that must be managed for upland disposal or prior to reuse at upland management sites when not disposing sediments in-water. Dewatering is generally accomplished using settling ponds or overland flow. Settling ponds are sized based on the settling characteristics of the dredge material and the rate of dredging. Water decanted from the sediments is discharged to a receiving water body. The chemical characteristics of the decant water will determine if treatment is necessary prior to discharge. Dewatering by overland flow requires that the dredge material and water are suitable for direct discharge to the ground or the receiving water body and that the solids have good settling characteristics. After dewatering, the material is either left in place at the dewatering/disposal site, or rehandled as necessary for reuse or disposal.

Best Management Practices (BMPs). Operational BMPs can be applied to hydraulic pipeline dredging activities to minimize the impacts of dredging and dredge material disposal on water quality. Operational BMPs applied to hydraulic pipeline dredging procedures include reducing cutter head rotation speed, reducing swing speed, preventing bank undercutting, and in-water work windows.

Reducing the cutter head rotational speed reduces the energy with which the sediment is excavated from the channel bottom. This in turn reduces the potential for sediment to be

cast away from the suction head where it becomes resuspended. This BMP is only viable for relatively loose, unconsolidated fine-grained material that can be excavated by suction alone.

Reducing the swing speed ensures that the rate at which the sediment is disturbed does not exceed the capacity of the dredge to hydraulically pump the sediment and convey it away from the dredge site. A swing speed of between 5 and 30 feet per minute is typically used.

Eliminating bank undercutting reduces resuspension by preventing the creation of unstable slopes behind the cutter head. Bank undercutting can be eliminated by removing the sediment in maximum lifts equal to 80 percent or less of the cutter head diameter.

In-water work windows can be applied to reduce dredging impacts on sensitive species, including anadromous and other game fish and threatened, endangered, or sensitive species, by limiting the work period to avoid the vulnerable life stages of these fish including migration, spawning and rearing. Currently ODFW has designated two in-water work windows for the Lower Willamette River, the first beginning July 1 and ending October 31, and the second beginning December 1 and ending January 31 (ODFW, 2000). In-water work permits are issued using these two work windows as guidelines for restricting the timing of work.

Evaluation of Technical Feasibility. Hydraulic pipeline dredges, specifically the cutter head dredge, are the most widely used dredge type in the United States. While they have not been used on the Willamette for the more recent maintenance dredging operations, they are used for maintenance dredging on the Columbia, indicating that equipment and operators are readily available in the region. The USACE Portland District contracts with the Port of Portland to operate the Port's 30-inch hydraulic cutter head dredge "Oregon". The tugboats and other equipment required to support a hydraulic dredge are also available in this region.

A hydraulic pipeline dredge can be used for in-water disposal of sediments or upland placement of sediments; however, hydraulic pipeline dredges are generally limited to conveyance of dredged material to the material management site via hydraulic pipeline. In the Lower Willamette FNC there are few in-water or upland material management sites within reach of a hydraulic dredge without the use of booster pumps. Additionally, mobilization of the transport pipeline will require effort and, once set up, the pipeline will require management so that an impedance to other river traffic does not occur on the Lower Willamette FNC.

The slurry produced by a hydraulic pipeline dredge has high water content, is typically only 10 to 20 percent solids by weight, and must be dewatered if managed at an upland site. If dredged material is determined to be unsuitable for in-water disposal, the dredged water must be managed prior to discharge to the receiving water body.

Evaluation by River Reach. The technical feasibility of a hydraulic pipeline dredge is rated as Marginal for all reaches of the Lower Willamette FNC due to the obstructions posed by constructing a hydraulic conveyance pipeline in the FNC and the lack of operational benefits when compared to hopper and mechanical dredges. In addition, there are few material management sites located within 1 mile of the Lower Willamette FNC, making transport and disposal of dredged materials difficult.

Evaluation of Environmental Acceptability. Generally, hydraulic pipeline dredging is a low turbidity dredging method, especially when no cutter head is used. In faster currents, moving upstream in the river while dredging would improve the efficiency of sediment capture, allowing less resuspended sediment to be disbursed into the water column and reducing turbidity. When dredging sediments that are unsuitable for in-water disposal, the horizontal and vertical accuracy of a hydraulic pipeline dredge is similar to that of a mechanical dredge and better than a hopper dredge, making the dredge capable of precise environmental dredging.

Sediments unsuitable for in-water disposal will most likely require dewatering at upland disposal site or at an upland dewatering site prior to offsite disposal. A hydraulic pipeline dredge is capable of pumping dredged materials to upland sites; however, the pumping energy required increases quickly with the elevation of the dewatering cells. A large volume of water must be managed prior to discharge to the receiving water body.

Evaluation by River Reach. The environmental acceptability of a hydraulic pipeline dredge is rated as Favorable for all reaches of the Lower Willamette FNC. Application of BMPs will enable a hydraulic pipeline dredge to minimize sediment resuspension caused by dredging activities on the FNC. In addition, a hydraulic dredge will be able to remove sediments with greater accuracy than a hopper dredge. Dredged material that is not suitable for in-water disposal will be transported to upland management sites and may produce a large volume of decant water that requires management.

Evaluation of Cost Effectiveness. Hydraulic pipeline dredging is usually most cost effective when dredging large volumes of material from one area. A hydraulic pipeline dredge combined with pipeline conveyance can operate on an almost continuous dredging cycle, providing maximum economy and efficiency. However, dredging operations must stop when moving between sites. Movement between dredging sites requires the use of tugboats to move the dredge and reconfiguration of the conveyance pipeline to adjust the length to fit the new location of the dredge.

The distance that a large hydraulic pipeline dredge can pump material is typically limited to less than 1 mile for in-water sites and may be greatly reduced when pumping to upland sites. Transporting the material past a dredge's maximum pumping distance will require booster pumps and will increase the material transport costs. The size of the dredge (if a smaller dredge is used) and the dredged material properties can further reduce the distance that material can be conveyed without the use of booster pumps.

Evaluation by River Reach. The cost effectiveness of a hydraulic pipeline dredge is rated as Marginal for Reach 1 of the Lower Willamette FNC. The in-water disposal site at Morgan's Bar is outside of the typical 1-mile pumping limit for hydraulic pipeline dredges, but material may be conveyed there using booster pumps with minimal additional effort if the materials are determined suitable for in-water disposal. Conveyance piping and booster pumps will be necessary to reach the nearest upland dewatering site at Hayden Island, but the use of booster pumps may be cost prohibitive.

The cost effectiveness of a hydraulic pipeline dredge is rated as Not Recommended for Reach 2 of the Lower Willamette FNC because there is relatively small volume of material to be removed from this reach of the FNC. In addition, there are no dredged material

management sites currently identified within 1 mile of this reach, indicating that booster pumps will be required.

The cost effectiveness of a hydraulic pipeline dredge is rated as Not Recommended for Reach 3 of the Lower Willamette FNC. This reach of the FNC contains the bulk of the sediments to be dredged from the three river reaches. The volume of material located within Reach 3 is large enough to indicate that dredging may be economical; however, there are no dredged material management sites currently identified within 1 mile of this reach and booster pumps will be required to transport the dredged material to the management site.

2.2 Transportation Methods

Dredged materials removed from the Willamette River FNC must be transported to the designated material management site. Several transportation methods exist for transportation of dredge materials; however, the technical feasibility and cost effectiveness of each method is dependant upon the material's physical and chemical characteristics, type of dredge used, and the distance from the Willamette River FNC to the material management site. Three material transport methods are evaluated below: barge/hopper transport, hydraulic (pipeline) transport, and surface (truck/rail) transport. Each was evaluated for use with the dredging methods discussed above.

2.2.1 Barge/Hopper Transport

2.2.1.1 Description of Material Transport Method

Barge transportation of dredge materials typically is used in conjunction with a mechanical dredge. The barge is moved into position by a tug and anchored in place using spuds or anchors. During dredging operations, the material is removed from the channel bottom, raised through the water column, and placed on the barge. Once the barge has reached its capacity, it is moved by a tug to the material offload site and another barge is moved into place next to the dredge to allow dredging operations to continue.

Hopper barge transport can be used in conjunction with either a hopper dredge, where the dredge and the barge/hopper are the same piece of equipment, or a mechanical dredge, in which case the dredge and barge are separate. The advantages of using a hopper dredge to transport dredge materials is that the hopper dredge dredges, stores and transports the dredged material, and will often have direct pump-out capabilities, which allows for hydraulic rehandle of the material without first discharging it into a receiving water body. A hopper dredge would not be used to transport mechanically dredged sediments.

Once at the offload site there are three methods for offloading material from the barge: mechanical, bottom dump, and hydraulic rehandle. Mechanical offload would be used for materials that are not suitable for in-water disposal or that have been designated for upland beneficial reuse and requires the use of a crane equipped with a bucket, an excavator, or a front-end loader to remove the material from the barge and place it in an upland stockpile or dewatering site (depending on the material water content) or directly into a truck or rail car for transport to a disposal or reuse site. Stockpiled material can also be managed onsite for beneficial use or disposal in accordance with the material's chemical and physical characteristics.

Bottom dump offload requires the use of a split-hull barge. After the barge is filled to capacity, it is moved by a tugboat to the in-water disposal site. Once the barge is in place, the hull doors are opened and the material is allowed to fall directly into the water to settle and disperse naturally through the water column. Dredge material that is bottom dumped at an in-water management site must meet the characterization guidelines for in-water disposal discussed in Section 3.

As discussed above, barge transport can be used to transport dredged materials to both upland and in-water material management sites. Dredged material management options that are available for use with barge transportation include: West Hayden Island, habitat restoration, confined disposal facility, Ross Island Lagoon, deep-hole offload in the Willamette River, in-water flowlane disposal at Morgan Bar, and beach nourishment. Barge transportation can also be used in conjunction with truck or rail transportation to transport dredged material to a solid waste landfill or to upland locations where it is used as construction fill. Dredged material management options are discussed in more detail in Section 3 of this appendix.

2.2.1.2 Best Management Practices (BMPs)

BMPs applied to barge transportation would include selection of a barge that is equipped to contain dredged material and restriction of barge fill levels to prevent spillage of material. Hopper or bin barges are capable of transporting dredged material while preventing the loss of materials over the side. A flat deck barge with watertight berms constructed around the sides may also be used. Additionally, restrictions can be placed on the fill level to prevent loss of material in rough water conditions. BMPs may also be applied to the offloading process to prevent release of material as it is transferred from the barge to the material-handling site. Regular inspections of the barges would be necessary to ensure their integrity.

2.2.1.3 Evaluation of Technical Feasibility

Barges and scows are commonly used in the Columbia and Lower Willamette FNCs and are commonly available in the region, as are the tugboats and tugboat operators who move the barges. Barges would most likely be used to transport material excavated with a mechanical dredge. Compared to other material transport methods, material transported by barge would have the greatest amount of flexibility in regards to moving between different dredging sites and different material management sites.

Material dredged mechanically and transported by barge would have a relatively low water content to maximize the efficiency of the barge and minimize the release of turbid water.

Advantages of barges and scows are that they can be maneuvered into tight spaces by tugboats as necessary and tied off to the dredge barge, which is held in place by spuds. In addition, multiple barges can be employed to allow for continuous dredging activities.

Evaluation by River Reach. The technical feasibility of barge transportation is rated as Very Favorable for all reaches of the Lower Willamette FNC. Barges and scows would be capable of transporting sediments from all locations of the channel and to most in-water material management sites, can be offloaded to upland material management sites, are readily available in the region, and have been proven effective in past dredging activities within the

Lower Willamette FNC. Barges would also be able to travel long distances to reach material disposal sites without delaying dredging operations if multiple barges are employed.

2.2.1.4 Evaluation of Environmental Acceptability

Hopper barges can be used to minimize the turbidity effects on the river caused by dredging and dredged material transport by minimizing or preventing the release of dredged materials during barge loading and material transportation.

Barges and scows are not able to move under their own power. Tugboats are required to move the barges between the dredging location and the material management site. Propeller wash may cause sediment resuspension in some areas of the Willamette and Columbia Rivers, increasing turbidity; however, these effects are expected to be relatively small when compared to turbidity caused by dredging activities.

Evaluation by River Reach. The environmental acceptability of barge transportation is rated as Very Favorable for all reaches of the Lower Willamette FNC due to the low turbidity and relatively small volume of return water produced when used in conjunction with a mechanical dredge.

2.2.1.5 Evaluation of Cost Effectiveness

Cost effectiveness would be determined to a large part by offload method at the dredged material management site. Offload of material at in-water sites would be quick and efficient when using a bottom-dump barge to release the material or a front-end loader to push the material off the barge deck. Offload of material at an upland site would require significant rehandle effort when compared to hydraulic transport unless the material could be fluidized and directly pumped from the barge (assuming a hopper barge is used).

One additional factor that affects cost effectiveness is the distance between the dredging site and the disposal site. As distance increases, fuel consumption and maintenance costs increase, as well as the number of barges needed to maintain continuous dredging operations.

Evaluation by River Reach. The cost effectiveness of barge transportation is rated as Favorable for all reaches of the Lower Willamette FNC because the cost of barge transport is expected to be less than or equal to the costs for hydraulic pipeline transport and less than surface transportation on a cost per unit volume basis.

2.2.2 Hydraulic Pipeline Transport

2.2.2.1 Description of Material Transport Method

Hydraulic pipeline transportation of dredged materials is generally used in conjunction with hydraulic dredge methods, including hopper dredges, but also can be used with mechanical dredging by employing a slurry pump. Material excavated by the dredge is pumped in slurry, through a pipeline, that either floats on the water using pontoons, is submerged, or runs across dry land. Slurries between 10 and 20 percent solids (dry weight) are typical, but the solids content will vary depending on the material properties and the type of dredge used. Dredged materials can typically be pumped distances of approximately 1 mile without the use of booster pumps. The use of booster pumps can

increase the pumping distance to more than 15 miles. The maximum economical pumping distance will vary for each project and must be determined for individual project conditions.

Dredged materials transported by hydraulic pipeline to an upland management site must be dewatered prior to final placement or rehandle. Dewatering generally is accomplished using settling ponds or overland flow. Settling ponds are sized based on the settling characteristics of the dredged material and the rate of dredging. Water decanted from the sediments is managed as necessary and discharged to a receiving water body. The chemical characteristics of the decant water will determine if treatment of the water is necessary prior to discharge. Dewatering by overland flow requires that the dredge material and water are suitable for direct discharge to the ground or the receiving water body and that the solids have good settling characteristics. After dewatering, the material would be left in place at the dewatering/disposal site, or rehandled as necessary for beneficial reuse or disposal.

Dredged materials transported by hydraulic pipeline to an in-water management site must be suitable for in-water disposal.

Hydraulic pipeline transport can be used to move dredge materials to both upland and in-water material management sites. Dredge material management options that are available for use with barge transportation include: West Hayden Island, solid waste landfill (via truck or rail), construction fill (via truck or rail), habitat restoration, confined disposal facility, Ross Island Lagoon, deep-hole offload in the Willamette River, in-water flowlane disposal at Morgan Bar, and beach nourishment. Dredge material management options are discussed in more detail in Section 3.

2.2.2.2 Best management practices (BMPs)

BMPs applied to the hydraulic pipeline transportation of dredged material would include implementation of comprehensive pipeline inspection and spill response plan. A pipeline inspection plan would ensure that all pipeline connections are properly fitted and that all connections remain watertight throughout the duration of dredging activities. The inspection program would also monitor the pipeline for leaks. A spill response plan would be developed to ensure proper communication and spill control measures in the event of a loss of integrity in the pipeline.

2.2.2.3 Evaluation of Technical Feasibility

Hydraulic pipeline transportation of dredged materials is most commonly used with a hydraulic dredge, though it can also be used with a hopper dredge with direct pump-out capabilities. The dredge “Oregon” is used in the Columbia FNC for maintenance dredging, and it is capable of pumping distances up to approximately 10,000 feet (less than 2 miles). Booster pumps would be needed to pump longer distances. The range of Hydraulic transport is further reduced when pumping to upland sites, which may be necessary if sediments that are unsuitable for in-water disposal are dredged. Each foot of elevation gain reduces the pumping range by approximately 100 feet. The greatest pumping distance typically used, even with booster pumps, is approximately 15 miles.

A hydraulic pipeline will require reconfiguration each time the dredge is moved to a new site and each time the material management site is changed. Additionally, if not properly

managed, constructing and maintaining a pipeline in the Lower Willamette FNC may cause an impediment to channel navigation.

Evaluation by River Reach. The technical feasibility of hydraulic pipeline transport of dredged materials is rated as Marginal for all reaches of the Lower Willamette FNC due to the lack of flexibility and adaptability of the transportation method compared to barge transportation.

2.2.2.4 Evaluation of Environmental Acceptability

Hydraulic pipeline transportation would not affect the turbidity of the water body that it floated on unless the pipeline was compromised due to equipment failure, damage by river traffic, or vandalism. Damage of the pipeline could result in a significant release of sediments to the water column; however, the probability of such an event is low.

Pipeline transportation is commonly used for transport of dredged materials not suitable for in-water disposal. With pipeline transportation, sediments are normally excavated and transported to the material management site without having to transfer the material between vessels and without the discharge of excess water, and the material is transported in a sealed pipeline. This makes it less likely that sediments are spilled to the surrounding waters when using pipeline transportation than when using barge or hopper transportation.

Evaluation by River Reach. The environmental acceptability of hydraulic pipeline transport of dredged materials is rated as Very Favorable for all reaches of the Lower Willamette FNC due to the low probability of solids being released during the transport process.

2.2.2.5 Evaluation of Cost Effectiveness

Hydraulic pipeline transportation, similar to hydraulic dredging, would be most cost effective when dredging large volumes of material from one area. Movement between dredging sites or material management sites requires the reconfiguration of the conveyance pipeline to adjust the length to fit the new location of the dredge. Dredging operations can not continue when moving between dredge sites and material management sites, resulting in downtime and increased costs.

Booster pumps would be necessary when the distance between the dredging site and the material management site are greater than approximately 1 mile for in-water management sites and significantly shorter, depending on the elevation gain, when pumping to upland sites. Booster pumps would incur additional maintenance, monitoring, and fuel costs.

Evaluation by River Reach. The cost effectiveness of hydraulic pipeline transportation is rated as Favorable for Reach 1 of the Lower Willamette FNC. The in-water disposal site at Morgan Bar would be approximately 3 miles from the dredge site, but can be conveyed there using booster pumps with minimal additional effort. If the material were determined unsuitable for in-water disposal, additional conveyance piping and booster pumps may be necessary to reach the nearest upland dewatering site at West Hayden Island.

The cost effectiveness of hydraulic pipeline transportation is rated Marginal for Reach 2 of the Lower Willamette FNC because there is a relatively small volume of material to be removed from this reach of the FNC and there are no dredged material management sites currently identified within 5 miles of this reach. Dredged material can be conveyed by

hydraulic pipeline to the material management sites with the use of booster pumps; however, construction and maintenance of a 5-mile piping system may not be economical given the relatively small volume of material located in this reach.

The cost effectiveness of hydraulic pipeline transportation is rated as Marginal for Reach 3 of the Lower Willamette FNC. This reach of the FNC contains the bulk of the sediments to be dredged from the three river reaches, indicating that dredging may be economical; however, there are no dredged material management sites currently identified within approximately 4 miles of this reach. The closest currently identified potential management site is Ross Island Lagoon. If Ross Island Lagoon is not available for use, the closest currently identified site is approximately 12 miles away.

2.2.3 Surface Transportation (Truck/Rail)

2.2.3.1 Description of Material Transport Method

Surface transportation of dredged material is used in conjunction with either barge or hydraulic transportation to move dredge materials to management sites that can not be reached by those methods due to either physical or economical factors. The material must be dewatered to acceptable water content prior to transferring the materials to trucks or freight cars for transport to a landfill, construction site, or other upland material management site. Dewatering cells are required to lower the water content of the material to reduce the transportations costs (by reducing both the weight and volume of the material) and to make the material acceptable to landfills or other management sites that impose water content limitations. Material is transferred from the dewatering cell to trucks or trains using excavators, loaders or cranes equipped with buckets.

Surface transport via truck or rail would primarily be used to transport dredge materials to upland material management sites. Dredge material management options that are available for use with surface transportation include: solid waste landfill, construction fill, habitat restoration, and confined disposal facility. Dredge material management options are discussed in more detail in Section 3.

2.2.3.2 Best Management Practices (BMPs)

BMPs applied to surface transportation of dredged material would ensure that all sediment is properly dewatered prior to transferal to a truck or rail car. Once in the truck or rail car, the material can be covered to limit potential for loss of sediments to wind erosion during transport. Truck drivers or train engineers would be trained in the proper communication and response procedures in the event of a rollover or spill.

2.2.3.3 Evaluation of Technical Feasibility

Trucks are readily available in the area and freight train lines connect the Portland area to several locations near landfills in Oregon and Washington. Surface transportation methods would be required if material is to be managed for transfer to upland disposal sites (that is, landfills) or for reuse as construction fill in areas away from the river. Material transported by truck or rail must have a relatively low water content to prevent water discharge to roadways or railways.

Truck and rail transportation must be used in conjunction with in-water transportation methods (either barge or hydraulic pipeline) unless the dredging operations take place near the shoreline and the dredged materials are of relatively low in situ water content. This means that the material would generally be transported to an offloading location where it either would be placed directly in trucks/rail cars or dewatered, then placed in trucks/rail cars. This rehandling of material adds complexity to the operation.

Truck transportation is very flexible and can be used to transport materials to any number of locations; however, trucks are affected by traffic patterns that could cause delays. Rail transportation is less flexible than truck transportation but still provides for a wider range of material management locations than barge or hydraulic pipeline transportation methods.

Evaluation by River Reach. The technical feasibility of surface transportation is rated as Favorable for all reaches of the Lower Willamette FNC. The technical feasibility of surface transportation will not be affected by the location of dredging operations on the river. However, truck or rail transportation is not possible without the use of pipeline or barge transportation to bring sediments to an upland material transfer site. Truck or rail transportation would be necessary if sediments are transported to a landfill site, either for disposal or beneficial use as daily landfill cover.

2.2.3.4 Evaluation of Environmental Acceptability

Surface transportation methods would have no effect on sediment resuspension or turbidity levels in the FNC. Surface transportation would be necessary to transport sediments to landfills where they can be used beneficially as material for daily landfill cover. Surface transportation by truck can transport clean dredged materials to construction sites or other sites where the materials are used beneficially as opposed to disposed in-water. Most upland beneficial use sites would require surface transportation methods in order to receive dredged materials.

Evaluation by River Reach. The environmental acceptability of surface transportation is rated as Favorable for all reaches of the Lower Willamette FNC. Surface transportation would be necessary to facilitate the use of dredged materials at the majority of upland beneficial use sites. In addition, if BMPs are followed, surface transportation methods would not cause dredging-related impacts to the environment.

2.2.3.5 Evaluation of Cost Effectiveness

Surface transportation is likely to be the least cost effective of all transport options because it would require multiple rehandling of the dredged material. Surface transportation is also the transportation method that is most affected by fuel costs. Trucks and trains are both powered by diesel fuel and are much less efficient than barges/tugs or hydraulic pipeline transport when considered on a sediment volume per unit of fuel basis.

Evaluation by River Reach. The cost effectiveness of truck and rail transportation is rated as Not Recommended for all reaches of the Lower Willamette FNC because it would be the most costly method of transportation per unit volume of material. However, truck or rail transportation may be necessary to facilitate upland disposal or beneficial reuse.

SECTION 3

Dredged Material Management Options

3.1 Introduction

The purpose of this section is to present dredge material-management options for the Willamette River DMMP, a 20-year plan. Material management options are based on what upland and in-water sites, known or anticipated, are available for the placement of dredge material through the next 20 years.

Depending on its characteristics, particularly grain size, and degree of contamination; dredged sediments may be suitable for beach nourishment projects, structural or nonstructural fill, landfill cover(s), habitat development projects, wetland enhancement/ restoration projects, capping open water disposal areas, or a variety of other uses. Upland, for the purposes of this report, is defined as the geochemical environment in which dredged material may become unsaturated, dried out, and oxidized. In-water, for the purposes of this report, is defined as geochemical environment in which dredged material is submerged under water and remains water saturated after disposal is completed (USACE and EPA, 2004). Disposal, for the purpose of this report is defined as the placement of dredge material at a site or within a facility that is not for beneficial use.

3.2 Beneficial Use

Beneficial use, for the purpose of this report is defined as the placement or use of dredged material for some productive purpose. Beneficial uses may involve either the dredged material or the placement site as the integral component of beneficial uses (USACE, 2003). Whenever the dredging cycle and beneficial use needs have been found to coincide, beneficial use of dredged material has been considered as a management option (USACE and EPA, 2004).

Dams and coastal developments in the Pacific Northwest have altered natural sand movement and replenishment of the littoral cells along the coasts and in rivers greatly. Dredged material can and should be considered a resource. While dredged material disposal facilities always will be needed in some capacity for sediments unsuitable for open water disposal, in the spirit of resource conservation, re-use, and recycling, it is imperative to evaluate and cultivate emerging beneficial use strategies to ensure a practical, productive and integrated long-term program for the management of dredged sediments.

The use of suitable dredged material as habitat and wetland creation, enhancement, and restoration offers a unique opportunity to use sediments as a resource and, at the same time, restore and improve degraded habitats in ocean, riverine, estuarine, and adjacent uplands. Degraded lands such as active and inactive landfills, Brownfield sites, and quarry sites can offer another unique opportunity to combine the use of dredged material with the environmental and economic restoration of otherwise unproductive or unsuitable

properties. All of these sites have disturbed environments and limited natural resource value in their present condition. Many of these sites also generate leachate and surface water runoff that contaminate surrounding soils, aquifers, and surface water. The beneficial use of dredged sediment for land remediation under properly controlled conditions and in conjunction with engineering and institutional controls can provide a safe and economical way of remediating these sites.

A number of procedural and logistic factors greatly influence the feasibility of specific, beneficial use proposals. Examples of logistic considerations include:

- Distance of the proposed beneficial use site from the dredging project
- Site accessibility
- Required equipment to dredge the channel (for example, hopper dredge in high-energy approach channels) versus equipment required to efficiently transport the material to the site (for example, quite often a pipeline dredge)
- Material rehandling requirements
- Size of project versus intended beneficial use and size of disposal site (for example, a 30-inch dredge required to efficiently move large volumes of shoal material may very quickly overwhelm a small wetland restoration site)
- Timing of the beneficial use need (for example, beach nourishment) versus maintenance dredging needs (USACE and EPA, 2004)

3.2.1 In-Water Beneficial Use

3.2.1.1 Beach Nourishment

Beach nourishment usually is accomplished by dredging sand from inshore or offshore locations and transporting by hydraulic pipeline to an eroding beach. These operations may result in displacement of the substrate, changes in the topography or bathymetry of the borrow-and-replenishment areas, and destruction of non-motile benthic communities. However, a well-planned beach nourishment operation can minimize these effects by taking advantage of the resiliency of the beach and nearshore environment and its associated biota, and by avoiding sensitive resources. When dredged material is used for beach nourishment, it should closely match the sediment composition of the eroding beach and be low in fine sediments, organic material, and pollutants. Beach nourishment and protection can also be accomplished by placement of dredged material mounds or berms on the bottom, where much of the material would be carried by wave action to the beach (USACE and EPA, 2004).

Because the dredged material from the Willamette River FNC contains predominately fine material, it is not suitable for beach nourishment and would not be acceptable for such applications. Beach nourishment was not evaluated further and was given a rating of Not Recommended for all evaluation categories.

3.2.1.2 Terminal 4

The Port of Portland may create a design for the cleanup of sediments unsuitable for in-water disposal at marine Terminal 4 as directed by EPA. Construction of the cleanup

schedule is to be determined. The cleanup emphasizes dredging sediment that is unsuitable for in water placement and placing it in a nearshore CDF that will be constructed at Terminal 4 (T4) Slip 1. The Port has indicated that they are in need of 500,000 cubic yards (cy) of material as clean cover for the CDF, if the material is determined to be suitable for use as capping material (EIS Reference Placeholder). This material management option is discussed further in Section 3.4.1.1.

3.2.1.3 Ross Island Lagoon

The Ross Island Lagoon is a deepwater, gravel borrow pit that is centered within the Ross Island complex of four gravel bar islands in the middle of the Willamette River at WRM 14. Gravel was mined from 1925 to 2000 when the owner, Ross Island Sand and Gravel (RISG), began a reclamation program. The reclamation plan proposed that 4.5 million cubic yards of material be placed in the existing lagoon, which is up to 140 feet deep. RISG is seeking fill material to meet requirements of an approved reclamation plan (EIS Reference Placeholder).

Ross and Hardtack islands form the boundary of Ross Island Lagoon. The lagoon is surrounded on all sides by both islands and an artificial berm connecting the islands. The lagoon mouth opening to the east at Holgate Slough has a sill approximately 30 feet deep. RISG operates a concrete operation on Hardtack Island. RISG transports gravel by barge into the lagoon from a gravel source up the Columbia River. The remaining upland areas are natural bottomland cottonwoods.

The goal of the mine restoration is to enhance anadromous fish and wildlife habitat, protect surface and groundwater resources and protect the structural integrity of the islands. The restoration would create shallow-water habitat by filling portions of the lagoon. Completely filling the lagoon to create the habitat would take at least 40 million cubic yards (mcy) of material. Over an approximate 10-year time frame RISG is to create 22 acres of emergent wetland habitat and 14 acres of shallow water habitat (DEQ, 2006).

Method of Delivery/Placement. Placement of material at Ross Island Lagoon would most efficiently occur using a barge or hopper dredge bottom dump placement. Specific placement of the material would be agreed on by landowners, stakeholders, dredging contractor, and regulating agencies prior to project initiation.

Evaluation Technical Feasibility. Ross Island Lagoon provides a close proximity dredge material management site for FNC dredging. The site enables offload of dewatered material into the lagoon using mechanical placement (barge and clamshell) technologies. The technical feasibility of the Ross Island Lagoon is Very Favorable for all river sections.

Evaluation of Environmental Acceptability. There are established criteria specific to Ross Island in-water and upland fill. The criteria include testing requirements, sample handling and sample analysis for sediment characterization of fill material. Regulatory agencies should be involved early in the dredge planning process if Ross Island Lagoon placement is the selected management option. The determination of environmental acceptability must ensure that standards or criteria agreed on by regulating agencies, landowner, and stakeholders during material management planning are met.

The environmental acceptability of Ross Island Lagoon is Very Favorable.

Evaluation of Cost Effectiveness. The Ross Island Lagoon material management option is cost effective if using a hopper or mechanical dredging operations. Placement of dredged material in Ross Island could also be performed using a hydraulic pipeline, if properly evaluated and designed. This material management option is Very Favorable for all river sections.

FIGURE 3-1
Ross Island (Google Earth)

3.2.1.4 Habitat Restoration

Aquatic habitats are typically submerged habitats extending from near sea, river, or lake level down several feet. Aquatic habitat development is the establishment of biological communities on dredged material placed at or below mean tide in coastal areas and in permanent water in lakes and rivers. Potential developments include such communities as freshwater aquatic plant establishment. The bottom of many water bodies potentially could be altered using dredged material; this could simultaneously improve the characteristics of the site for selected aquatic species (USACE and EPA, 2004). Habitat restoration evaluations are presented in Section 3.3.2.4.

3.2.2 Upland Beneficial Use

3.2.2.1 Solid Waste Landfill

Daily cover of solid waste landfills is another beneficial use of dredged material that has proven to be feasible in laboratory and field tests (USACE and EPA, 2004). This use would require large quantities of dredged material that could be moderately unsuitable for in-water placement and still be acceptable for daily cover. The use would ultimately provide nonconsumptive vegetative cover to unsightly areas, and the areas could be further reclaimed for minimal-use recreation sites and/or wildlife habitat (USACE, 1987).

Discussion and evaluation of material disposal at solid waste landfills can be found in Section 3.4.2.2.

3.2.2.2 Construction Fill

Industrial/commercial development near waterways can be aided by the availability of hydraulic fill material from nearby dredging activities. The use of dredged material to expand or enhance port-related facilities generally has received support because of the readily apparent potential benefits to the economy. Approval of the disposal operation generally is predicated on the advancement of the development project and not on the incidental need for proper disposal of the dredged sediments. Use of dredged material to reclaim former industrial sites (Brownfield) for other uses also has been considered in some areas (USACE and EPA, 2004).

Construction fill opportunities are abundant in the greater Portland metro area. Material transport businesses are soliciting material for reuse in construction projects and in some cases can identify rehandling sites for suitable dredge material. Unsuitable material can also be handled and transported for disposal by these businesses. However, due to the fact that the Willamette River FNC material is predominately fine grained, it would require mixing with other material before it would be suitable for this use.

Method of Delivery/Placement. Placement of material for construction fill would be most efficient using barge or truck transportation. Material would require dewatering at an upland staging facility prior to transport to specific construction sites. Specific placement of the material would need to be agreed on by landowners, stakeholders, dredging contractor, and regulating agencies.

Evaluation Technical Feasibility. Construction fill is a useful commodity in the Portland area. Dredge material from the Willamette FNC could be beneficial reused as construction fill, depending upon physical and chemical characteristics. Dewatered material could be offloaded using pipeline, hopper, or material barge. Once material is placed it can be transported to different locations within a site by earth moving equipment. The necessity of mixing this material with other types of fill means this option is Marginal for technical feasibility in all river sections.

Evaluation of Environmental Acceptability. Regulatory agencies should be involved early in the dredge planning process if dredged material is used for construction fill as a selected material management option. The determination of environmental acceptability must ensure that standards or criteria agreed on by regulating agencies, landowner, and stakeholders during material management planning are met.

Dewatering of the dredged material requires proper planning and design for environmental acceptability. The environmental acceptability is Marginal.

Evaluation of Cost Effectiveness. Reuse of dredged material as construction fill will require dewatering of dredged material for each of the dredging methods and subsequent mixing with suitable fill materials. Potential rehandle sites such as Glacier NW, West Hayden Island, and Construction Materials Exchange near the Willamette FNC make this management option Marginal if the material is environmentally acceptable.

3.2.2.3 Mine Reclamation

Beneficial use of dredged material at reclamation sites has proven to be feasible in laboratory, field, and District tests (USACE and EPA, 2004). Reclamation of abandoned mine sites using dredged material is a relatively new material management option. This use would require large quantities of dewatered dredged material. This use would ultimately provide cover to unsightly areas, and the areas could be further reclaimed for minimal-use recreation sites and/or wildlife habitat (USACE, 1987).

Method of Delivery/Placement. The preferred method of material placement for mine reclamation would be truck transportation. Material would require dewatering at an upland staging facility prior to transport to the site. Specific placement of the material would be agreed on by landowners, stakeholders, and regulating agencies.

Evaluation Technical Feasibility. Dewatering the material adds rehandling to the disposal operation. The material would also have to meet site specific criterion prior to placement. Technical feasibility of reuse of dredged material for mine reclamation is Marginal for all river sections.

Evaluation of Environmental Acceptability. Regulatory agencies should be involved early in the dredge planning process for use of dredged material as mine reclamation. The determination of environmental acceptability must ensure that standards or criteria agreed on by regulating agencies, landowner, and stakeholders during material management planning are met. The environmental acceptability of mine reclamation is Marginal.

Evaluation of Cost Effectiveness. Mine reclamation will require dewatering of dredged material and rehandling, which will significantly increase overall project costs. Based on the significant costs associated with material rehandling, truck transport, and the unknown quantity of material, this management option is Not Recommended for all river sections.

3.2.2.4 Habitat Restoration Sites

Habitat development refers to the establishment and management of relatively permanent and biologically productive plant and animal habitats. Use of dredged material as the substrate for habitat development is one of the most important beneficial use categories. The use of dredged material for habitat development offers a beneficial use that is an attractive and feasible alternative to more conventional disposal options. Within various habitats, several distinct biological communities may occur. For example, the development of a dredged material island may involve a wide variety of wetland, upland, island, and aquatic habitats.

Wetland habitat is a broad category of periodically inundated communities, characterized by vegetation that survives in wet soils. These are most commonly tidal freshwater and saltwater marshes, bottomland hardwoods, freshwater swamps, and freshwater riverine and lake habitats. Disposal of dredged material on a viable wetland, so that the wetland is destroyed and converted into a disposal site, is never an environmentally preferable alternative. However, restoration/enhancement of wetlands is an alternative that can benefit the environment and has the potential of gaining wide public acceptance when some other techniques cannot. In selecting a site, alteration of substrate and changes in circulation and sedimentation patterns should be considered. In general, the material used for wetland

restoration should remain water-saturated, reduced, and near neutral in pH. These characteristics have a great influence on the environmental activity of any chemical contaminants that may be present (USACE and EPA, 2004).

Upland habitat includes a broad category of terrestrial communities, characterized by vegetation that normally is not subject to inundation. Types may range from bare ground to mature forest. Regardless of the condition or location of a disposal area, considerable potential exists to convert it into a more productive habitat. Small sites in densely populated areas may be keyed to small animals adapted to urban life, such as seed-eating birds and small mammals. Larger tracts may be managed for a variety of wildlife including waterfowl, game mammals, and rare or endangered species (USACE and EPA, 2004).

Opportunities for upland habitat restoration in the Portland area will ebb and flow over the 20-year planning horizon described in this document. Many projects will benefit by incorporating suitable Willamette River dredge material. The Metropolitan Service District has identified high priority habitat restoration areas throughout the city, associated with riparian and greenway habitats along the river. Also, the City of Portland regularly implements restoration projects in parks and through water quality improvements projects. Brownfield sites will be redeveloped. Transportation system improvements, such as the Sellwood Bridge, Interstate Bridge over the Columbia, eastside Interstate-5, and the future light rail bridge over the Willamette, offer potential restoration opportunities, either directly through construction or through habitat mitigation actions. Existing and future port terminals (for example, Hayden Island) and rail yards may lend their hand to habitat restoration. Furthermore, several opportunities exist for emergent marsh restoration. For example, new land forming naturally at Willamette Park offers the dual chance to enhance fish habitat while controlling sedimentation and erosion rates in the river (see Figure 3-2).

Each identified restoration/enhancement site will require investigation and cooperation between sponsoring agencies and stakeholders.

Method of Delivery/Placement. Delivery of clean dredge material to habitat restoration sites is dependent on the location of the restoration site. In water and nearshore restoration sites may be best served by hopper, pipeline, or barge placement. Upland sites may require truck transport.

FIGURE 3-2
Willamette Park (Google Earth)

Evaluation Technical Feasibility. Limited habitat restoration sites are located within close proximity to the Willamette FNC. Sites may become available over the 20-year timeframe of this document. The most common technical impairment to these sites is offload locations. This material management option is Marginal for all river sections.

Evaluation of Environmental Acceptability. Habitat restoration sites have strict and varying requirements for environmental acceptability. Requirements will be determined by the specific habitat restoration site selected. Regulatory agencies should be involved early in the dredge planning process if habitat restoration/enhancement is the selected material management option. The determination of environmental acceptability must ensure that standards or criteria agreed upon by regulating agencies, landowner, and stakeholders during material management planning are met.

This management option is Marginal for all river sections.

Evaluation of Cost Effectiveness. Cost associated with restoration sites will be dependent on the site location and should be closely examined prior to selecting habitat restoration as material management option. Offload site improvement costs will also contribute to this management option, but will be specific to the selected restoration site. Due to the uncertainty of habitat restoration projects, cost sharing between parties is a common occurrence. This material management option is Marginal (cost sharing) for all river sections.

3.3 Disposal

Beneficial use of dredged material is usually a preferred option, however, when reuse is not an option disposal of dredge material may be required. Dredged material can contain contaminants that do not allow them to be reused in a beneficial manner. In this section disposal options are described.

3.3.1 In-Water Disposal

3.3.1.1 Confined Disposal Facility (CDF)

A CDF is an engineered structure consisting of dikes or other structures that extend above any adjacent water surface and enclose a disposal area for containment of dredged material, isolating the dredged material from adjacent waters or land (USACE and EPA, 2004). CDFs are an option commonly considered for disposal of sediments unsuitable for open water disposal dredged either as temporary rehandling sites or for final disposal. CDFs are also used for disposal of clean sediments where other options are too costly or present additional environmental problems (USACE, 2003).

If unsuitable sediments are placed in a CDF, consideration of pathways for migration of contaminants from the site and potential contaminant impacts may be required. A suite of evaluation procedures and laboratory test procedures has been developed to evaluate CDF contaminant pathways (USACE, 2003).

CDFs may be constructed as upland sites, nearshore sites with part of the perimeter on shore and part in water, or as island containment areas (Figure 3-3). CDFs also vary considerably in size, dike type, and method of filling. The isolation of the dredged material from adjacent waters and land during and following disposal distinguishes a CDF from other forms of disposal such as unconfined upland, open water, wetland, or contained aquatic disposal (CAD), which is a form of subaqueous confinement with capping.

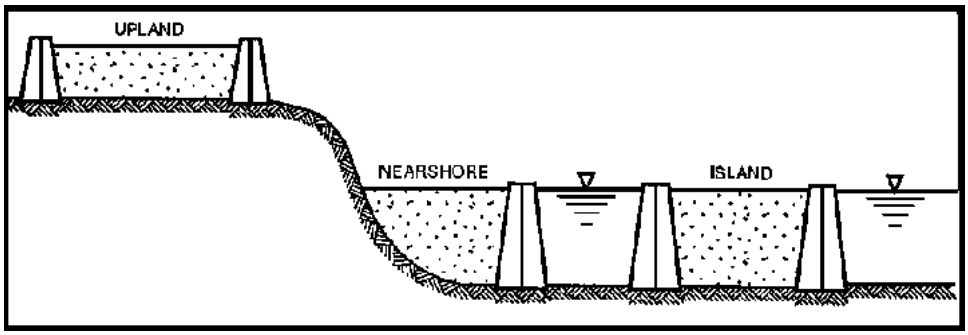

FIGURE 3-3
Upland, Nearshore and Island CDFs (USACE and EPA, 2004)

CDFs are not solid waste landfills. They are designed and constructed specifically for disposal of dredged sediment and are designed for the unique properties of sediments, such as high water content and return flow of excess water as effluent to surface waters. However, if needed, CDFs can be designed with control measures, such as liners or surface covers, to provide containment equivalent to that of an engineered landfill (USACE, 2003).

Method of Delivery/Placement. Placement of material at a CDF would occur most efficiently with hopper dredge pumpout, or bottom dump with hydraulic pipeline conveyance.

Evaluation of Technical Feasibility. Few CDF facilities currently are planned or are present in or near the lower Willamette River. The proposed CDF at Terminal 4 in Portland Harbor is a potential disposal option of unsuitable material from the Willamette FNC. Timing of material placement is crucial at this site due to the cleanup schedule at Terminal 4 (which is currently on hold).

Pipeline placement of material into the CDF adds several volumes of water for each volume of sediment and the excess water normally is discharged as effluent during the filling operation. The amount of water added depends on the dredge, physical characteristics of the sediment, and operational factors such as pumping distance. When dredge material initially is placed in the CDF, it may occupy several time its original volume. Adequate volume must be considered prior to dredging operation and should contain the total volume of sediment to be dredged, accounting for any volume changes during placement.

Mechanically rehandled material from barges is at or near its in situ water content. Therefore, if CDF sites are constructed in water, the effluent volume may be limited to water displaced by the dredged material, and the settling behavior of the material is not important (USACE and EPA, 2004).The Terminal 4 site is in close proximity to all river sections and may allow for placement of unsuitable material. Due to lack of identified sites, this management option is Marginal for all river sections.

Evaluation of Environmental Acceptability. Regulatory agencies should be involved early in the dredge planning process if a CDF is the selected material management option. The determination of environmental acceptability must ensure that standards or criteria agreed upon by regulating agencies, landowner, and stakeholders during material management planning are met.

Control of contaminants is a major objective in determining environmental acceptability of this material management option. Contaminant migration pathways should be examined prior to placement of material in a CDF. Pathways may include effluent discharges to surface water during filling operations and subsequent settling and dewatering, rainfall surface runoff, leachate into groundwater, volatilization to the atmosphere, and direct uptake (USACE and EPA, 2004).

If the analysis of contaminant pathways (Figure 3-4) and associated testing indicates that the standards are met, the CDF is acceptable environmentally, from the standpoint of contaminant effects for that pathway. If standards are not met, contaminant control measures should be considered to reduce impacts to acceptable levels (USACE and EPA, 2004). This management option is Marginal for all river sections.

Evaluation of Cost Effectiveness. The CDF material management option is cost effective if using mechanical dredge technology, barge transport and disposal offloading operations. This material management option is Favorable for all river sections.

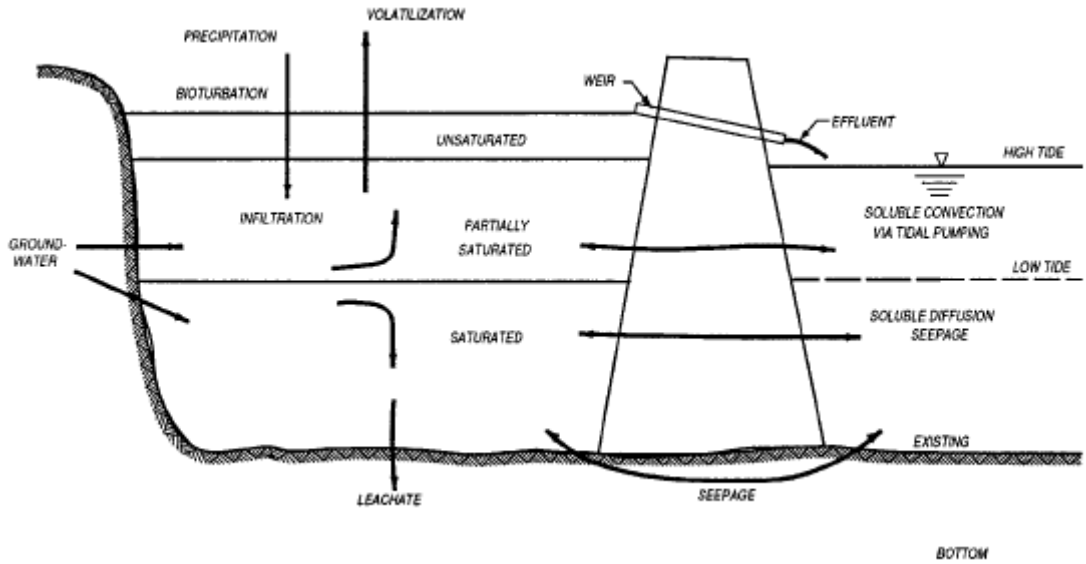

FIGURE 3-4
Contaminant Pathways for Nearshore CDFs (USACE and EPA, 2004)

3.3.1.2 Deep Hole—Willamette River

The deep hole designated WRKE-1 is located from WRM 4 to WRM 5 and originally was dredged to provide fill for Port of Portland's Terminal 4. The deep hole designated WRKE-2 is located from WRM 9 to WRM 10 and originally was dredged to provide fill for the Port of Portland's Swan Island and Terminal 2. As such, neither are naturally occurring deep water sites.

WRKE-1 is about 4,500 feet long; the bank-to-bank width of the river at WRKE-1 is about 1,400 feet. If used for in-water disposal, the capacity of this site is approximately 2.4 mcy. An additional 0.7 mcy of volume would be available in the deep hole if filled to -42 CRD. WKRE-2 is smaller than WKRE-1 with a length of 3,500 lineal feet and a capacity of 1 mcy. The lower Willamette is approximately 1,200 to 1,400 feet wide at WRKE-2.

Method of Delivery/Placement. Hopper or barge transport is the preferred methods of delivery to Deep Hole sites in the Willamette River. Placement of material can efficiently be completed by hopper barge or mechanical offloading technologies. The use of a submerged diffuser pipe or "tremie" would facilitate placement and limit suspended solids at the disposal site.

Evaluation of Technical Feasibility. Deep Hole in-water disposal of dredge material is technically feasible if dredge material is determined acceptable for in-water disposal. The Deep Hole sites in the Willamette are in close proximity to the proposed dredging operations. Deep Hole placement of material would cut down on transportation time compared to other material management options. This management option is Very Favorable for all river sections.

Evaluation of Environmental Acceptability. Regulatory agencies should be involved early in the dredge planning process if the Willamette Deep Hole is the selected material management option. The determination of environmental acceptability must ensure that

standards or criteria agreed upon by regulating agencies, landowner, and stakeholders during material management planning are met.

Deep Hole in-water disposal areas in the Willamette are present. Due to lack of biological studies and modeling of the available sites, this material management option cannot be evaluated at this time. As biological studies and modeling are completed, Deep Hole sites in the Willamette should be examined as a material management option.

Evaluation of Cost Effectiveness. The Deep Hole material management option is cost effective if using mechanical or hopper dredge technology, barge or hopper transport, and barge or hopper disposal offloading operations. This material management option is Favorable for all river sections.

3.3.1.3 Flowlane— Morgan Bar

Flowlane disposal is the placement of dredged material in or adjacent to a channel where the material will continue to flow downstream. Material is placed at an appropriate depth where sediment moves slowly from the site in the bedload (EIS Reference Placeholder).

In the Columbia River, Morgan Bar (RM 97.8-101.3100-101) has been used in the past for flowlane disposal of material from Portland Harbor. It was first used in 1984 and approximately 500,000 cubic yards (cy) was placed there on average every 3 years until the last Willamette River dredging event in 1997. Material dredged from Portland Harbor is fairly fine grained (silty sands and sandy silts) and disperses quickly from the site on Morgan Bar, moving downstream in the Columbia River (EIS Reference Placeholder).

Method of Delivery/Placement. Hopper or barge transport is the preferred methods of delivery to the Morgan Bar site in the Columbia River. Placement of material can efficiently be completed by hopper barge or mechanical offloading technologies.

Evaluation of Technical Feasibility. Morgan Bar historically has been the disposal site for Willamette FNC dredged material. The site is accessible for placement of dredged material using a mechanical or hopper dredge; and is also accessible with hydraulic pipeline dredge from the first reach using a booster pump. Bedload transport of the sediment, once placed at Morgan Bar is approximately 3 to 5 years. At this rate of transport, Morgan Bar could be used for disposal every 4 to 5 years. The Morgan Bar clean material management option is Very Favorable for all river sections.

Evaluation of Environmental Acceptability. Regulatory agencies should be involved early in the dredge planning process if Flowlane disposal is the selected material management option. The determination of environmental acceptability must ensure that standards or criteria agreed upon by regulating agencies, landowner, and stakeholders during material management planning are met.

Evaluation of Cost Effectiveness. The Morgan Bar material management option is cost effective using hopper or mechanical dredging operations, as well as its close proximity to the FNC. Close proximity cuts down on travel time to and from the disposal site. This clean material management option is Very Favorable for all river sections.

3.3.2 Upland Disposal

3.3.2.1 West Hayden Island

West Hayden Island (WHI) is a 102-acre upland disposal site owned and operated by the Port of Portland. The site is located approximately 2 miles upriver of the confluence of the Willamette and Columbia Rivers at Columbia River Mile (RM) 105. The site is on the northwest portion of the island, downstream of the Burlington Northern Santa Fe railroad tracks.

A 79-acre site was identified in the Columbia River Channel Improvement Project (CRCIP), as a 40-foot channel maintenance disposal site. The 79-acre site is located within the confines of the entire 102-acre site. Site improvements in place include a 1000-foot-by-20- to 50-foot dredged material retention pond. Settling basin, weirs, dikes, drainage canals, improved gravel road with culverts, a locked gate and wire fencing for cattle containment are also present (EIS Reference Placeholder).

The site was reconfigured in 2005-2006 and improvements such as a permanent outfall were installed (Figure 3-5). The capacity of the disposal site is 5.75 mcy. No expansion of the footprint for the site would be required for disposal of lower Willamette River material. Willamette River sediments that do not meet the criteria for in-water disposal and that pass a leachate test would be suitable for placement at West Hayden Island.

CH2MHILL

SOURCE:
AIRPHOTO: 2007
STREET DATA PROVIDED BY
CLARK COUNTY & PORTLAND METRO

File Path: \\Hosa\Proj\Local\Portland\Sitins\352\HHGI\SXXX2\WestHaydenIsland.mxd; Date: May 22, 2007 11:48:39 AM

West Hayden Island Dredge Disposal Site

N

0 250 500 1,000
Feet

Figure 3-5

Legend

- Informal Road
- Dewatering Basin w/Outfall
- Mitigation Site
- Cell

State of Oregon solid waste rules should be evaluated to determine if dredged material may be considered solid waste.

A single concrete weir was constructed in 2005 to handle return water to the Columbia River. The weir has three outfalls; each sized for 30-inch pipes, and has connected pipes that extend through the berm. The outfalls' inverts at the concrete weir are at elevation + 15.0 feet National Geodetic Vertical Datum (NGVD).

Method of Delivery/Placement. Hydraulically (pipeline) transported material is the preferred method of delivery to the WHI site. Overland placement of the pipeline could be used to strategically place material in the material disposal cells.

Mechanical offload of material from a barge is also feasible; however, modifications to the existing facility would be required. Construction of an offloading berth for material barges could provide a relatively economical method of transfer from barge to the site.

Evaluation of Technical Feasibility. WHI is in close proximity as a disposal site for all river sections. The site allows for dewatering of material in the same location as disposal, eliminating the need for rehandling of material. In its current condition the site is prepared to handle clean material. Site preparation would need to occur prior for placing unsuitable material at WHI. Liners or other environmental controls may need to be installed. Controls and monitoring should be agreed upon by regulating agencies. This clean material management option is Very Favorable for all river sections. This option is also Marginal for non-hazardous contaminated material.

Evaluation of Environmental Acceptability. Regulatory agencies should be involved early in the dredge planning process if WHI placement is the selected material management option.

This material management option is Very Favorable for clean material and Marginal for contaminated material.

Evaluation of Cost Effectiveness. The WHI material management option is cost effective if using hydraulic pipeline for dredging and disposal offload operations, as well as its close proximity to the FNC. This clean material management option is Very Favorable for all river sections and Marginal for non-hazardous contaminated material.

3.3.2.2 Solid Waste Landfill

Sediment removed from the lower Willamette FNC that is not suitable for in-water disposal or other upland beneficial reuse options would be disposed of in a licensed solid waste landfill. Local and regional solid waste landfills are regulated under Resource Conservation and Recovery Act (RCRA) Subtitle D, which enables the landfill to receive domestic and commercial solid wastes. Landfills will require that the dredge material be tested using the toxicity characteristic leaching procedure (TCLP) to determine if it is hazardous under RCRA guidelines and pass the paint filter test. In addition, landfills may require a specific water content level in the dredged material (EIS Reference Placeholder). Landfills listed below have potential use of dredge material for daily cover.

Hillsboro Landfill (Hillsboro, OR)—Operated by Waste Management and permitted to accept unsuitable material for in-water placement as special waste. The landfill was first opened in the mid 1960s and is estimated to close in 2040. The landfill is located approximately

20 miles from the lower Willamette. Material may need dewatering prior to truck transport to meet landfill requirements. A special waste permit is required prior to disposal at the landfill, and can be obtained from Waste Management. Dry material is used as alternative daily landfill cover. Hillsboro has a set of environmental controls that include:

- Multi-layered composite liner system
- Leachate collection and removal system
- Multi-layer composite cap
- Active gas collection system
- Ground water monitoring network
- Perimeter gas detection probes

Columbia Ridge Landfill (Arlington, OR) (CRL)—Operated by Waste Management and permitted to accept unsuitable material as special waste. The landfill is located approximately 145 miles from the lower Willamette and is permitted to accept free liquids, such as partially dewatered dredge material. A special waste permit is required prior to disposal at the landfill, and can be obtained from Waste Management. Transportation of dredge material to CRL is by barge to the Port of Arlington, and then offloaded onto trucks for final transport to landfill. Dry material is used as alternative daily landfill cover. CRL has a set of environmental controls that include:

- Multi-layered composite liner system
- Leachate collection and removal system
- Active gas collection system

Wasco County Landfill (The Dalles, OR)—Operated by Wasco County and permitted to accept material unsuitable for in-water placement as special waste. The landfill is located approximately 100 miles from the lower Willamette River. Material will need dewatering prior to transport. The Bernert Barge Lines Dock in The Dalles is the barge offload terminal. Travel time by barge to the terminal is approximately 8-10 hours from Portland. Barges are offloaded at the terminal into trucks and transported approximately 10 miles to the landfill. Material can be dewatered prior to truck transport or at the landfill. Dry material is used as alternative daily landfill cover. Wasco County landfill has a set of environmental controls that include:

- Multi-layered composite liner system
- Leachate collection and removal system
- Multi-layer composite cap
- Active gas collection system
- Ground water monitoring network
- Perimeter gas detection probes

Roosevelt Landfill (Roosevelt, WA)—Operated by Rabanco/Allied Waste and permitted to accept unsuitable non-hazardous material as special waste. The landfill is located approximately 135 miles from the lower Willamette. The landfill has a demonstration permit from Klickitat County Health Department to accept dredge material that does not past the paint filter test (EPA Method 9095B). Dewatered material or material with liquid is typically transported by rail to the landfill. Barge offload is available at the Roosevelt, WA, intermodal terminal, but is not the preferred method of transport. Water from the material is

reclaimed and dry material is used as alternative daily landfill cover. The Roosevelt landfill has a set of environmental controls that include:

- Multi-layered composite liner system
- Leachate collection and removal system
- Multi-layer composite cap
- Active gas collection system
- Ground water monitoring network
- Perimeter gas detection probes

Paint Filter Test. To comply with 40 CFR 264.314, the EPA method 9095B paint filter test is used to determine landfill acceptability of bulk or containerized free liquids, such as partially dewatered dredge material. A predetermined amount of material is placed in a paint filter. If any portion of the material passes through and drops from the filter within the 5-minute test period, the material is deemed to contain free liquids and is therefore unacceptable for landfill disposal.

Dewatering. Dewatering technologies are available to reduce the water content of dredged material. The most appropriate technology for each project will depend on many factors including dredged material characteristics, site setting, and regulatory requirements. Typical dewatering techniques include:

- Gravity settling
- Chemical Treatment, such as polymer to assist with particle separation
- Filter presses
- Hydrocyclones
- GeoTubes® or geotextile bags

Method of Delivery/Placement. All landfill options require some sort of truck transport with the exception of Columbia Ridge and Wasco County facilities, which barge transport to an offload facility is the preferred method. Dewatering of material adds rehandling to the process and requires the additional use of earth moving equipment to load dewatered material into trucks for delivery.

Evaluation of Technical Feasibility. The use of dredge material as landfill daily cover is a technically feasible management option for Willamette River sediments not suitable for in-water disposal, beach nourishment, mine reclamation, or habitat creation/restoration. The location of landfills in Arlington, OR; The Dalles, OR; and Roosevelt, WA, are a considerable distance from the Willamette FNC and, therefore, associated transportation of material significantly increases project time and costs. Options for transport to the landfills vary depending on the location and Columbia River access. Barge offload for the CRL occurs at the Port of Arlington and is then is transported by truck to CRL. Barge offload also is available at the Wasco County and Roosevelt landfills. Hillsboro landfill does not have river access, so barge or hydraulic offloading is not applicable for this landfill. Truck transport of material is the overland transportation option to Hillsboro. Due to complications with transporting material via truck to a landfill, technical feasibility is Not Recommended.

Evaluation of Environmental Acceptability. Increased air emissions (fugitive and air volatilization) due to the use of fossil fuels for transport and potential of spills during transport, both of unsuitable dredge material and oil from transport vehicles are considered a potential pollutant. The use of land for landfills is considered as land and aesthetics degradation and a long-term impact.

As previously stated, dredge material determined unsuitable for in-water placement may be required by DEQ to be managed as a solid waste in Oregon. Existing environmental controls (liners, leachate collection systems, etc.) at landfill sites should be reviewed prior to placement of material to ensure that further contamination from the material will not degrade groundwater or downgradient water bodies. This material management option is Not Recommended for clean material and for non-hazardous unsuitable material.

Evaluation of Cost Effectiveness. The solid waste landfill material management option is not cost effective, but may be necessary if other disposal options will not accept unsuitable Willamette River dredge material. This management option is Not Recommended for all river sections. Landfill placement will likely only occur when other dredge material management options are not available.

SECTION 4

Positioning Accuracy

Understanding the positioning accuracy of dredging is a critical component of quality control in dredging projects and is necessary for tracking dredging progress. The typical vertical standard for maintenance dredging projects on navigation channels is 2 feet. Under tighter restrictions, greater precision and accuracy can be achieved. The typical limit is between 6 and 12 inches mechanical dredges, between 0.5 and 1 diameter of the intake pipe for hydraulic dredges, and within 1 diameter of the intake pipe for hopper dredges.
The positioning and tracking systems used to accomplish accurate dredging are discussed below.

4.1 Clamshell Positioning Systems

A variety of positioning methods can be used to locate the clamshell bucket in three dimensions (X-Y-Z). For several years, the Global Positioning System (GPS) has been the standard for determining horizontal locations for dredge control systems. Both differential (DGPS) and real time kinematic (RTK) correction methods are used to improve position accuracy in dredging. Some systems that use RTK position correction are theoretically capable of accuracies of less than one inch, so the horizontal position can be determined very accurately. In practice, locating the bucket within 6 to 12 inches of its true horizontal location is practical in standing water. For clamshell dredging or capping, a GPS antenna is typically located directly over the tip of the crane boom, coinciding with the centerline of the bucket attachment to the cable (Figure 4-1).

FIGURE 4-1
GPS Antenna Mounted For Clamshell Dredging

Unlike fixed and articulating boom equipment that can use the elevation from the GPS receiver and angle sensors on the boom to calculate directly the depth at the end of the

boom, cable suspended systems must determine bucket depth by other methods. A variety of methods has been used including calculation from boom angle and wire rope length measurements and sonar. However, the method currently in most favor in shallow water is direct measurement of bucket depth with pressure transducers. Combining depth measurements with pressure transducers, with water level elevations from tide gauges corrected to the appropriate datum, give vertical accuracies of less than 1 foot for bucket position.

In areas with strong currents, the cable-suspended bucket can move laterally from the X-Y-Z location determined from GPS and the pressure transducer. In shallow water, the distance that the bucket is moved by the current is generally small enough to have no effect on operations. Even in areas with strong currents, the bucket offset is generally predictable, relatively constant, and construction adjustments can be made if the direction and magnitude of the current does not change. However, in deep water and in areas with strong or changing currents, the bucket can be moved enough from the vertical to unacceptably degrade bucket positioning and tracking. In these cases, the extra cost and complexity of acoustical positioning systems could be warranted for controlling dredging accuracy.

4.2 Acoustical Positioning Systems

Acoustic positioning systems could be used in conjunction with mechanical, hydraulic or hopper dredging methods. Acoustic positioning systems consist of one or more transponders/transducers placed on the seabed, clamshell bucket, or ship's hull (Figure 4-2). The transducer sends an acoustic signal to the transponder, which is triggered to reply. As the velocity of sound through water is known, the distance is known. Because there are either multiple transponders or multiple elements on the transducer, the direction of the signal from the transponder can be determined. The position of the ship relative to the transponders can be calculated then. Disadvantages are those typical of underwater acoustical systems - the vulnerability to noise by thrusters or other acoustic systems, different sound velocities with differing temperatures and salinities, and ray bending that occurs in shallow water when sound travels through water horizontally. Several acoustic positioning systems are available, including ultra-short baseline, short baseline, and long baseline, with each varying in complexity and accuracy.

FIGURE 4-2
Short Baseline System (http://www.sonardyne.co.uk/Support/PositioningTechniques)

SECTION 5

Summary

The following three tables summarize the evaluations discussed in the previous sections of this appendix. A summary table is provided for each of the dredging components: dredging methods, transportation methods and disposal methods. As discussed earlier, the methods are compared using a relative system with four categories: Very Favorable, Favorable, Marginal, and Not Recommended. In other words, the methods have been compared against each other rather than against a hard independent standard.

TABLE 5-1
Dredging Methods Evaluation Matrix

River Reach	Dredge Type	Technical Feasibility	Environmental Acceptability	Cost Effectiveness
1	Mechanical	Very Favorable	Very Favorable	Favorable
	Hopper	Favorable	Marginal	Favorable
	Hydraulic Pipeline	Marginal	Favorable	Marginal
2	Mechanical	Very Favorable	Very Favorable	Favorable
	Hopper	Marginal	Not Recommended	Marginal
	Hydraulic Pipeline	Marginal	Favorable	Not Recommended
3	Mechanical	Very Favorable	Very Favorable	Favorable
	Hopper	Marginal	Not Recommended	Marginal
	Hydraulic Pipeline	Marginal	Favorable	Not Recommended

TABLE 5-2
Dredged Material Transport Methods Evaluation Matrix

River Reach	Transport Method	Technical Feasibility	Environmental Acceptability	Cost Effectiveness
1	Barge/Hopper	Very Favorable	Very Favorable	Favorable
	Hydraulic (pipeline)	Marginal	Very Favorable	Favorable
	Surface (Truck/Rail)	Favorable	Favorable	Not Recommended
2	Barge/Hopper	Very Favorable	Very Favorable	Favorable
	Hydraulic (pipeline)	Marginal	Very Favorable	Marginal
	Surface (Truck/Rail)	Favorable	Favorable	Not Recommended
3	Barge/Hopper	Very Favorable	Very Favorable	Favorable
	Hydraulic (pipeline)	Marginal	Very Favorable	Marginal
	Surface (Truck/Rail)	Favorable	Favorable	Not Recommended

TABLE 5-3
Dredged Materials Disposal/Beneficial Reuse Methods Evaluation Matrix

Disposal Method	Technical Feasibility	Environmental Acceptability	Cost Effectiveness
In-Water (Suitable Material)			
Beach Nourishment	Not Recommended	Not Recommended	Not Recommended
Ross Island Lagoon	Very Favorable	Very Favorable	Very Favorable
Confined Disposal Facility	Marginal	Marginal	Favorable
Deep Hole- Willamette R.	Very Favorable	—	Favorable
Flowlane Morgan Bar	Very Favorable	Marginal	Very Favorable
Upland (Suitable Material)			
Construction Fill	Marginal	Marginal	Marginal
Mine Reclamation	Marginal	Marginal	Not Recommended
Habitat Restoration	Marginal	Marginal	Marginal
West Hayden Island	Very Favorable	Very Favorable	Very Favorable
Solid waste landfill	Not Recommended	Not Recommended	Not Recommended
In-Water (Unsuitable Material)			
Beach Nourishment	Not Recommended	Not Recommended	Not Recommended
Ross Island Lagoon	—	—	—
Confined Disposal Facility	Marginal	Marginal	Favorable
Deep Hole- Willamette R.	—	—	—
Flowlane- Morgan Bar	—	—	—
Upland (Unsuitable Material)			
Construction Fill	—	—	—
Mine Reclamation	Marginal	Marginal	Not Recommended
Habitat Restoration	—	—	—
West Hayden Island	Marginal	Marginal	Marginal
Solid waste landfill	Not Recommended	Not Recommended	Not Recommended

Notes:

If no ranking is listed for one of the criteria then it cannot be considered as a disposal option (see corresponding report section for clarification).

SECTION 6

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ATTACHMENT A

Computation of Mixing Zone Requirements for Clamshell Dredging of the Lower Willamette River

CEERD-EP-E 5 May 2007

MEMORANDUM FOR: Mr. James Crain, CENWP-EC-HY
Mr. Timothy Sherman, CENWP-EC-HR
Ms. Carolyn Schneider, CENWP-PM-E
Mr. Donald Erickson, CENWP-PM-PM

SUBJECT: Computation of Mixing Zone Requirements for Clamshell Dredging of the Lower Willamette River

1. **Background.** The USACE Portland District is evaluating dredging of sediments from the Lower Willamette River (RM 8 to 10 and RM 2 to 3) to determine potential environmental impacts by resuspension, particularly the impacts on aquatic organisms by the release of contaminants from the resuspended sediment. As a first cut conservative screen of potential impacts, losses of suspended solids and contaminants are predicted based on literature values of the sediment physical and chemical properties, site characteristics and dredging operational parameters. Then, the fate and transport of the released solids and contaminants are modeled using the USACE DREDGE model that assumes steady-state conditions, discrete settling of flocculated particles, and equilibrium partitioning of contaminants between the solids and water column (Hayes and Je 2000). The dissolved contaminant concentrations are compared with primary and secondary water quality criteria for the protection against chronic toxicity to freshwater aquatic organisms in lieu of an ecological risk assessment specific to the lower Willamette River.

2. **Site Data.** The site characteristics are described in Portland Harbor RI/FS, Comprehensive Round 2 Site Characterization Summary and Data Gaps Analysis Report (2007). The flow rate ranges from 7000 cfs to 126,000 cfs with an annual average of about 40,000 cfs. The characteristic flow rate during the summer when dredging would occur is about 15,000 cfs. Low flow rate provides less dilution and therefore is considered to be a conservative (worst-case) condition for modeling. The navigational channel has a depth of about 13 meters, a bottom width of about 250 meters and a top width of about 320 meters. The water depth at the top of the channel side slope is about 5.5 meters. The effective river cross-sectional area is the narrower reaches of the lower Willamette River is about 5100 sq meters. The river is tidally influenced and has a channel velocity of 20 cm/sec during flood tide and 15 cm/sec during ebb tide at a daily flow rate of 15,000 cfs. For these flow condition without stratification in a river system, the vertical diffusion coefficient (e_v) is computed as follows (Fischer et al. 1979):

$$ev = 0.067\ d\ u^* \text{ where } u^* = \text{sqrt}(gdS) \text{ or } u^* = 0.15\ Ua$$

where d is the channel depth, g is gravity, S is the slope, and U_a is the mean velocity. The transverse diffusion coefficient (e_t) is computed as follows (Fischer et al. 1979):

$$et = 0.5\ d\ u^*$$

3. **Physical Sediment Data.** The physical sediment characteristics are described in Portland Harbor RI/FS, Comprehensive Round 2 Site Characterization Summary and Data Gaps

Analysis Report (2007). The in situ dry bulk density of the sediment is about 770 kg/cu meters and has an organic content of about 3.5 percent. On average, the sediment is about 8 percent clay, 47 percent silt and 45 percent sands and gravels and is classified as silt. The background TSS concentration was about 4 mg/L. The mean floc size of the fine-grained material is 20 microns. The floc discrete settling velocity is estimated to be 0.00031 m/sec based on Stokes law. Atterberg limits and specific gravities were not reported in the Portland Harbor RI/FS but were reported in the Terminal 4 Early Action Characterization Report for the Port of Portland (BBL September 17, 2004). The surficial sediments at the Port of Portland appear to be very similar, being organic silts with a dry bulk density of 800 kg/cu meters. These sediments have an average liquid limit of 90 percent and an average plastic limit of 35 percent. The specific gravity of the solids is about 2.65.

4. **Dredge Operations Data.** Dredging is primarily accomplished by mechanical clamshell dredges of sizes varying from 15 cu yd to 26 cu yd, with a 20 cu yd open bucket being most typical (personal communication with Mr. James Crain, CENWP-EC-HY). Closed buckets are also available but the 20 cu yd open bucket is selected for modeling as a conservative scenario. The cycle time is assumed to be 60 seconds and the buckets are assumed to be full, yielding a production rate of 918 cu yd per hour. This is a very high production rate that is being used to be conservative for modeling. A more typical production might have a cycle time of 75 to 90 seconds and the bucket would be only 80 to 90 percent full, yielding a typical production of about 750 cu yd per hour. In addition, some buckets would be lost due to debris limiting closure of the bucket. For this analysis, it is assumed that 5 percent of the buckets would be lost. The sediment was assumed to be moderately sticky and erosive, which would yield above average conditions for resuspension losses. Resuspension losses are estimated to be about 1 percent based on the description of the sediment and dredging operations (Hayes et al. 2007, Hayes and Wu 2001).

5. **Sediment Contaminant Data.** The chemical sediment characteristics are described in Portland Harbor RI/FS, Comprehensive Round 2 Site Characterization Summary and Data Gaps Analysis Report (2007). The contamination varies in a somewhat log normal distribution typical of sites with discrete sources. As such, the mean contaminant concentration is larger than the median concentration and appears to near the 70th to 75th percentile concentration. Therefore, the mean sediment concentration provides a reasonable maximum concentration for use in a conservative modeling scenario. The contaminant concentrations in the federal navigation channel are expected to be considerably lower than the sediments described in the Portland Harbor RI/FS report; therefore, a range of lower sediment contaminant concentrations are also evaluated in this mixing zone analysis. The sediments have a TOC concentration of 1.8 percent and a pH of about 6.9. This TOC concentration is somewhat low for organic silts, which provides for conservation predictions of equilibrium partitioning coefficients for the contaminants of concern (CoCs). The main CoCs are PCBs, DDT, PAHs, and TBT. The contaminant concentrations, partitioning coefficients, and screening criteria are given in Table 1.

6. **DREDGE Modeling Results.** The DREDGE model assumes that the solids losses are steady, continuous and uniform throughout the depth of the water column and is represented as a non-moving, vertical line source in a uniform, constant velocity field. The DREDGE model disperses the solids from the centerline of the source by Gaussian diffusion while the solids are

settling. The total concentration of contaminants at a location is equal to product of the TSS concentration and the bulk sediment concentration. The dissolved concentration is equal to the total contaminant concentration multiplied by the fraction dissolved computed as a function of the equilibrium partitioning coefficient and the TSS concentration in kg/L as follows:

$$Fd = 1 / [1 + (Kd * TSS)]$$

The dissolved concentration is conservatively estimated by this method because equilibrium partitioning will take hours or days to be achieved while the time needed to disperse ranges from minutes to a few hours. The results of the mixing zone requirements are given in Table 2.

7. **POC.** If you have any questions regarding my computations, please contact me at 601 634-3709 or Paul.R.Schroeder@erdc.usace.army.mil.

Table 1. Sediment Contaminant Properties and Water Quality Criteria

Contaminant	Range of Sediment Conc (mg/kg)	log Koc (L/kg)	Kd (L/kg)	Freshwater Chronic WQC for Screening* (ug/L)
PCBs	0.06 to 0.30	5.49	5562.5	0.014
DDx**	0.0069 to 0.10	5.18	2724.4	0.001
High M.W. PAHs	1 to 24	4.94	1567.7	0.2***
TBT	0.075 to 2	2.90	14.3	0.072
TEQ	0.0003	6.30	35914.7	0.00001
Aldrin	0.006	4.69	881.6	1.3****
Phenanthrene	5.0	4.12	237.3	6.3
Benzo(a)anthracene	0.25 to 2.0	4.63	767.8	0.027
Pthalates	0.02 to 2.0	5.22	2987.3	3

* from UTM Tier II Screening Spreadsheet (Schroeder et al. 2007)
** approximately 60 percent DDT, 30 percent DDE and 10 percent DDD
*** estimate
**** acute WQC (no chronic WQC available)

Table 2. Mixing Zone Requirements

Contaminant	Sediment Conc (mg/kg)	TSS Conc (mg/L)	Mixing Zone Length (meters)	Mixing Zone Width (meters)
PCBs	0.06	>1000	0	0
	0.12	330	1	1
	0.2	115	4	4
	0.3	63	10	8
DDx	0.0069	240	1	1
	0.02	58	10	8
	0.05	21	75	23
	0.1	10	300	47
High M.W. PAHs	1	292	1	1
	5	43	19	11
	15	14	175	36
	24	8.5	400	56
TBT	0.075	973	1	1
	0.15	483	1	1
	1	72	7	7
	2	36	30	10

Table 2. Mixing Zone Requirements				
Contaminant	Sediment Conc (mg/kg)	TSS Conc (mg/L)	Mixing Zone Length (meters)	Mixing Zone Width (meters)
TEQ	0.00001	>1000	0	0
Aldrin	1.3	>1000	0	0
Phenanthrene	6.3	>1000	0	0
Benzo(a)anthracene	0.25 0.5 1 2	118 56 28 14	3 11 45 200	4 9 16 36
Pthalates	2	>1000	0	0
TSS		5 10 15 20 30 50	14 38 81 145 310 1000	10 17 25 32 46 90

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