6 EFFECTS ANALYSIS

Section 6 uses the conceptual model, which is described in Section 5, to evaluate potential effects from the proposed Project. Focusing the effects analysis on the changes in ecosystem indicators of function helps to clarify how the proposed Project may influence listed salmonid production, successful ocean entry, and return migration. It also clarifies influences on critical habitats and the related processes where small, indirect changes may influence ecosystem functions in the long term.

Section 6.1 is an analysis of how the proposed project activities may have the potential to change the 38 ecosystem indicators that are parts of the conceptual model. It is only intended to identify potential changes to each indicator as a first step in the ultimate analysis of potential effects on listed species. The analysis is specific to effects that might occur to the indicator that is addressed and, as such, it is not intended to address potential effects to other related indicators. The analysis in Section 6.1 for each indicator builds upon all previous related indicator analyses. Therefore, it is important to read all of Section 6.1 to fully understand the analysis. The analysis addresses all direct and indirect effects to the indicator, as well as potential effects from interrelated and interdependent activities. Changes to an ecosystem indicator that are identified in Section 6.1 are carried into Section 6.2 for further pathway analysis. These indicator changes will be evaluated to determine how the Project affects ecosystem pathways identified in the conceptual model.

Any changes to the pathways that are identified in Section 6.2 are also carried forward into Section 6.3, which focuses on whether the identified impacts to the pathways will affect salmonids. Accordingly, Section 6.3 provides the actual determination of potential project effects. This section also includes a discussion of short-term and long-term effects. Short-term effects are defined as those that are identifiable now; long-term effects are those that are not identifiable now but may occur over the 50-year life of the Project. Beginning 5 years after construction, the dredging and disposal plan consultation will be reviewed by both the Corps and the Services at 5-year intervals. Section 6.4 presents information about activities not included in this BA: development of additional ports or port facilities and the Willamette River.

6.1 Project Effects on Indicators

This section of the BA is an evaluation of the potential effects of the proposed action on the 38 individual indicators identified in the conceptual model for the lower Columbia River (see Section 5 and Appendix E for details of the conceptual model). The analysis identifies whether there is potentially an effect and, if so, quantifies, as much as possible, the potential effect. If quantification is not possible, an estimate of the effect in nonquantitative terms is provided. The tools used for these analyses also include two numerical models (Appendices G and H) that predict project-influenced changes in depth, velocity, and salinity, and deliberations by the Biological Review Team (BRT), an interagency team of specialists who reviewed the Project's effects.

6.1.1 Suspended Sediment

The Project is not expected to cause changes to sediment supply or river hydraulics that would alter the rates of suspended sediment transport. The Columbia River bed consists of alluvial sand deposits that vary in thickness from 400 feet in the estuary to 100 feet at Vancouver (Gates, 1994). The dredging would generally remove 3 feet or less of that riverbed material from approximately 46 percent of the 600-foot-wide navigation channel. The hydraulic effects of dredging 3 feet deeper are very small (see Section 6.1.7, Bathymetry). Given the consistency in suspended sediment measured at different times and locations (see Section 2.3.1.1, Suspended Sediment), those small hydraulic changes are not likely to affect suspended sediment transport rates. Therefore, the volume and rate of suspended sediment transport in the Columbia River will not be changed by the Project.

Some temporary increases to suspended sediment concentrations are expected to occur during construction and maintenance dredging activities, as the result of both dredging and the disposal of dredged materials. These dredging and disposal activities will occur in both estuarine and riverine environments. Disposal will occur also in the open ocean, beyond the river mouth. There are no anticipated actions that would cause effects to this indicator in the area above Vancouver.

During the course of the consultation process, there was consideration of whether changes to the channel depth would alter ship wakes and cause associated increases to suspended sediment. The discussion in this section indicates that no alteration of current ship wake patterns will occur.

6.1.1.1 Suspended Sediment Caused by Dredging Activities

The channel deepening project will require 18 to 19 mcy of construction dredging and 90 mcy of maintenance dredging (12 mcy above and beyond the 78 mcy required to maintain the present 40-foot channel) during the first 20 years of the project (Corps, 1999a). For the long-term analysis, it has been assumed that dredging volumes for years 21 through 50 would remain constant at 3 mcy per year. The action of dredging that material will resuspend sediment and cause an increase in suspended sediment concentrations. Because most of the resuspended sediment is expected to be sand, it is expected to settle rapidly.

There are three types of dredges likely to be used on this project: pipeline, hopper, and mechanical. Pipeline and hopper dredges are expected to do the majority of the dredging, with a mechanical dredge being used only in the rock areas during construction. Each dredge has specific actions that can cause resuspension of sediment. A pipeline dredge would resuspend material at the river bottom, around its cutterhead. A hopper dredge would resuspend sediment at the bottom, around the draghead, and also at the surface if there is overflow water discharged from the hopper. A mechanical dredge would resuspend sediment at the bottom, where the bucket disturbs the riverbed, through the water column as the bucket is raised, and from the barge if there is overflow water.

A single pipeline dredge operating at 20,000 cubic yards per day in the Columbia River would potentially resuspend between 1 and 150 cubic yards per day (1.6 to 205 tons per day) of sediment, which is mainly (99 percent) sand (Eriksen, SEI Presentation, 2001). Because this resuspension will occur very near the bottom, the sand will redeposit very quickly. The fall velocities for Columbia River sands are in the range of 1 to 2 centimeters per second, so sand resuspended 1 meter off the bottom would redeposit in approximately 1 to 2 minutes. Because the riverbed sediment in the navigation channel is generally (99 percent) sand, the downstream release of sediment should be very small (less than 1 percent fine components released). Even under low flow conditions of only 100,000 cfs, the downstream increase in suspended sediment from the less than 1 percent fine components (silt, clay, organics) could range from near zero mg/L to less than 1 mg/L. Given that the LC_{50} for salmonids is 1.2 g/L of suspended sediment (see Section 4.1.1) and the amount identified here is three orders of magnitude less than that level, this effect is expected to be insignificant.

A hopper dredge operating at 20,000 cubic yards per day in the Columbia River has been estimated to resuspend 90 cubic yards per day (120 tons per day) at the draghead (Eriksen, SEI Presentation, 2001). This sediment would behave the same as described above for a pipeline dredge. The sand would redeposit in approximately 1 to 2 minutes and a very small amount of fine sediment would be released downstream. The hopper dredge would also release sediment with its overflow water from the hopper. This release would tend to be composed of silt and clay that can remain in suspension longer than sand.

The upper limit of this release would therefore be the volume of fine sediments in the dredging volume (i.e., less than 200 cubic yards per day [less than 1 percent of 20,000 cubic yards per day]). The total downstream increase in suspended sediment could approach 1 mg/L at a river discharge of 100,000 cfs, composed mostly of fine sediment discharged at the surface.

A mechanical dredge has a greater potential for resuspending sediment than do pipeline or hopper dredges operating in similar sediments (WES, 1999). For this project, however, the mechanical dredges would probably only be used in the rock areas at Warrior Rock and Longview. Those areas have a combined volume of approximately 300,000 cubic yards. Test pit observations indicate that fine sediments make up only a small portion of the total rock volume, suggesting that the release of sediments would be correspondingly small, but larger than for either pipeline or hopper dredging techniques.

Riverine Reach

Construction and maintenance dredging are expected to occur throughout this reach. During the 2-year construction period, pipeline dredges are expected to remove 18 mcy (3 mcy of operations and maintenance [O&M] material related to the 40-foot channel, 12 mcy of new 43-foot channel work, and 3 mcy of O&M material related to the 43-foot channel). After construction, the maintenance volumes in this reach are expected to be around 5 to 7 mcy per year and then steadily decline to 1 to 2 mcy per year in 20 years as the river reaches equilibrium with the deeper navigation channel. Pipeline dredges are expected to do most of the maintenance dredging. Hopper dredges may be used occasionally during construction and maintenance to remove small amounts of material.

Based on the above information on sediment resuspension from pipeline and hopper dredges, the increase in suspended sediment caused by a single pipeline dredge would range between 1 cubic yard per day and 150 cubic yards per day and a hopper dredge could produce up to 200 cubic yards per day. Therefore, during construction when two pipeline dredges would be working in this reach, there would be an increase in suspended sediment of 2 cubic yards per day to 300 cubic yards per day. Those volumes would convert to suspended sediment concentration increases of zero mg/L to 1 mg/L at a river discharge of 100,000 cfs and zero mg/L to 0.6 mg/L at 200,000 cfs. Because the dredged sediment is 99 percent sand, the downstream concentration increases are very likely to be near the lower end of those ranges. A third dredge, either a hopper or pipeline, might be used for short periods during the construction period to do construction or maintenance work. When operating, the third dredge would generate an additional increase in suspended sediment of less than 1 mg/L. As discussed in Section 2, the background suspended sediment concentrations at 100,000 and 200,000 cfs are less than 10 mg/L (2,000 cubic yards per day) and around 20 mg/L (8,000 cubic yards per day), respectively. The combined background and project-related suspended sediment concentrations are well below known salmonid impact levels.

A pipeline dredge will generally do maintenance dredging in this reach, with some work by hopper dredges. Generally, only one dredge would be operating in this reach at any time, but occasionally a hopper dredge may also be working at the same time. The suspended sediment increases during maintenance dredging would range from near zero mg/L to slightly more than 1 mg/L for a river discharge of 100,000 cfs. The maintenance impacts would ordinarily occur from May through September.

Somewhat higher suspended sediment concentration increases than those discussed above may occur when vessel berths at ports along the Columbia River are dredged to accommodate deeper-draft vessels. The material in these berths and slips may not be as sandy as those in the main channel; there may be more silts and clays. Impacts from suspended sediments resulting from berth deepening would be short term. The volumes to be removed are relatively small, as listed below:

- Terminal 6 Berths 603, 604, and 605 at Port of Portland: 24,500 cubic yards

- U.S. Gypsum at St. Helens: 12,500 to 14,000 cubic yards
- United Harvest Berth at Port of Kalama: 250,000 cubic yards

Estuary

Suspended sediment concentrations in the estuary will be influenced by construction and maintenance dredging in the estuary and upstream riverine reach. During the 2-year construction period, hopper dredges are expected to remove approximately 11 mcy (3 mcy of O&M material related to the 40-foot channel, 6 mcy of new 43-foot channel work, and 2 mcy of O&M material related to the 43-foot channel) from the estuary. After construction, the maintenance volumes in this reach are expected to be around 2 to 4 mcy per year and then steadily decline to 1 to 2 mcy per year in 20 years as the river reaches equilibrium with the deeper navigation channel. Pipeline and hopper dredges are expected to do the maintenance dredging.

During construction when two hopper dredges would be working in this reach, there would be an increase in suspended sediment of less than 400 cubic yards per day. The resuspended sediment from hopper dredge overflow water would be composed mostly of fine sediment. That volume would convert to suspended sediment concentration increases of less than 2 mg/L at a river discharge of 100,000 cfs and less than 1 mg/L at 200,000 cfs. A third dredge, either a hopper or pipeline, might be used for short periods during the construction period to do construction or maintenance work. When operating, the third dredge would generate an additional increase in suspended sediment of less than 1 mg/L. During construction, the estuarine increases in suspended sediment would be in addition to the increased suspended sediment caused by dredging in the riverine reach.

As discussed in Section 2, the background suspended sediment concentrations in the estuary vary with time and space. The inflowing suspended sediment from the riverine reach is distributed throughout the estuary, where local erosion and deposition and mixing with ocean waters can greatly alter the concentrations. A fine-grained sediment particle may remain in suspension within the estuary for up to 4 months, depending on flow conditions.

During maintenance operations, increased suspended sediment could be caused by dredging in either the estuary or upstream riverine reaches. Hopper dredges could work anywhere within the estuary or river, but pipeline dredges will generally be limited to areas upstream of Tongue Point (RM 18). Typically, one or two dredges could be working in the estuary or river at any time during the May through September maintenance season. However, three dredges may occasionally do maintenance work simultaneously. The increases in suspended sediment caused by maintenance dredging will depend on the number and type of dredges working at any one time, but would generally be limited to less than 2 mg/L at 100,000 cfs. The maintenance impacts would ordinarily occur from May through September.

River Mouth

No dredging activities associated with the Project would occur within the river mouth reach; however, there would be increases in suspended sediments caused by the upstream dredging. The increases for both construction and maintenance dredging would be the same as those described for the estuary.

The MCR Project is a separately authorized project. Maintenance dredging at the MCR is not part of this BA and is covered by a separate consultation.

6.1.1.2 Suspended Sediment Caused by Disposal Activities

Material dredged from the existing navigation channel is currently placed in a combination of shoreline, upland, and in-water (or flowlane) disposal sites (Corps, 1999a). Disposal from construction and maintenance of the proposed action is planned for 29 upland sites, a gravel pit, an in-water mitigation site, three shoreline disposal sites (for beach nourishment), in-water (flowlane) (generally in 50- to 65-foot depths throughout the Project), and in the ocean at the deep water site.

At upland disposal sites, dredge material will be placed in diked disposal areas that will contain the sands and the return water. Return water will be held in settling ponds until it meets applicable Oregon or Washington water quality standards at an appropriate point of compliance after dilution for suspended sediment.

Shoreline disposal is an unconfined disposal method used by pipeline dredges. The pipeline discharges the sediment/water slurry onto the beach, and the sand settles out of the slurry as it flows toward the shoreline. The beach is built out into the river and the return water flows freely into the river. There is an increase in suspended sediment adjacent to the beach that then dissipates as it moves downstream. Suspended sediment concentrations in these plumes have not been measured. However, surface measurements taken by the Corps 50 feet offshore from a shoreline disposal operation found increases of 5 to 15 NTUs. Based on the relationship between NTUs and silt/clay concentrations observed in the Columbia River, that would equate to increases of approximately 10 to 30 mg/L (Eriksen, SEI Presentation, 2001). The shoreline plume will mix with the river water as it moves downstream, and the suspended sediment concentrations will diminish to near background levels. This is not expected to create a potential impact because this activity will occur at shoreline sites, which, as explained previously (see Section 3.2.7), are highly disturbed, erosive areas with low or no benthic populations. Consequently, salmonids do not feed or rear in these areas. In Carlson (2001), juvenile salmonids were found to migrate rapidly past shoreline disposal areas, likely because of disturbance in the area and lack of suitable habitat.

Flowlane disposal is most commonly done by hopper dredges, but may occasionally be done by a pipeline dredge. The sediment from a hopper dredge would be released over a period of approximately 5 minutes at a depth of 20 to 30 feet. The sediment concentration in the plume would depend on river currents, dredge speed, and the amount of fines (silt and clay) in the disposal material, as the sand will fall quickly to the bottom. In the Columbia River the dredged sediment is less than 1 percent fines, but that would be further reduced by the fines discharged by the overflow water during dredging. A single disposal from a 3000-cubic-yard hopper dredge would therefore release less than 30 cubic yards of fine suspended sediment. Measurements taken by the Corps during hopper disposal operation found increases of zero to 10 NTUs. Based on the relationship between NTUs and silt/clay concentrations observed in the Columbia River, that would equate to increases of approximately zero to 20 mg/L (Eriksen, SEI Presentation, 2001). The plume will begin in the bottom 20 to 30 feet of the water column and will mix with the river water as it moves downstream. The suspended sediment concentrations will diminish to near background levels as the plume moves downstream.

During flowlane disposal, the sediment from a pipeline dredge would be released at a depth of 20 feet or more. Because the dredged material is discharged in a slurry, the sand will fall to the riverbed in about 5 minutes, while nearly all the fines can be expected to be released into the water column. In the Columbia River the maximum fines release for a pipeline dredging operating at 20,000 cubic yards per day would be less than 200 cubic yards per day. As described previously, some of the fines would be released during dredging, but most would be released during the flowlane disposal operation. The total downstream increase in suspended sediment could approach 1 mg/L at a river discharge of 100,000 cfs. Given that the LC_{50} to salmonids is 1.2 g/L of suspended sediment (see Section 4.1.1) and the amount identified here for both hopper and pipeline dredges is approximately three orders of magnitude less than that level, this effect is expected to be insignificant.

Ocean disposal is done by hopper dredges. The sediment from a hopper dredge would be released at a depth of 20 to 30 feet below the surface and the sediment would fall to the ocean bottom in a plume. Sediment concentrations in the plume would depend on the fall velocities of the material being disposed, the depth of the disposal site, the ocean currents, and the speed of the dredge during disposal. Most of the sand will settle to the bottom, while the fines may remain in suspension for some time. A single ocean disposal from a 4,000-cubic-yard hopper dredge would therefore release a sediment plume containing less than 40 cubic yards of fine suspended sediment.

Riverine Reach

Disposal activities will occur in many areas throughout the riverine reach. Most of the disposal for both construction and maintenance will be upland (see Appendix C), but some flowlane disposal is likely and shoreline disposal will occur at Sand Island (O-86.2). The suspended sediment increases in this reach will be small because the vast majority of the disposal will be at upland sites where settling ponds will reduce suspended sediments in return flows. The flowlane disposal is expected to be about 0.5 mcy during construction and 0.5 to 1.0 mcy per year over the first 20 years of maintenance. Shoreline disposal at Sand Island is expected to be required at 3- to 4-year intervals to replace eroded beach sand. The total suspended sediment released by dredging and disposal during flowlane and shoreline disposal operations would be limited to the fines content of the sediments. As a result, there could be a suspended sediment increase of less than 200 cubic yards per day, resulting in an average downstream concentration increase of less than 1 mg/L at 100,000 cfs.

Estuary

During construction, the disposal in this reach will be about 2 mcy of flowlane disposal around RM 30 to 40 and, as described in Section 8, construction material will be used to form the Lois Island Embayment Restoration. This will consist of a two-step process that will require materials to be dredged from the navigation channel with a hopper dredge, then temporarily deposited in the Tongue Point turning basin. From this point, materials would then be moved to the Lois Island Embayment using a pipeline dredge. Two dredges, a hopper and a pipeline dredge, might be used simultaneously to do this work, so the maximum suspended sediment increase from dredging and disposal would be less than 400 cubic yards per day. That rate would convert to average downstream suspended sediment concentration increases of less than 2 mg/L at a river discharge of 100,000 cfs and less than 1 mg/L at 200,000 cfs. However, there would be plumes with higher concentrations that would move with the currents. The concentrations in these plumes would not exceed the observed increases from hopper discharge of zero to 10 NTUs (zero to 20 mg/L). Again, given that the LC_{50} to salmonids is 1.2 g/L of suspended sediment (see Section 4.1.1) and the amount identified here is two to three orders of magnitude less than that level, this effect is expected to be insignificant.

Throughout the first 20 years of channel maintenance, flowlane disposal will occur in and adjacent to the navigation channel throughout the estuary. The annual flowlane disposal volumes are expected to begin at about 1 mcy per year and decline to about 0.7 mcy per year in 20 years. Upland disposal will occur at Welsh, Pillar Rock, and Rice Islands. Shoreline disposal will occur at Skamokawa and Miller Sands. The increases in suspended sediment caused by upland and shoreline disposal will be similar to those described above for the riverine reach.

The inflowing suspended sediment from the riverine reach, including any increases from dredging and disposal, would be distributed throughout the estuary. Because of the location of the flowlane disposal in the estuary, most of the sediment released will be carried to the open portion of the estuary, downstream of RM 23. Once flow enters the estuary, local erosion and deposition processes, and mixing with ocean waters, can greatly alter the suspended sediment concentrations.

River Mouth

This reach will be impacted by disposal at the ocean site and by the increases in suspended sediments caused by the upstream dredging and disposal. The increases from upstream for both construction and maintenance dredging would be the same as those described for the estuary.

Ocean disposal, using a 4,000-cubic-yard hopper dredge, will result in the release of discrete sediment plumes containing less than 40 cubic yards of fine suspended sediment. The individual plumes will drift with the ocean currents and eventually disperse. The rate at which the plumes disperse will depend on several factors, including river discharge, tide, ocean currents, ocean upwelling, wave size and direction, winds, and disposal location.

Adult and juvenile salmonids can occur in the vicinity of the ocean disposal site during their ocean life-history stage. Both adults and juveniles are feeding in this area, primarily on pelagic organisms. Dredged material disposed of in the ocean will result in only a short-term impact to the water column over the site. It is unlikely that this would significantly affect feeding behavior and may, in fact, provide additional food in the disposal material.

6.1.1.3 Suspended Sediment Caused by Ship Wakes

Ship wakes breaking on shore can erode sediment and then suspend the eroded material. Larger waves contain more energy and have greater capability to mobilize sediment. Accordingly, during the consultation process, there has been analysis of whether the proposed activities would lead to more frequent or larger ship wakes.

While the proposed channel improvements would increase the efficiency of river commerce, it is not anticipated to increase the volume of river traffic. Accordingly, there is no expectation of more frequent ship wake instances occurring as a result of the proposed improvements.

In addition, a recent analysis of technical studies related to ship wakes indicates that little if any change is expected (Hermans, SEI Presentation, 2001) as a result of channel deepening activity. Hermans analyzed several mechanisms by which ships generate waves. The analysis found that for deep-draft vessels the most important wave mechanism in the Columbia River would be the primary or “suction” wave generation. This mechanism depends on the "blockage" ratio, which is the ratio of the cross-sectional area of the ship to that of the channel (Figure 6-1). Given the proposed increase in channel depth and the expected increase in vessel draft, the ratio changes very little. The blockage ratio of a 43-foot draft vessel in a 43-foot channel is only 1 to 5 percent higher than that of a 40-foot draft vessel in a 40-foot channel. However, for the much more numerous smaller ships that would not increase their draft, there would be a slight decrease (in the range of 1 to 5 percent) in the blockage ratio with the deeper channel. Thus, while 43-foot draft ships may generate slightly larger wakes than occur now, this would be offset by most ships producing slightly smaller wakes. As a result, the overall changes in wave size caused by the deeper channel are negligible. Application of equations presented in Weggel and Sorensen (1986) to deeper draft vessels in a deeper channel support this conclusion.

Figure 6-1: Cross-Sectional Representation of Vessels in 40-Foot and 43-Foot Channels

Riverine Reach

Deep-draft ship traffic in this reach averages around five to six transits per day, including both inbound and outbound ships. Most ships currently transiting the Columbia River have sailing drafts of less than 30 feet, with less than 10 percent of the outbound ships having drafts of 40 feet or more (Corps, 1999a). These Panamax grain vessels and Panamax and larger container vessels carry between 50 percent and more of the cargo tonnage leaving the Columbia River in a 43-foot channel (Daly, 2001). Abbe (1990) estimated that ship wakes accounted for between 4 and 24 percent of the observed erosion of sand from a shoreline disposal site on Puget Island. Given the location, beach conditions, and river hydraulics of that site, that estimate should be applicable to all the sandy beaches on the river. The hydraulic effects from the ships also disturb the bottom sediments and create a small but undetermined amount of suspended sediment and related turbidity.

In the future, the actual number of transits will depend on trade volumes but are expected to be similar with either a 40-foot or 43-foot channel. As explained above, the resulting effects of a 43-foot channel on ship wakes would be small and could be either positive or negative, depending on vessel draft. Because of this, shoreline erosion caused by ship wakes is not expected to change. The changes in the hydraulic effects on the river bottom have not been calculated, but should follow the same trend as ship wakes. Therefore, because most ships will have more underkeel clearance (distance between the ship's hull and the riverbed), sediment resuspension and turbidity could be slightly less in a 43-foot channel.

Estuary

The vessel traffic and ship draft patterns described for the river reach will also apply to the estuary. Therefore, there are no anticipated changes in estuarine shoreline erosion or suspended sediment related to ship wakes or hydrodynamics.

It should also be noted that under existing or future conditions, the deepest draft vessels, those with more than a 37- to 38-foot draft, can be expected to transit the estuary at or just prior to high tide. This timing suggests that much of the silt or clay resuspended by a vessel downstream of Tongue Point (a reach that includes most of the ETM zone) would be discharged to the ocean during the ebb tide flow.

River Mouth

See Estuary, above.

6.1.1.4 Conclusion

Settling of suspended sediment caused by dredging, disposal, and ship wakes is expected to be rapid. Based on the data indicating that less than 1 percent of the dredged material is fine enough to remain in suspension following disposal, the Corps estimates that disposal of construction-related dredging will contribute up to 180,000 cubic yards of suspended sediments over the 2-year construction period. Background suspended sediment loads for the same 2-year period have been estimated at 4 mcy. This is a maximum increase of 4.5 percent in the suspended sediment load and generally equates to less than 1 mg/L increase in suspended sediment concentrations.

Riverine Reach

In riverine areas where neither dredging nor disposal is occurring, there should be no observable increase in suspended sediment concentration. In areas where dredging and disposal activities occur, there may be noticeable, short-term increases in suspended sediment near hopper dredges and shoreline disposal operations. Dredging operations are likely to cause downstream suspended sediment increases of zero to 2 mg/L, depending on the number and type of dredges operating.

There will be no change to suspended sediment from ship wakes.

Estuary

See Riverine Reach, above.

River Mouth

Upstream dredging operations are likely to cause suspended sediment increases of zero to 2 mg/L, depending on the number and type of dredges operating. Disposal of sediments will occur at open-water ocean sites beyond the river mouth. Ocean disposal will result in the release of discrete sediment plumes of fine suspended sediment that will slowly disperse. There should be no change to suspended sediment from ship wakes.

6.1.2 Bedload

This section of the BA addresses bedload aspects related to side-slope adjustment as well as volume and rate of bedload transport. This analysis of side-slope adjustment assumes that the Project is not expected to alter volume or rate of bedload transport.

6.1.2.1 Potential Reduction in Volume of Bedload Caused by Removal of Channel Materials

Sand from upstream areas is one of the sources of material for habitat-forming processes (accretion) in the estuary. This sand is important to the formation of tidal marsh and swamps and shallow water and flats habitat. An issue arose during the reconsultation process concerning the potential to reduce the quantity of bedload moving downstream to the estuary. This was based on the concern that removing sand from the upstream channel would cause a concomitant reduction in the amount of sand (habitat-forming material) that would reach the estuary.

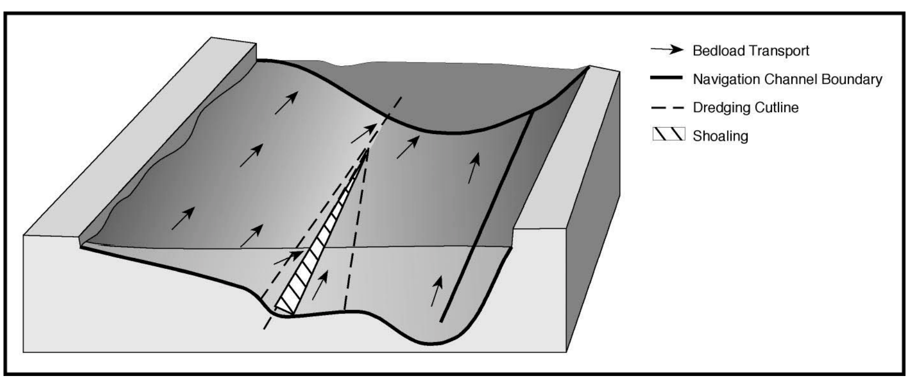

Figure 6-2: Relative Magnitude and Direction of Bedload Transport in a Typical Reach of the Columbia River

The amount of sand that reaches the estuary is based on the river's sediment transport potential and the available sediment supply. Sediment transport potential is a function of hydraulic parameters such as depth, velocity, slope, and discharge. The available sediment supply comes from upstream discharges, the riverbed and banks, and tributary inflows. As noted above, dams and flow controls have significantly changed flow and sediment transport (see Sections 2.3.1.1, Suspended Sediment and 2.3.1.2, Bedload).

The Project will have inconsequential effects on river hydraulics (see Section 6.1.7.4, Bathymetry – Conclusion). Therefore, the Project will not significantly alter the sediment transport potential. This finding is supported by the fact that sediment inflow to the dredging area from upstream of Vancouver (RM 106.5) is essentially the same as the sediment transport at RM 54, two reaches with markedly different hydraulic conditions. The river's transport potential is fully used before the Project area. Therefore, reducing the amount of sand in the Project area does not affect the amount of sediment transported to the estuary.

Of the three sediment sources, the sediment inflows from upstream and tributaries will not be altered; therefore, the amount of sand available for transport could only be affected by the project if it were to deplete the sand available in the riverbed and banks. The Columbia River bed consists of alluvial sand deposits that vary in thickness from 400 feet in the estuary to 100 feet at Vancouver (Gates, 1994). The volume of sand that will be dredged over the life of the project is a tiny fraction of the total volume of sand in the riverbed; thus, the project will not reduce the available sand supply in the riverbed.

6.1.2.2 Potential Effects to Salmonid Habitat Caused by Side-Slope Adjustment

Side-slope adjustment is a process that will occur after the channel is deepened. After the initial dredging to deepen the channel, the channel slopes will be steeper than can be maintained naturally. These slopes will go through a process of change that will result in a slope that can be naturally maintained at a new dynamic equilibrium.

Side-slope adjustment will not occur quickly. It will not result in slumping or caving in of the channel slopes. This natural process will take an estimated 5 to 10 years to reach the new dynamic equilibrium. Essentially what will happen is that the bedload that is moving downstream will change direction until the adjustment is complete. As described in Section 6.1.6, Accretion/Erosion, the volume and rate of the bedload movement is not expected to change. Only the direction of the sand particles will change as the bedload naturally moves downstream. Figure 6-2 illustrates the side-slope adjustment process. Without the creation of the steeper slopes, bedload would generally move in a downstream direction. After the channel is deepened, the sand particles (bedload) will shift direction along the face of the channel edge (cutline). Instead of moving generally downstream, gravity will cause it to move down the slope until a new dynamic equilibrium is reached. As noted above, this process of side-slope adjustment could continue for several years until the gravitational forces reach a new dynamic equilibrium.

Side-slope adjustment may cause lateral erosion toward the shoreline. Most of this side-slope adjustment will occur in deeper areas of the river (see Section 6.1.10, Water Column Habitat), but some shoreline areas might be affected. Natural shoreline areas of the Columbia River are composed of hard silt/clay or rocky material; they have been very stable over the past 100 years or so. Previous deepenings of the channel and maintenance dredging have not caused side-slope adjustments to the natural shoreline areas. Side-slope adjustments caused by the deeper channel will not occur in natural shoreline areas because they are stable (Corps, 1999a). This means that no tidal marsh and swamp habitat (see Section 6.1.8, Tidal Marsh and Swamp Habitat) would be affected by side-slope adjustments. Side-slope adjustments could cause shoreline erosion in areas with sandy beaches. These beaches are prone to side-slope adjustment erosion because the noncohesive sands are easily eroded and do not have stabilizing vegetation. Because there are not any naturally occurring sandy beaches in the Columbia River, these are areas that have been created in the past by disposal of dredged material. This type of habitat is included in the category described in Section 6.1.9 (Shallow Water and Flats Habitat). Specific sites where side-slope adjustment might occur are limited and are identified below for each project reach.

Side-slope adjustment could cause the shoreline of sandy beaches to move laterally or shoreward. Given the range of sandy beach slopes found by Abbe (1990) of 0.10 to 0.02 foot per foot, a 1-foot change in riverbed elevation at the shoreline could result in 10 to 50 feet of lateral shoreline erosion on shoreline disposal sites. Over time, this shallow water and flats habitat will tend to move shoreward into former areas of created beach that have slowly eroded. This gradual erosion allows for new shallow water and flats habitat to establish. As discussed above, erosion would occur over a number of years; therefore, the quantity of shallow water and flats habitat would be expected to remain constant over time. This habitat type would migrate the eroded areas shoreward, but the gross amount of area that is 6 feet or shallower would remain the same. Likewise, the rate of bedload movement would be the same, only in a different direction, so it would not be expected that the quality of aquatic habitat would change. See Section 6.1.9, Sahllow Water and Flats Habitat, for a discussion of the effects of this erosion.

Riverine Reach

Side-slope adjustments that would affect shallow water and flats habitat might occur in the riverine reach at five locations – RM 99, 86, 75, 72, and 46 through 42. These are all past shoreline disposal sites, and only the RM 86.2 site is proposed for use in this reach due to the proximity of the dredging needed in this section of the river. These sites do not include tidal marsh and swamp habitat. Side-slope adjustment could cause 10 to 50 feet of lateral shoreline erosion of sandy beaches in each of those areas; however, this is not expected to reduce salmonid habitat (see Section 6.1.9, Shallow Water and Flats Habitat).

Estuary

The reach at RM 12 has undergone significant side-slope degradation, but it is not an adjustment related to the channel depth. Side-slope adjustments that would affect shallow water and flats habitat might occur at RM 22.5, Miller Sands. This site is proposed for use throughout the Project life. Miller Sands forms the southern shoreline in that area, and the proposed beach nourishment disposal is expected to limit lateral erosion. This area is currently eroding at a rapid pace. Side-slope adjustment is not expected to increase this rate of erosion; consequently, no project impact is expected.

River Mouth

Under this proposed action, no dredging will occur in this reach; therefore, side-slope adjustment caused by the Project will not occur here.

6.1.2.3 Conclusion

The proposed Project will not affect transport potential because the amount of material to be removed from the system is not the limiting factor for bedload movement; flow available to move the material is the limiting factor and the Project will not affect flow. The Project will not significantly reduce the sand supply. The proposed Project will result in some side-slope adjustment as a result of altered bedload transport direction within the action area. This process will not affect water column or tidal marsh and swamp habitats. The side-slope adjustment process will take 5 to 10 years, and over that time shallow water and flats habitat at six shoreline disposal sites will tend to migrate laterally. All of these shoreline sites have been used in the past due to the proximity of the dredging. Two of the six shoreline sites, at RM 86.2 and RM 22.5, will be used throughout the project life.

Because the bedload transport rate during side-slope adjustment is the same rate at which normal bedload transport would occur without the Project (just in a different direction), the quantity and quality of shallow water and flats habitat is expected to remain constant. The Corps is proposing to verify this conclusion through a monitoring survey of habitat conditions before, during, and after completion of the project (see Section 7).

Riverine Reach

The proposed Project could cause side-slope adjustment that might cause shallow water and flats habitat at five past beach nourishment sites to migrate laterally.

Estuary

The proposed Project could cause side-slope adjustment that might cause shallow water and flats habitat at RM 22.5 to migrate laterally.

River Mouth

The Project will not cause any side-slope adjustments in this reach.

6.1.3 Woody Debris

Woody debris is present in natural settings primarily within the forested wetlands portions of large rivers and estuaries such as the lower Columbia River. Here the debris provides potential refuge structures along side channel shorelines. During the consultation process, two potential means for affecting woody debris input to the system were identified: changing water levels and changing salinity.

6.1.3.1 Role of Woody Debris in the Ecosystem

Changes in water level that would either dry out or flood existing tidal marsh or swamp habitat could result in such habitat no longer providing appropriate conditions and being distant from aquatic habitat. This would likely require water level changes on the order of more than 19 inches to produce changes in the tidally influenced area.

In addition, substantial increases in salinity could result in the loss of trees providing woody debris. Although tidal marsh and swamp habitat tree species commonly tolerate moderate salinities, they do not survive in high salinities. Salinity increases of several parts per thousand or more would likely change the distribution and potentially the amount, of tidal marsh and swamp habitat contributing woody debris to the estuarine habitat. This would potentially result in a short-term increase in woody debris at the expense of a long-term decrease in woody debris.

Riverine Reach

The riverine reach is a freshwater system, and no changes resulting from the Project are anticipated to introduce salinity to this reach. In addition, the anticipated change in water elevation is expected to be less than an inch, well less than the 19 inches necessary to cause an impact. Accordingly, no change to woody debris input is anticipated as a result of the proposed Project.

Estuary

Projected project-related changes to salinity are anticipated to be much less than the several parts per thousand needed to affect tidal marsh and swamp habitat (see Section 6.1.5, Salinity). In addition, the anticipated change in water elevation is expected to be less than 1 inch (see Section 6.1.7, Bathymetry), much less than the 19 inches that would be necessary to cause an impact. Accordingly, no change to woody debris input is anticipated as a result of the proposed Project.

River Mouth

Not applicable.

6.1.3.2 Conclusion

Changes in water level and salinity estimated for the proposed action are not estimated to be great enough to cause changes in the distribution or abundance of woody debris.

6.1.4 Turbidity (as related to Habitat-Forming Processes)

This section addresses turbidity as it relates to habitat-forming processes (see Section 6.1.36, Turbidity). Turbidity is discussed within the Habitat-Forming Processes Pathway because the ability of light to penetrate the river affects the amount of plant growth that can occur. This is important for habitat development, particularly in the shallow water areas, because the plant growth adds stability and reduces the chance for erosion.

Some temporary and localized changes to river turbidity levels are anticipated to occur from the Project at the location of dredging and disposal of dredged materials. These turbidity increases are not expected to be appreciably different in scope than the temporary turbidity increases associated with annual maintenance dredging, which would occur even without the deepening project. In addition to the potential effects from dredging and disposal activities, consideration is given in the following text to whether changes in ship wakes will occur that would lead to increased turbidity levels.

6.1.4.1 Increase in Turbidity Caused by Dredging Activities

There are three types of dredges, pipeline, hopper and mechanical, that will be used for project construction and maintenance. Each dredge has a slightly different effect on suspended sediment, and consequently on turbidity levels. The resuspension of sediment by each type of dredge and within each reach is explained in Section 6.1.1.1, Suspended Sediment Caused by Dredging Activities. The potential effects on turbidity are described below for each river reach.

Riverine Reach

Turbidity increases would be highest at the dredging location, but would be subject to mixing and related dilution by dispersive processes as it moves downstream. During construction, when two dredges may be operating in this reach, the total downstream suspended sediment increases are in the ranges of zero to 1 mg/L at 100,000 cfs and zero to 0.6 mg/L at 200,000 cfs (see Section 6.1.1.1, Suspended Sediment Caused by Dredging Activities). Based on the relationship between suspended sediment and turbidity shown in Figure 6-3, the resulting downstream turbidity increases would be on the scale of zero to 0.5 NTU and zero to 0.3 NTU for 100,000 cfs and 200,000 cfs, respectively. These increases are comparable to the natural variations in turbidity. The turbidity increases are transitory, existing only during actual dredging operations. The turbidity increases during maintenance dredging would be equal or less than those described here for construction.

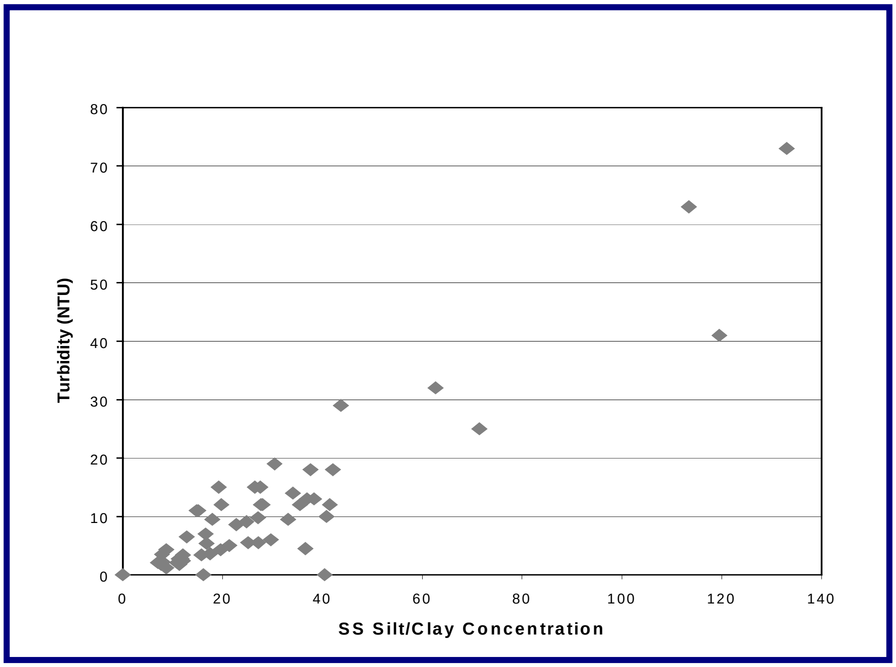

Figure 6-3: Relationship Between Turbidity and Suspended Silt and Clay in the Columbia River at Beaver, Oregon (RM 54)

Somewhat higher suspended sediment concentration increases (Section 6.1.1.1, Suspended Sediment Caused by Dredging Activities), and therefore turbidity increases, than those discussed above may occur if vessel berths at ports along the Columbia River are dredged to accommodate deeper-draft vessels. The material in these berths and slips may not be as sandy as that in the main channel; there may be more silts and clays. Any impacts from berth deepening would be short term, as the volume to be removed is relatively small.

Estuary

Construction and maintenance dredging in the estuary and the river upstream will influence turbidity in the estuary. As in the river, turbidity increases would be highest at the dredges and decrease as the plume moves downstream. Some turbidity measurements have been taken in the vicinity of an operating hopper dredge at RM 36. Those measurements found only 1 out of 22 readings above 10 NTUs.

During construction, two hopper dredges will be working in the estuary. After mixing, the combined turbidity increase from the two hopper dredges is expected to be less than 1 NTU. Most of this turbidity would be generated downstream of RM 25. The distribution within the estuary of the turbidity plume will depend on dredging location, river discharges, and ocean tides. Turbidity from upstream dredging would enter the estuary near RM 40 and be distributed throughout the estuary. The individual suspended particles causing increases in turbidity may remain in the estuary for up to 4 months. Local erosion and deposition, and mixing with ocean water, will continually change the turbidity levels. There is not likely to be any noticeable increase in turbidity in the ETM as a result of the dredging.

Turbidity increases from maintenance dredging will be similar to those during construction. The increase will depend on the number and location of dredges, but will generally be less than 1 NTU in the estuary.

River Mouth

No dredging activities associated with the Project will occur within the river mouth reach. The turbidity increases caused by upstream dredging will be discharged into the Columbia River plume.

6.1.4.2 Increase in Turbidity in Vicinity of Disposal Activities

As with the discussion of suspended sediments (see Section 6.1.1.2, Suspended Sediment Caused by Disposal Activities) caused by dredging activities, disposal activities at flowlane and ocean sites will temporarily increase turbidity when dredged material is released into the water column. Drainage water discharged from shoreline disposal sites will also contribute suspended sediments to the river causing localized turbidity increases at the disposal site outfalls.

Riverine Reach

Disposal activities will occur in many areas throughout the riverine reach. Most of the disposal will be upland, but some flowlane disposal is likely and shoreline disposal will occur at Sand Island. The turbidity increases will be the result of the suspended sediment increases described in Section 6.1.1.2, Suspended Sediment Caused by Disposal Activities. Return water from upland disposal sites will be held in settling ponds until it meets applicable Oregon or Washington water quality standards at an appropriate point of compliance after dilution for suspended sediment.

Shoreline disposal can generate elevated turbidity in the vicinity of the disposal site. The Corps measured turbidity near a shoreline disposal site at RM 24. Levels ranged from 9 to 20 NTUs in the disposal plume (within 50 feet of shore), compared to background measurements of 5 NTUs. At the mouth of the discharge pipe, turbidity reached 26 NTUs. These turbidity levels are substantially lower than levels of concern identified in Section 4.1.1. Dredging and shoreline disposal would generate a combined total of less than 1 NTU of additional turbidity, after mixing, and would only occur every 3 to 4 years at Sand Island.

Hopper dredging and flowlane disposal would create a fluctuating amount of turbidity increase due to the cycle of dredging, transport, and disposal. The turbidity increase from one hopper dredge would average less than 1 NTU, but levels could be higher in the disposal discharge plume and would be zero during transit periods (Eriksen, SEI Presentation, 2001).

Estuary

The turbidity increases in the estuary will be the result of the suspended sediment increases described in Section 6.1.1.2, Suspended Sediment Caused by Disposal Activities. There will be no upland or shoreline disposal in the estuary during construction.

The turbidity increases from upland disposal at Welsh, Pillar Rock, and Rice Islands will be very small because of the use of settling ponds at upland disposal sites during maintenance. Return water from upland disposal sites will be held in settling ponds until it meets applicable Oregon or Washington water quality standards at an appropriate point of compliance after dilution for suspended sediment.

Turbidity from shoreline disposal at Skamokawa and Miller Sands will be similar to that described for Sand Island. Shoreline disposal will only occur during maintenance dredging.

During construction, flowlane disposal would occur between RM 30 and 40. During maintenance dredging, flowlane disposal may occur anywhere along the channel in the estuary. Flowlane disposal will generate an average increase in turbidity of less than 1 NTU, but levels will vary as explained above. The location of flowlane disposal sites will cause most of the increased turbidity from those sources to be dispersed in the open portion of the estuary, downstream of RM 23.

Turbidity from the riverine reach could be distributed throughout the estuary, including the Cathlamet Bay area.

River Mouth

This reach will be affected by disposal at the ocean site and by increases in turbidity caused by the upstream dredging and disposal. The increases from upstream for both construction and maintenance dredging would be the same as those described for the estuary.

Ocean disposal will result in the release of discrete sediment plumes with an unknown level of turbidity. The individual plumes will drift with the ocean currents and eventually disperse. The rate at which the plumes disperse will depend on several factors, including river discharge, tide, ocean currents, ocean upwelling, wave size and direction, winds, and disposal location.

6.1.4.3 Ship Wakes

Riverine Reach

The potential change to ship wakes is not expected to be measurable; consequently, no resulting changes in suspended sediment are expected (see Section 6.1.1.3, Suspended Sediment Caused by Ship Wakes). In addition, no related change in turbidity is expected.

Estuary

There are no anticipated changes in estuarine shoreline erosion or suspended sediment related to ship wakes or hydrodynamics (see Section 6.1.1.3, Suspended Sediment Caused by Ship Wakes). Therefore, there would be no change in turbidity.

River Mouth

See Estuary, above.

6.1.4.4 Conclusion

Localized turbidity levels of 5 to 26 NTUs that might be caused by the proposed action are not likely to produce detectable effects on plant growth in the lower river. Not only is the amount of increase too low, but it will be localized to areas where dredging and disposal will occur, which does not include shallow water areas. In addition, the combined background and project-related turbidity concentrations are well below known salmonid impact levels. Turbidity as high as 400 NTUs is commonly found in river systems and estuaries where salmonids are produced (see Section 4.1.1).

There should be no change to turbidity from ship wakes.

Riverine Reach

In riverine areas where neither dredging nor disposal is occurring, there should be no observable increase in turbidity levels. In areas where dredging and disposal activities occur, there may be noticeable, short-term increases in turbidity near hopper dredges and shoreline disposal sites. Dredging operations (dredging and disposal combined) are likely to cause downstream turbidity increases of zero to 1 NTU, depending on the number and type of dredges operating.

Estuary

See Riverine Reach, above.

River Mouth

Upstream dredging and disposal operations will cause a turbidity increase of zero to 1 NTU, depending on the number and type of dredges operating. Ocean disposal will result in the release of discrete sediment (turbidity) plumes that will slowly disperse. There should be no change to turbidity from ship wakes.

6.1.5 Salinity

Salinity is an important indicator in assessing the successful adaptation and outmigration of juvenile salmonids in the lower Columbia River. The concentration of salinity in important habitat and rearing areas of the system and the longitudinal gradient of salinity between the freshwater and ocean environments that bound the estuary portion of the system are particularly important. The location of the ETM, which is an important location of nutrients in the system, is driven by tidal forcing processes that influence salinity intrusion. For these reasons, it is important to determine the extent to which channel deepening actions might change the salinity profile in the action area. This section describes the results of hydrodynamic/salinity models used to make this determination. See Appendices F and G for additional salinity modeling results.

6.1.5.1 Changes to Salinity Intrusion

Riverine Reach

Salinity intrusion does not extend upstream to RM 40, which is the division between the riverine reach and the estuarine reach. Consequently, salinity is not applicable in the riverine reach.

Estuary

The salinity profile in the estuary is governed by two opposing processes: freshwater outflow and ocean tidal inflow. The potential effect on salinity as a result of dredging actions taken to deepen the navigation channel will, therefore, come from alteration of the river/estuary cross-sectional area. The alteration of bathymetry through the dredging of the navigational channel in the estuary portion of the system (RM 3 to 40) is the area of concern with regard to potential effects on salinity gradients.

Two models have been applied to the system to assess the impact of the proposed channel deepening on salinity in the system: the Corps of Engineers – Waterways Experiment Station (WES) applied the RMA-10 model and OHSU/OGI applied the ELCIRC (Eulerian – Lagrangian CIRCulation) model as part of their CORIE system. A description of the models and presentation of all model results are provided in Appendices F and G.

Based on the WES RMA-10 modeling, the largest impacts on salinity profiles occur at the lowest river flow analyzed (70,000 cfs). For this base versus plan comparison, the model predicts that deepening the channel would increase salinity by 0.1 to 0.15 ppt in shallow areas of the estuary. In particular, this range of increase shows up in Cathlamet Bay and Grays Bay. Salinity increases in the range of 1.0 to 1.5 ppt are also predicted to occur at the bottom of the navigation channel in the vicinity of Tongue Point and back through the Miller Sands channel.

The OHSU/OGI application of ELCIRC for the base versus plan model comparison was conducted as an independent check on the WES RMA-10 modeling. In addition, OHSU/OGI used their results to determine if the plan would be expected to cause a significant change in habitat opportunity as defined by Bottom, et al. (2001) and the SEI workshop process. The low-flow results of the ELCIRC model are for a base versus plan comparison for what OHSU/OGI calls salinity "accumulation" (depth- and time-averaged salinity over the course of the weeklong run). This confirms that the largest salinity changes would occur in the navigation channel and that salinity changes in Cathlamet Bay and Grays Bay will be small (less than 0.25 ppt). Most changes in the navigation channel were similar to those predicted by RMA-10 (about 1 ppt), but those around RM 8 to 10 were somewhat higher (in the range of 3 to 5 ppt). The ELCIRC model also predicted a slight (less than 1 ppt) decrease in salinity in the shallow water areas of the central estuary. But it does indicate that larger increases in salinity than those predicted by RMA-10 might occur in Youngs Bay and along the Oregon side of the navigation channel up to Tongue Point. In Youngs Bay, the ELCIRC model predicted salinity increases of -0.5 to 1.0 ppt above the base condition salinity of 7 to 23 ppt and zero to 3 ppt increases to base salinity of 17 to 34 ppt. The base salinity in Youngs Bay is highly variable because of the Bay's bathymetry and freshwater inflows.

When the ELCIRC results were used to compute habitat opportunity based on the salinity criterion of zero to 5 ppt, it was determined that in Cathlamet Bay there was virtually no difference in the hours per week for the base and plan. Habitat opportunity based on salinity was always between 145 and 150 hours per week, regardless of whether base or plan bathymetry was used and regardless of the base flow condition used. These results suggest that channel deepening will have no significant impact on salinity intrusion.

River Mouth

Salinity changes in the river mouth are predicted by both models to be near zero.

6.1.5.2 Altered Location of ETM

The estuary is the location where saltwater and freshwater are mixed. In the Columbia, as in most river-dominated estuaries, tidal processes and river flow results in a zone of increased turbidity, the ETM. The turbidity in the ETM is the combination of both the concentration of suspended organic matter and the resuspension of organic and inorganic matter from the bottom. The length of the ETM is typically 0.6 to 3 miles. The position of the ETM ranges between RM 9 and 18 from Youngs Bay to Tongue Point (Simenstad, 1994). This section looks at the effect of the Project on the ETM.

Riverine Reach

As shown in Figure 6-4, the mean of the ETM fluctuates from approximately RM 9 to 18 (Simenstad, 1994). Therefore, there are no effects associated with alteration of the location of the ETM in the riverine reach.

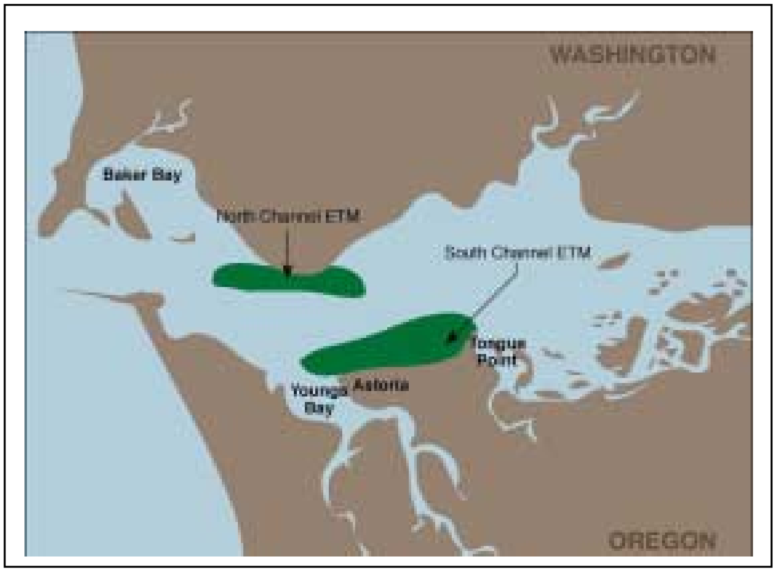

Figure 6-4: Location of the ETM

Estuary

The ETM is an important zone of organic matter accumulation and cycling. A change in the location range of the ETM may affect the distribution of nutrients and thereby the location and abundance of salmonid food in shallow water habitats.

The position of the turbidity maximum appears to be associated with the tide and river currents that control salinity intrusion. The turbidity maximum in the Columbia River estuary currently fluctuates up to 9 miles each day between RM 9 and 18 (Simenstad, 1994). Its range depends on the river discharge and tidal conditions as shown in Figure 6-5. According to the RMA-10 modeling results, with the deeper navigation channel the limit of salinity intrusion could move upstream about a mile for any given discharge. To the extent that the ETM is related to salinity intrusion, this may result in an upstream shift of up to 1 mile in the upstream and downstream limits of the ETM.

The potential shift of the ETM would occur in a relatively small part of the estuary as demonstrated in Figure 6-4. It would generally remain within the current range or path of the ETM, with a small shift in the upstream and downstream boundaries. In addition, it would be smaller than the existing daily fluctuations caused by flow conditions. The effect of the potential shift of the ETM on distribution of nutrients in the estuary is expected to be so small that it cannot be measured. The ETM suspends nutrients in the estuary, which are then distributed by tides and currents in the river system. Any fluctuation in the location of the ETM that may result from the Project is not expected to affect the tidal influences and currents that distribute nutrients throughout the estuary. Further, salmonids do not feed in the area occupied by the ETM; rather, salmonids benefit from the distribution of nutrients out of the ETM throughout the estuary. These are the nutrients that are used as food by the organisms on which juvenile salmonids prey in shallow water habitats.

River Mouth

The ETM occurs only in the estuary. Therefore, no effects are associated with alteration of the ETM location in the river mouth reach.

Figure 6-5: Characteristic Estuarine Turbidity Maximum (ETM) Variations Under "Three Scenarios" in the Columbia River Estuary

6.1.5.3 Conclusion

Based on modeling results, the proposed actions will have little to no impact on salinity intrusion. The Corps is proposing to verify this conclusion through a monitoring survey of habitat conditions before, during and after completion of the Project (see Section 7).

Riverine Reach

No changes to salinity are expected to occur in the riverine reach because the ETM does not extend into this reach.

Estuary

Based on modeling results, the proposed actions will have little to no impact on salinity intrusion:

- Salinity increases of less than 0.5 ppt in the shallow embayments of the estuary (e.g., Cathlamet Bay, Grays Bay). Salinity increases up to 5 ppt would occur in areas not used by juvenile salmonids (bottom of the navigation channel).

- No measurable difference in habitat opportunity is anticipated, based on the modeling results.

The computed differences between base and plan for salinity in shallow areas are much smaller than natural temporal variations due to normal variations in freshwater flow and tidal dynamics.

Likewise, the potential upstream shift of the ETM of less than a mile will have an insignificant effect on the distribution of nutrients in the estuary and, therefore, on salmonids.

River Mouth

No changes to salinity caused by the proposed action are expected to occur in the river mouth reach.

6.1.6 Accretion/Erosion

Some anticipated changes in accretion/erosion due to the proposed channel improvement project include shoal formation (accretion) and shoreline erosion. Following deepening of the channel, accretion will occur in the navigation channel for some time as the riverbed adjusts (stabilizes) to the new depth via side-slope adjustment. Gradual bank erosion in sandy beach nourishment sites may also occur for some time, in response to the side-slope adjustment. These effects are addressed in Sections 6.1.2, Bedload, and 6.1.7, Bathymetry.

Riverine Reach

Riverbed side-slope adjustments and some shoreline erosion will alter the accretion and erosion patterns within this reach. Those effects are addressed in Sections 6.1.2, Bedload, and 6.1.7, Bathymetry. The alteration of the accretion and erosion patterns will not affect suspended sediment or bedload transport rates (see Sections 6.1.1, Suspended Sediment and 6.1.2, Bedload). The slight increases in suspended fine sediments during dredging and disposal operations will not increase accretion in the riverine reach because the river will transport those sediments to the estuary.

Estuary

The estuary is the area most likely to undergo changes in accretion due to the proposed Project. Accretion/erosion in the estuary could be altered by side-slope adjustments along the navigation channel, or by changes in river hydraulics or sediment supply. The project is more likely to increase accretion than to increase erosion.

The potential side-slope adjustments are limited to the Miller Sands area, and those effects are addressed in Sections 6.1.2, Bedload, and 6.1.7, Bathymetry. There could be resulting minor changes in accretion/erosion at this location.

The changes in river hydraulics are very small (see Sections 6.1.7, Bathymetry and 6.1.6, Accretion/Erosion) and are not likely to change accretion or erosion in the estuary.

Accretion in the estuary is influenced by the amount and type of sediment being delivered from upstream. This is reflected in the estimated reduction in the amount of flow and estuary accretion from 2 to 5 mm per year before flow regulation to about 1 mm per year after flow regulation (see Section 2). The deepening project will cause small increases in fine-grained suspended sediment delivered to the estuary during dredging and disposal operations (see Sections 6.1.1.1, Suspended Sediment Caused by Dredging Activities and 6.1.1.2, Suspended Sediment Caused by Disposal Activities). Based on the resuspension of less than 200,000 cubic yards (fine material makes up less than 1 percent of the total volume to be dredged), a fine material deposition rate of 30 percent (Hubbell and Glenn, 1973), and a uniform distribution of deposition throughout the 95,500 acres of open water in the estuary, there would be an average of about 0.1 mm per year of additional accretion during construction. The natural background deposition during that 2-year period would be around 2 mm per year.

Over the long term, the Project will have little effect on accretion in the estuary. There will be slightly more suspended fine sediment as a result of maintenance dredging and disposal. Over 20 years, this could result in less than 0.1 mm of estuary deposition above what would be caused by maintaining the existing channel. An upstream shift in the ETM may cause a minor change in accretion patterns, but the long-term effects are not expected to be detectable.

Sandy sediment within the river channel is one potential source of material for habitat-forming accretion in the estuary. During the reconsultation process, discussion and analysis focused on the potential long-term effects on accretion of removing sand from the upstream channel. The concern was that removing sediment would reduce the source of the estuary's sediment supply . However, as explained in Sections 6.1.1, Suspended Sediment, and 6.1.2, Bedload, the removal of sand from the river will not alter sediment transport to the estuary. The volume to be dredged over the life of the project is only a tiny fraction of the total volume of sand in the riverbed. In addition, transport potential, rather than sand supply, is the limiting factor in sediment supply to the estuary. Also, sediment inflow to the dredging area from upstream of Vancouver is essentially the same as the sediment transport at RM 54, indicating the main material source is upstream of the project.

The above predicted changes in accretion are all the results of very slight project-related changes in suspended sediment concentrations. The effects are thus dispersed throughout the estuary by the distribution of flows. The naturally occurring local accretion and/or erosion rates are influenced by site specific hydraulics and can be much greater than regional rates caused by the deposition of suspended sediment. As an example, Eriksen (SEI Presentation, 2001) found the north channel between RM 5 and 7 had infilled up to 20 feet between 1982 and 2000. Natural accretion and erosion will continue on this scale in the estuary and will likely dwarf any project-related changes.

River Mouth

The Project is not anticipated to have an effect on accretion or erosion at the river mouth.

6.1.6.1 Conclusion

Riverine Reach

Riverbed side-slope adjustments and some shoreline erosion will alter the accretion and erosion patterns within this reach.

Estuary

The Corps believes that the amount of material to be removed from the system is such a small proportion of the total available sand within the system that there is no potential for a discernible effect on estuary accretion.

River Mouth

No changes to accretion/erosion are expected in this reach.

6.1.7 Bathymetry (as Related to Bottom Elevation Contours and Water Surface)

Bathymetric changes will result from the Project. First, dredging will immediately lower the riverbed at the dredge site and lead to long-term changes to the adjacent side slopes. Effects of side-slope adjustment are addressed in Section 6.1.2.1, Potential Reduction in Volume of Bedload Caused by Removal of Channel Materials. Second, in-water and shoreline disposal will raise bed elevations at the disposal site. The disposal material will then be incorporated into the riverbed, forming sand waves and gradually moving downstream, mainly as bedload transport (see Section 6.1.2.2, Potential Effects to Salmonid Habitat Caused by Side-Slope Adjustment). Third, the deeper navigation channel will cause a slight effect on water surface elevations. This could result in a change in water depth. These three potential effects are addressed below.

6.1.7.1 Bathymetric Changes from Dredging

Immediate lowering of the channel will occur where dredging occurs. This is not expected to affect salmonid habitat (see Section 6.1.10, Water Column Habitat).

Riverine Reach

Dredging will lower the riverbed by up to 3 feet in those areas shown in Figures 3-4 to 3-7 of this BA. The exact amount of riverbed lowering and the final dredging locations will depend on river bathymetry just prior to construction. There will be no changes in bathymetry in the approximately 40 percent of the navigation channel in this reach that will not require dredging.

Estuary

Dredging will lower the riverbed by up to 3 feet in those areas shown in Figures 3-8 and 3-9 of this BA. The exact amount of riverbed lowering and the final dredging locations will depend on river bathymetry just prior to construction. There will be no changes in bathymetry in the approximately 55 percent of the navigation channel in this reach that will not require dredging.

River Mouth

No changes to bathymetry are anticipated to occur within this reach.

6.1.7.2 Bathymetric Changes from Disposal

In-water and shoreline disposal will raise elevations at disposal sites. The disposal material will then be incorporated into the riverbed and gradually move downstream as bedload transport (see Section 6.1.2.2, Potential Effects to Salmonid Habitat Caused by Side-Slope Adjustment).

Riverine Reach

Shoreline disposal at Sand Island (O-86.2) will periodically alter the bathymetry of the site. Disposal will raise the riverbed of shallow water areas along the beach. Some areas could change from shallow water to beaches. The disposal will erode away in 3 to 4 years and then the areas will be filled again by disposal.

Flowlane disposal will raise the riverbed intermittently along the channel throughout the life of the project. Flowlane disposal will generally be in portions of the river in or near the navigation channel that are between elevations -50 and -65 feet CRD. The sand will be spread out during disposal by keeping hopper dredges moving as they dump and by frequently moving the discharge pipe from a pipeline dredge. The disposal material will then be incorporated into the riverbed, forming sand waves and gradually moving downstream, mainly as bedload transport. Flowlane disposal is expected to be about 0.5 mcy during construction and 0.5 to 1.0 mcy per year over the first 20 years of maintenance.

Estuary

Shoreline disposal at Skamokawa (W-33.4) and Miller Sands (O-23.5) will cause bathymetric changes similar to those described for Sand Island.

Disposal is expected to occur periodically at Skamokawa and annually on at least part of Miller Sands.

The bathymetric changes caused by flowlane disposal in the estuary will be similar to those described for the riverine reach. The annual flowlane disposal volumes are expected to begin at about 1 mcy per year and decline to about 0.7 mcy per year in 20 years.

River Mouth

No changes to bathymetry are anticipated to occur within the entrance. Ocean disposal will create mounds in the deep water disposal site that are not expected to change.

6.1.7.3 Changes in Water Surface Elevation Resulting from Hydrodynamic Changes

The changes in channel geometry from dredging and disposal may affect the flow of water in the lower Columbia River. As a result, water surface elevation and water depth may change in response to deepening of the navigation channel. These potential effects on river hydrodynamics may occur throughout the river system below Bonneville Dam; however, since the proposed changes in channel geometry are small relative to the current depth and width of the river, the magnitude of this effect on water depth is not expected to be significant. Numerical models discussed below are used to assess these potential changes in water depth.

Riverine Reach

There are no predicted changes in water surface elevations downstream of RM 80 as a result of the Project. Modeling predicts water surface reductions would begin near RM 80 and become progressively larger in the upstream direction. The decreases would be in the range of 0.12 to 0.15 feet at RM 106. These reductions would be caused by removal of sediments in the riverine reach of the navigation channel. This change is not expected to have a discernible impact in this area.

Estuary

The WES RMA-10 model indicates that the impact of channel deepening on surface water elevation is minimal. Differences between base and plan are estimated to be between -0.02 foot and 0.02 foot for all locations between the mouth and the upper estuary (Puget Island).

Modeling conducted by OHSU/OGI supports the results of the WES model. The OHSU/OGI model presents elevation differences in terms of hours of habitat opportunity. Habitat opportunity, as defined by Bottom, et al. (2001), considers water depth and velocity conditions that provide favorable habitat for juvenile salmonids. In terms of water depth, habitat opportunity is defined as shallow environments between 10 centimeters and 2 meters (about 0.5 to 6 feet). Using this definition of habitat opportunity, Table 6-1 lists the average number of hours in which the depth criterion is met (over a 168-hour week) for Cathlamet Bay. Results are shown for five 1-week model simulations spanning a range of flow conditions. The area-weighted averages are nearly identical for base and plan, indicating that the proposed actions will not have an impact on habitat opportunity as it relates to water depth.

Table 6-1. Area-weighted Average Habitat Opportunity Hours – Elevation, Cathlamet Bay

Model Period	Approximate Flow Range (10^3 cfs)	Base (hr)[1]	Plan (hr)[1]
July 01-week 27	70 – 150	45.0	45.0
July 01-week 28	70 – 110	49.4	49.3
May 01-week 18	130 – 165	45.8	45.6
May 01-week 19	70 – 165	43.5	43.5
May 97-week 18	360 – 500	44.5	44.4

[1] Area-weighted average number of hours meeting habitat opportunity criteria over a 168-hour model run.
Source: Baptista, SEI Presentation, 2001b.

River Mouth

No changes to water surface elevations are anticipated in this reach.

6.1.7.4 Conclusion

Bathymetric changes related to the proposed actions include those caused by dredging and disposal. In addition, water surface elevations could change because of deepening the channel. The Corps is proposing to verify this conclusion through a monitoring survey of habitat conditions before, during, and after completion of the Project (see Section 7).

Riverine Reach

Bathymetric changes will include up to 3 feet of deepening in areas of the navigation channel that are currently shallower than -48 ft CRD and some rise in the riverbed at shoreline and flowlane disposal sites. In addition, there is a potential for up to 3 feet of deepening along the side slopes adjacent to the dredge cuts (see Section 6.1.2.1, Potential Reduction in Volume of Bedload Caused by Removal of Channel Materials). Water surface elevation could be affected between RM 80 and 146. The decrease could be up to 0.18 feet (approximately 2 inches) at the upstream end of the project.

Estuary

Bathymetric changes will include up to 3 feet of deepening in areas of the navigation channel that are currently shallower than -48 ft CRD and some rise in the riverbed at shoreline and flowlane disposal sites. In addition, there is a potential for zero to3 feet of deepening along the side-slopes adjacent to the dredge cuts (see Section 6.1.2.1). Water surface elevation is not affected in the estuary by the proposed actions.

River Mouth

No changes to bathymetry are anticipated from the Project in the entrance. Ocean disposal will create mounds in the deep water site that are not expected to change.

6.1.8 Tidal Marsh and Swamp Habitat

Juveniles of each of the 14 listed salmonids and coho (candidate species) may potentially use tidal marsh and swamp habitat, but ocean-type chinook and chum salmon and cutthroat trout are more likely to commonly use the habitat. The results of numerical salinity changes models (see Section 6.1.5, Salinity), a review of salinity tolerances and ranges of marsh species, and data on elevation ranges occupied by these habitats indicate that the Project will have minimal effects on tidal marsh and swamp habitat.

6.1.8.1 Effect on Tidal Marsh and Swamp Habitat

Deepening the lower Columbia River channel is not likely to directly change the amount or character of tidal marsh and swamp habitat. No dredging within the tidal marsh and swamp habitat or filling of tidal marsh and swamp habitat is proposed as a part of the Project.

Riverine Reach

The Project may lower the river surface elevation by up to 0.18 foot at Bonneville Dam and then decreasing downriver to no change at RM 80 (see Section 6.1.7, Bathymetry) and change salinity levels in the lower Columbia River as discussed in Section 6.1.5, Salinity. At the upstream end of the project area (Bonneville Dam to Vancouver), the daily tidal fluctuation between high and low tides is approximately 1.5 feet to 2.5 feet. Flow regulation at the mainstem dams above the action area can significantly increase this daily fluctuation. Lower water level would allow marsh progradation (i.e., building out) waterward of the marsh. Modeled changes in water levels of an inch or less may produce changes in tidally influenced marsh and swamp areas, but the changes are likely to be too small to detect.

Tidal marsh and swamp habitat occurs sporadically along the margins of shallow water areas of the Columbia River from Vancouver down to the estuary, which are scattered throughout the action area. There is also substantial marsh and swamp habitat in rivers and stream tributaries to the mainstem of the Columbia River. However, most tend to be concentrated in the estuary and downstream portions of the riverine reach. Although progradation could occur within the tidal marsh and swamp areas within this reach, no predicted increase or decrease in tidal marsh and swamp habitat is expected as a result of the proposed Project. Areas where gradual shoreline erosion could be expected to occur are RM 99, 86.2, 75, 72, and 46 to 42 (see Section 6.1.2, Bedload). These areas do not contain shoreline tidal marsh or swamp habitat.

Estuary

Water level changes will not significantly change with the Project in the estuary. Water levels within the tidally influenced area of the estuary commonly vary from 4 to 12 feet twice each day as the result of tides, varying between neap and spring tide periods. Neap tides are periods of minimum difference between sequential high and low tides. Spring tides are periods of maximum difference between sequential high and low tides.

During the course of reconsultation, consideration was given to whether changes in salinity resulting from the Project could potentially affect tidal marsh and swamps. In particular, the potential for a salinity shift to cause shifts in the location of aquatic conditions that support existing vegetation within tidal marsh and swamp habitat was examined.

Baseline, pre-project salinity conditions within the estuary vary daily with tide condition and seasonally with changes in river discharge. Daily changes at specific locations can vary from low salinities of less than 1 ppt to as high as 15 to 20 ppt. Modeling (see Section 6.1.5, Salinity) indicates a post-project increase in salinity of from 0.1 to 0.15 ppt in shallow areas of the estuary, such as Cathlamet and Grays Bays. These two bays contain the vast majority of tidal marsh and swamp habitat within the action area.

A literature review of salinity tolerances and ranges of tidal marsh and swamp species showed that most of the dominant species in the estuary adapted for some salinity can tolerate relatively wide variation in salinity (Hutchinson, 1989; Corps, 1999a). For example, Macdonald (1984) found that the sedge (*Carex lyngbyei*) and bent grass (*Agrostis alba*) occurred over a salinity range of zero to 16 ppt. Even predominantly freshwater species, such as American waterplantain (*Alisma Plantago-aquatica*) and spike rush (*Eleocharis* spp.) can tolerate salinity ranges of zero to 4 ppt and zero to 3 ppt, respectively. This literature review and the results of the modeling suggest that it is unlikely that the Project will result in a measurable change in the species distribution of the dominant marsh and swamp assemblages within the estuary. In addition, the potential for an effect is further reduced because the extent of salinity distribution within the action area is unlikely to change within the shallow water areas where much of the tidal marsh and swamp habitat is located.

River Mouth

Not applicable.

6.1.8.2 Conclusion

The structure, distribution, net productivity, and detritus production of marshes and swamps in the action area will not be directly affected by the Project. Based on modeling results, the major habitat-forming processes of bathymetry and salinity are predicted to be affected in a minor way by the Project. The amount or characteristics of tidal marsh and swamp habitat along the shallow water margins of the lower Columbia River are not expected to be significantly affected by salinity or water elevation changes associated with the Project. The Corps is proposing to verify this conclusion through a monitoring survey of habitat conditions before, during, and after completion of the project (see Section 7).

6.1.9 Shallow Water and Flats Habitat

Shallow water and flats habitats, provide, important feeding and rearing areas for outmigrating juvenile salmonids, especially ocean-type chinook salmon (Snake River fall chinook, lower Columbia River fall chinook), chum salmon, and cutthroat trout. Some individual juveniles of each of the other listed salmonids and coho may potentially use shallow water and flats habitat within the lower Columbia River, but they are more likely to be in open water away from the shallow shorelines. In addition, adult chum salmon use shallow water habitat for spawning in the riverine reach. These sites are all above the Interstate 5 Bridge at Vancouver, Washington (Howard Schaller, pers. comm., 2001). They are located near Bonneville Dam and the city of Vancouver. No other spawning occurs in the action area by this or other salmonid populations.

The Project could affect shallow water and flats habitat in several potential ways. First, side-slope adjustments associated with channel deepening may cause a shift in the location of shallow water habitats associated with past beach nourishment sites. This potential effect is discussed in Section 6.1.2, Bedload. Second, shoreline disposal for beach nourishment will result in the placement of dredge materials in shallow water habitats at three locations. Third, changes in water surface elevation have been evaluated to determine whether a potential exists for habitat opportunity to be reduced within shallow water areas. This effect is discussed in Section 6.1.7, Bathymetry. Effects on salmonid spawning habitat by changing surface elevations are discussed below.

6.1.9.1 Shoreline Disposal in Shallow Water and Flats Habitat

Shoreline disposal for beach nourishment is proposed for three sites within the action area. Shoreline disposal involves discharge of dredged materials from a discharge pipe that is placed on the beach and then moved slowly into the shallow shoreline areas until they are converted to upland. During reconsultation, discussions regarding shoreline disposal have focused on the potential for disturbing salmonids that use existing shallow water habitat within these areas. None of the proposed sites will provide additional habitat for avian predators that prey on juvenile salmonids, such as Caspian terns.

Shallow water areas at discrete locations will be affected by shoreline disposal. The shoreline disposal locations have steep side slopes (around 10 percent) that provide about 7 acres per mile of shallow water areas. Shoreline disposal will affect a total of about 4.5 miles or 30 acres of shallow water areas. However, the three disposal sites are all highly erosive and do not contain many of the important habitat features that shallow water habitats typically include, such as low velocity, vegetation, and food sources. These sites had previously been approved by NMFS for shoreline disposal because of their low productivity. Side-slope adjustment will occur over a period of 5 to 10 years. This process will cause shallow water and flats habitat at six historical shoreline disposal sites to migrate laterally; however, the quantity and quality of shallow water and flats habitat is expected to remain constant.

Riverine Reach

One shoreline disposal site is located within the riverine reach at Sand Island (O-86.2). The site is a beach nourishment site intended for disposal during both construction and maintenance dredging. The site is intended to provide recreational benefits, as well as to protect existing riparian habitat. A narrow band of shallow water will be affected by disposal at the Sand Island (O-86.2) shoreline disposal site. This site is highly erosive and does not provide any salmonid habitat. This site has been previously approved for shoreline disposal by NMFS because of its low productivity (Hinton and Emmett, 1994).

Estuary

Miller Sands Island, which is located within the estuary at O-23.5, is a beneficial use site that will provide long-term benefits by maintaining the existing embayment for salmonid habitat. The site is intended for use during maintenance dredging. The shoreline disposal site at Miller Sands is along the channel side of the island and affects a narrow band of shallow water along the shore. The site is highly erosive and provides little shallow water or juvenile salmonids rearing habitat. This site has been previously approved for shoreline disposal by NMFS because of its low productivity.

Skamokawa Beach, which is located at W-33.4, is a beneficial use site intended to enhance the public beach as well as provide sand for sale for other uses. The site is used for maintenance dredging, but only periodically. The shoreline disposal site at Skamokawa Beach affects a narrow band of shallow water along the shore. The site is highly erosive and provides little shallow water or juvenile salmonids rearing habitat. This site has been previously approved for shoreline disposal by NMFS because of its low productivity (Hinton and Emmett, 1994).

River Mouth

No shoreline disposal is planned for the river mouth and no changes in shallow water habitat are anticipated.

6.1.9.2 Potential Effect on Salmonid Spawning Activity and Spawning Habitat

Section 6.1.7, Bathymetry, describes a potential decrease in water surface elevation of up to 0.18 foot. The potential lowering would occur between RM 80 and 146. This magnitude of surface elevation change on salmonid redds (spawning nests) in the mainstem of the Columbia River (action area) would have no effect on adult spawning or survival of eggs in redds. The location of spawning and redds is in water depths of several feet and areas that water elevations fluctuate several feet each day.

Riverine Reach

There are two areas of known salmonid spawning in this reach; adult chum salmon spawn near Bonneville Dam and by the Interstate 205 bridge near some under waterspring seeps in the vicinity of Vancouver, Washington. The proposed actions will have no effect on spawning activity or habitat.

Estuary

No salmonid spawning occurs in this reach.

River Mouth

No salmonid spawning occurs in this reach.

6.1.9.3 Conclusion

There is little potential to disturb salmonids that use shallow water habitats at the three shoreline disposal sites. None of the sites offers the conditions that provide salmonid habitat because the shallows at all three sites have high velocity currents and relatively rapid erosion. These currents are likely to prevent benthic invertebrate populations from establishing and young salmonids from rearing in these areas. As with tidal marsh and swamps habitat, the Corps is proposing to verify any impacts to shallow water areas that may occur through a monitoring survey of habitat conditions subsequent to completion of the project (see Section 7).

Limited chum salmon spawning occurs in the project action area above the Interstate 5 bridge at Vancouver, Washington. The proposed action will not affect spawning activities or habitat.

6.1.10 Water Column Habitat

The proposed Project may cause the following potential modifications to characteristics of the water column habitat. First, there is the potential for a slight shift in the upstream limit of the ETM. This issue has already been discussed in Section 6.1.5.2, Altered Location of ETM. Second, there is the potential for a slight shift in the upstream limit of salinity intrusion (See Section 6.1.5, Salinity). Third, proposed drilling and blasting activities have the potential to disturb water column habitat. Finally, the Corps is proposing to use a dredging schedule that is consistent with the existing BO for O&M dredging. Because these activities will occur in areas where salmonids are not present, at depths of greater than 20 feet, timing window recommendations for activities within the Columbia River do not apply (see Table 3-1).

6.1.10.1 Effects of Drilling and Blasting on Water Column Habitat

Riverine Reach

Blasting will be done during the preferred in-water work window. This is the period when salmonid abundance is lowest and will minimize impacts to the listed populations. In addition, because there may be some fish in the river, the blasting plan will be designed to further minimize any impacts by keeping over-pressures above the blast zone to less than 10 psi (Corps, 1999a). This level is generally believed to be below the level at which salmonids will be impacted. A state-approved plan for blasting will also be developed to further minimize impacts.

Estuary

No drilling and blasting is proposed within the estuary, and no effects are anticipated to the water column habitat within the estuary from drilling and blasting activities.

River Mouth

Not applicable.

6.1.10.2 Proposed Dredging Timelines

Riverine Reach

Dredging and disposal during construction will be done year-round for 2 years. Though this is outside of the normal November 1 to February 28 in-water work period for the lower Columbia River, it is not anticipated that it will have any major impact on listed salmonids. (See Table 3-1 for dredging timing.) Salmonids normally do not occur to any extent in the areas being dredged or the disposal sites (except the three shoreline sites). Juvenile salmonids normally migrate along the channel margins using the side slopes as structure. They occur primarily at depths less than 20 feet and so would not be expected to be impacted by dredging and disposal operations. Though juvenile salmonids can occur near the three shoreline sites, these sites are highly erosive and do not provide much, if any, habitat.

Estuary

See Riverine Reach, above.

River Mouth

No dredging will occur in the river mouth reach.

6.1.10.3 Conclusion

Based on the discussion, above it is unlikely that dredging and disposal year-round for 2 years will have any effect on listed salmon. This is primarily a result of the fact that salmonids do not occur in the deeper channel areas to any extent. Restricting blasting to the in-water work period, in conjunction with an approved blasting plan, will reduce or eliminate impacts to listed salmonids because this is the period when they are the least abundant.

6.1.11 Light

Light drives photosynthesis and ultimately the growth of plants. The most likely potential effect on light penetration comes from anticipated turbidity increases associated with dredging and disposal activities.

6.1.11.1 Reduction in Light from Increases in Turbidity

Riverine Reach

See Estuary, below.

Estuary

The amount of light reaching plankton and benthic macrophytes is a function of water clarity. Any action that reduces water clarity will reduce the amount of light reaching plants. The discussion of turbidity (see Section 6.1.4, Turbidity) summarizes the sources of increased turbidity and is highly relevant to the present discussion of light.

Short-term reductions in light could be associated with turbidity from dredging, flowlane disposal, dredged material disposal, and ship wakes. In Section 6.1.4, Turbidity, it was concluded that the transitory nature of dredging activity and the dilution effect of currents would allow turbidity associated with the Project to dissipate relatively rapidly in a given area (i.e., in less than an hour).

Localized turbidity levels of 5 to 26 NTUs (see Section 6.1.4, Turbidity) that might be caused by the proposed Project are not likely to produce detectable effects on plant growth in the lower Columbia River. Not only is the amount of increase too low (particularly given the short duration of the increase), but it will be localized to areas where dredging and disposal will occur (within a few hundred yards of the activity), which avoid shallow water areas.

River Mouth

See Estuary, above.

6.1.11.2 Conclusion

Light will be temporarily reduced in the water column where sediments are either stirred up or discharged by dredging and disposal activities. Information on the location and duration of dredging and disposal activities indicates that they will affect a very small but unquantified area relative to the entire wetted surface of the system. Given the transient and localized nature of the anticipated turbidity increases, it is unlikely that they will result in discernible effects to primary productivity within the action area.

6.1.12 Nutrients

A balance of nutrient input is important for the maintenance of a healthy river system. If nutrients, especially phosphate and nitrate, are in short supply within a system, it will limit the growth of plants. Conversely, if nutrients are overabundant (i.e., eutrophic), noxious blooms of algae and aquatic macrophytes can occur, which can have a negative effect on water and sediment quality. Nutrients are dissolved in water both in the water column itself and in sediment pores. They are also constantly being released through organic matter mineralization in the water and sediments. Zones of most intense remineralization in the Columbia River are associated with the ETM (Simenstad, 1994) and sediments. Nutrients can be released to the water column through disturbance of bottom sediments.

Nutrients in the Columbia River have not been evaluated sufficiently to develop nutrient level criteria. These criteria are used to define nutrient levels indicating a properly functioning system. Sullivan, et al. (2001), summarized data over a 1-year period (1995-1996) from a station at RM 53 and monthly averages over a 16-year period (1978-1994) from RM 141. The concentrations varied from a winter-spring high to a summer low, with all responding to typical patterns of nutrient use by phytoplankton during the spring-summer increase (Table 6-2). The winter increase in the river appears to be related to discharges from the dams. Nutrient concentrations do not appear to be causing algal blooms or other problems and can be used as the best estimate of proper function for the current system. Even if sufficient nutrients were added to the system to cause an algal bloom, the flow rates and currents within the river and estuary would prevent such a bloom.

Table 6-2: Nutrient Concentrations[1] at USGS Stations at RM 53 and RM 141

Nutrient	Season	Concentration (μmol) at Station RM 53	Concentration (μmol) at Station RM 141
Nitrate + Nitrite	Winter	30	25
	Summer	6	5
Phosphate	Winter	0.70	0.80
	Summer	0.10	0.40
Silicate	Winter	220	180
	Summer	125	120

1 Concentrations are approximate values for the period of greatest to least concentrations in winter and summer, respectively.

Source: Summarized from Sullivan, et al., 2001.

6.1.12.1 Increase/Decrease in Nutrients

Riverine Reach

See Estuary, below.

Estuary

Suspending sediments, particularly those that may have higher organic matter content, will release inorganic nutrients into the water column. For example, dredging and flowlane disposal will release sediments into the water column, which in turn have the potential to release some inorganic nutrients. However, the sediments in the lower Columbia River generally have very low organic levels (5 percent or less), which suggests that the release of inorganic nutrients will be small. In addition, any release of inorganic nutrients during dredging will be confined primarily to the bottom of the navigation channel. Given the nutrient input levels necessary to disrupt the nutrient balance within the Columbia River, the proposed activities are not likely to have a discernible effect on nutrients in the action area.

The accumulation of suspended materials in the turbidity maximum is an important sink for detritus and a source of entrained nutrients for food web consumers (Small, et al., 1990). The ETM also serves as a mechanism by which suspended materials and phytoplankton remain in the estuary longer in the face of the strong outward river flow (Sherwood, et al., 1990). In addition, actions of the ETM result in the lateral movement of suspended materials into peripheral areas, where they become available to suspension feeders and, as they settle, to deposit feeders in shallow water areas. The potential effect of the Project on the ETM is addressed in Section 6.1.5, Salinity. Changes that could occur to the ETM as a result of the Project are not expected to increase or decrease nutrients available to salmonids in the estuary.

River Mouth

See Estuary, above.

6.1.12.2 Conclusion

Any nutrient release that occurs as a result of sediment disturbance is expected to be small because of the low percentage of organic materials in the action area. In addition, effects of nutrient releases that occur are expected to be minimal overall because of rapid transport and dilution in the navigation channel. Although small amounts of nutrients will likely be released during dredging and flowlane disposal, because tidal hydrology and flow are dynamic in the system, the buildup of nutrients to levels that could result in algal blooms is not expected. In addition, changes to the ETM are not expected to cause any change in nutrient quantity or location as they relate to salmonids.

6.1.13 Imported Phytoplankton Production

During reconsultation, consideration was given to whether the proposed Project has the potential to either increase or decrease the production of imported phytoplankton.

6.1.13.1 Increase/Decrease in Imported Phytoplankton Production

Riverine Reach

See Estuary, below.

Estuary

Salmonids feeding in the water column eat prey that in turn, feed on plankton and microdetritus. It is believed that, since flow regulation, the food web has been fundamentally altered from one supported primarily by marsh macrodetritus to one supported mainly by imported microdetritus (Sherwood, et al., 1990; Weitkamp, 1994). This shift has resulted from the following:

- Loss of marsh areas as a result of diking
- Loss of marsh areas associated with other filling activities not related to channel deepening
- An increase in imported plankton as a result of increased production in Columbia River reservoirs

It is uncertain whether this shift has adversely affected juvenile salmonids.

A major zone for cycling of imported plankton is at the ETM. Because salinity may intrude farther into the estuary as a result of deeper channel depth, the point where imported phytoplankton contact dilute seawater and die will be farther upstream from present conditions. The location is coincident with that of the ETM. Because the slight shift in the ETM will often occur the natural variation of the ETM location, there is no expectation that the shift will have a discernible effect on imported phytoplankton.

River Mouth

See Estuary, above.

6.1.13.2 Conclusion

Modeling by OHSU/OGI and WES predicts a minor upstream shift in the ETM of up to 1 mile. This will affect the location where imported phytoplankton contacts dilute seawater and, therefore, the location where imported phytoplankton die and are broken up and processed. However, no change in type or quantity of imported phytoplankton within the system is anticipated. As noted in Section 6.1.5, Salinity, the shift in the ETM and salinity will affect the location of phytoplankton mortality. It is not anticipated that this will affect salmonids; however, this will be discussed further in an interagency workshop on the ETM.

6.1.14 Resident Phytoplankton Production

During reconsultation, consideration was given to whether the proposed Project has the potential to either increase or decrease the production of resident phytoplankton.

6.1.14.1 Increase/Decrease in Resident Phytoplankton Production

Riverine Reach

See Estuary, below.

Estuary

Salmonids feeding in the water column eat prey that feed on plankton and microdetritus. Because of loss of marsh areas and an increase in imported plankton, it is believed that the food web has been fundamentally altered from one supported primarily by marsh macrodetritus to one supported mainly by imported microdetritus (Sherwood, et al., 1990; Weitkamp, 1994).

Resident phytoplankton have always contributed to the food web in the estuary. Their contribution to total system phytoplankton may have been reduced since the increase in abundance of the upriver species. Upriver abundance and species have been changed by the increase in habitat provided by the reservoirs. It is uncertain whether this shift has resulted in a net negative effect on juvenile salmonids, but the Project will not affect this situation. An upstream relocation of the ETM could potentially result in enhanced resident phytoplankton production in this area. However, it is likely that the slight shift in the ETM will be within the natural variation of the ETM location, resulting in no discernible effect on resident phytoplankton.

River Mouth

See Estuary, above.

6.1.14.2 Conclusion

Modeling by OHSU/OGI and WES predicts a minor salinity upstream shift of up to 1 mile. This shift may result in a slight shift in the ETM as well, which may enhance of resident euryhaline phytoplankton production. As noted in Section 6.1.5, Salinity, the shift in salinity, with its associated effects on phytoplankton production, is not anticipated to affect salmonids. However, this will be discussed further in an interagency workshop on the ETM.

6.1.15 Benthic Algae Production

During reconsultation, consideration was given to whether the proposed Project has the potential to either increase or decrease benthic algae production.

6.1.15.1 Increase/Decrease in Benthic Algae Production

Benthic algae consist primarily of benthic diatoms that occur on sediment grains and larger inorganic material and on macrophytes as epiphytes. Benthic macroalgae (e.g., green seaweeds such as *Ulva* spp. and *Enteromorpha* sp.) can also be abundant in some areas. There will be no dredging in the shallow flats and channels where benthic algae primarily occur. Flowlane disposal is not expected to affect benthic algae because it is done below the depth range where benthic algae occur, about 1 meter below MLLW.

Nutrients will likely be released during dredging and flowlane disposal. However, as discussed in Section 6.1.9, Nutrients, tidal hydrology and river flow should prevent the buildup of nutrients to levels that result in substantial algal blooms. Furthermore, benthic algal productivity is generally not nutrient limited, so increases in nutrients alone will not be sufficient to increase algae production.

Riverine Reach

No dredging or disposal activities are proposed for areas with significant benthic production. The closest potential effect would be from the shoreline disposal at Sand Island (O-86.2). However, the existing currents and erosion rates at the beach nourishment site create a coarse-grained and erosive environment that severely limits the potential for significant benthic production. Accordingly, no effects to benthic production are anticipated in the riverine reach.

Estuary

Because salinity will intrude farther into the estuary as a result of the deeper channel depth, the spatial distribution of benthic algae may change; any such change would occur primarily in the navigation channel, not in productive side channels or lateral habitats (see Section 6.1.5, Salinity). However, it is likely that the slight shift in the salinity will be undeterminable within the natural variation, resulting in no discernible effect on benthic production.

River Mouth

See Estuary, above.

6.1.15.2 Conclusion

Modeling by OHSU/OGI and WES predicts a minor upstream shift of salinity of less than a mile. Accordingly, there may be a small upstream shift in the location of benthic algae production, but this is very difficult to predict with any precision because many of the myriad diatom species consitituting the flora are euryhaline. As noted in Section 6.1.5, Salinity, the shift in salinity, with its associated effects on benthic algae production, is not anticipated to affect salmonids. However, this will be discussed further in an interagency workshop on the ETM.

6.1.16 Tidal Marsh and Swamp Production

Some individual juveniles of each of the 14 listed salmonids and coho may potentially use these habitats within the lower Columbia River. However, ocean-type chinook and chum salmon and young cutthroat trout are likely to commonly use the habitat.

Tidal marsh and swamps are an important habitat for juvenile salmonids that feed both epibenthically and in the water column. During reconsultation, consideration was given to whether the proposed Project has the potential to either increase or decrease tidal marsh and swamp production.

6.1.16.1 Increase/Decrease of Tidal Marsh and Swamp Production

The effects analysis for this indicator focused on the potential effect on tidal marsh and swamp production from changes in water surface elevation and salinity intrusion.

Riverine Reach

Marsh and swamp habitat occur sporadically along the riverine reach. Water surface elevation changes predicted in the FEIS (Corps, 1999a) range from zero to 0.18 foot. These slight changes are within the existing range of variability in the river system and are not anticipated to result in changes to habitat distribution or production because the changes are negligible compared to the natural variability of the system.

Estuary

As noted in Section 6.1.8, Tidal Marsh and Swamp Habitat, the structure, distribution, net production, and detritus production of marshes and swamps in the action area will not be significantly affected by the Project. Although OHSU/OGI and WES modeling results indicate slight changes to water surface elevation and salinity intrusion (see Sections 6.1.7, Bathymetry and 6.1.5, Salinity, respectively), these slight changes are not anticipated to result in changes to marsh distribution or production because the changes are negligible compared to the natural variability of the system.

In addition, even if slight changes in salinity intrusion occur, the salinity tolerances of plants within these habitats are much greater than the potential change. Accordingly, very minimal changes to tidal marsh and swamp production are anticipated.

River Mouth

See Riverine Reach, above.

6.1.16.2 Conclusion

While the Project is not anticipated to have a measurable effect on tidal marsh and swamp production, the Corps is proposing to conduct ecosystem monitoring that will assess changes to tidal marsh and swamp habitat. This monitoring will help validate the ultimate conclusions regarding tidal marsh and swamp productivity reached here. The proposed monitoring programs are discussed in Section 7.

6.1.17 Deposit Feeders

Ocean-type salmonids frequently feed on deposit feeders. During reconsultation, consideration was given to two potential ways in which the proposed Project could either increase or decrease the deposit feeders within the action area. First, whether dredging or disposal activities will have an effect on deposit feeder populations was considered. Second, whether changes in salinity within the estuary will affect deposit feeder populations was also considered. The second issue is assessed in Section 6.1.30, Habitat-Specific Food Availability.

6.1.17.1 Increase/Decrease of Deposit Feeders

Riverine Reach

See Estuary, below.

Estuary

Dredging will result in removal of some deposit feeders from the navigation channel. Flowlane disposal will bury some animals and, if deposition of sediments is heavy, will result in the loss of some communities. Removal and burial effects are expected to be relatively short-lived, with dredge and disposal areas being recolonized by deposit feeders. Deposit feeders occur in low densities in the navigation channel because the sand waves create constantly shifting habitat conditions. In these and other areas of the river, densities fluctuate as a result of constantly changing environmental conditions. No changes to deposit feeders are anticipated in shallow water areas, side channels, or embayments, which are the important locations for salmonid feeding opportunities.

River Mouth

See Estuary, above.

6.1.17.2 Conclusion

Limited removal and burying of deposit feeders will occur in portions of the navigation channel and deep water areas during the course of the Project. No significant change in deposit feeder populations is anticipated because the navigation channel does not provide suitable habitat. The Corps' proposed monitoring program, which will include a post-project survey of ecosystem conditions, will specifically address deposit feeders in shallow water areas.

6.1.18 Mobile Macroinvertebrates

During reconsultation, consideration was given to whether the proposed Project has the potential to either increase or decrease mobile macroinverebrate populations. Particular concern has been expressed concerning the impacts to Dungeness crab populations.

6.1.18.1 Increase/Decrease of Mobile Macroinvertebrates

Riverine Reach

Crayfish (*Pacifasticus trowbridgii*) occur primarily in the freshwater portions of the riverine reach near the shoreline, but are also found in the estuary. They are a food source for many fish species and may be eaten by adult or larger juvenile salmonids. However, they are not a significant aspect of salmonid diet, particularly for juvenile salmonids.

Estuary

Dredging will result in removal of mobile macroinvertebrates in the channel. Entrainment by dredges is generally lethal. In addition, flowlane disposal may temporarily bury some animals and, if deposition of sediments is heavy, will result in the loss of some members of the group. Removal and burial effects are expected to be relatively short-lived, with dredged areas being recolonized within 6 to 12 months (Flemmer, et al., 1997). Mobile macroinvertebrates located in shallow water, flats, and tidal marsh channels will not be affected.

Entrainment of Dungeness crab (*Cancer magister*), shrimp (*Crangon franciscorum*), and mysids (e.g., *Neomysis mercedis*) will occur in the project area; however, the entrainment is expected to be limited. Entrainment of Dungeness crab is likely to be limited because most Dungeness crabs occur in the lower part of the estuary outside of the project area or the main navigation channel. Large numbers of young of the year (YOY) Dungeness crab are carried into the lower portions of the estuary in the spring and early summer as they are carried inshore by ocean currents to rear. Adult crabs are abundant in the lower estuary in the shallow areas and Baker Bay where salinity levels are high enough to support them. An entrainment study done for the MCR Project (Larson, 1993) indicated that YOY crabs were entrained in larger number than juveniles and adults. Entrainment of *Crangon* and mysids is also likely to be small because they predominantly occur in the shallow areas over the tidal flats. They can also be found in the channel areas during low river flows. During this time, entrainment of these species may occur. During high flows the velocity is thought to be too great for them to be in the channel areas (CREDDP, 1984).

Indirect effects on macroinvertebrates from changes to temperature, salinity, and suspended sediments were also assessed, but were determined to be unlikely to cause lethal or sublethal effects on mobile macroinvertebrates. Because of the relatively wide salinity tolerances of most members of this group, slight shifts in salinity intrusion are not expected to change the abundance of mobile macroinvertebrates. Further, the proposed action is not expected to significantly affect temperature or suspended sediments (see Sections 6.1.35, Temperature and Salinity Extremes and 6.1.1, Suspended Sediments, respectively).

River Mouth

See Estuary, above.

6.1.18.2 Effects from Sediment Disposal on Dungeness Crab

Riverine Reach

Not applicable.

Estuary

See River Mouth, below.

River Mouth

Disposal of dredged material near the river mouth and offshore may bury crab and other members of this group. Studies have indicate that Dungeness crab are susceptible to burial and subsequent mortality. A laboratory study indicated that a portion of the soft-shelled crabs did not survive burial (Antrim and Gruendell, 1998).

Some mortality of Dungeness crabs from dredging and disposal operations will occur; however, this mortality is expected to have an insignificant effect on crab populations. In addition, although crab larvae are eaten by salmonids in other river estuaries, food studies in the lower Columbia River have indicated that these larvae are not a primary food source for salmonids in the lower Columbia River. In addition, crab are low in nutritional value because of the amount of chitin. See Table D4-2 in Appendix D-4 for additional information.

It is unlikely that the decrease in Dungeness crab will be significant enough to adversely affect salmonid populations.

6.1.18.3 Conclusion

Riverine Reach

See Estuary, below.

Estuary

Mobile macroinvertebrates in the estuary appear to be adapted to respond rapidly to disturbances and can recolonize areas following these disturbances. Changes to salinity intrusion, temperature, and suspended sediment are not expected to have an effect on the distribution of this group. It is predicted that there will be no effect on salmonids through loss or alteration of mobile macroinvertebrates in the navigation channel.

Some mortality of Dungeness crabs by dredging and disposal operations will occur; however, this mortality is expected to have an insignificant effect on crab populations in either the estuary or the river mouth.

As stated previously, although crab larvae are eaten by salmonids in other river estuaries, food studies in the lower Columbia River have indicated that these larvae are not a primary food source for salmonids in the lower Columbia River.

River Mouth

As stated previously, some mortality of Dungeness crabs by dredging and disposal operations will occur; however, this mortality is expected to have an insignificant effect on crab populations in either the estuary or the river mouth.

6.1.19 Insects

Insects include larval forms, as well as adults. These insects are associated with vegetated areas and also reside in the upper water column, often at the surface. They are most abundant in areas where current velocities are low and most feed directly on marsh vegetation. Insects are abundant and important to salmonids. Insect larvae and some adults are often found in the stomachs of salmonids that feed in shallow flats and marsh channels. All listed salmonids and coho could potentially feed on insects. The following analysis considers whether project activities will result in a potential increase or decrease of habitat for relevant insects within the food web.

6.1.19.1 Decrease of Insects

Riverine Reach

See Estuary, below.

Estuary

Insects are primarily freshwater organisms, but do occur in abundance in brackish water habitats. Increases or decreases in marsh habitat or production will have an equivalent effect on abundance and distribution of insects. However, as concluded in Section 6.1.8, Tidal Marsh and Swamp Habitat, the amount and characteristics of tidal marsh and swamp habitat along the shallow water margins of the lower Columbia River are not expected to be significantly affected by the proposed action.

Salinity intrusion, associated primarily with the main channel, is not expected to change the abundance of insects that are located primarily along the water margins in shallow wetlands and marsh channels. Since OHSU/OGI and WES modeling results suggest that anticipated changes to salinity in these areas are very small (see Section 6.1.5, Salinity), those changes should have an insignificant effect on relevant insect populations.

River Mouth

See Estuary, above.

6.1.19.2 Conclusion

Insects are abundant and important to salmonids. The proposed project is not anticipated to affect tidal marsh or swamp areas that support insect production. In addition, projected salinity increases are not expected to affect the distribution of this group. However, the Corps' proposed monitoring, which will include a post-project survey of ecosystem conditions, will include monitoring of habitat used by insects. (see Section 7).

6.1.20 Suspension/Deposit Feeders

Impacts to suspension/deposit feeders are the same as those to deposit feeders. (See Section 6.1.17, Deposit Feeders, for analysis). The Corps' proposed monitoring program, which will include a post-project survey of ecosystem conditions, will specifically address suspension/deposit feeders in shallow water areas (see Section 7).

6.1.21 Suspension Feeders

Impacts to suspension feeders are the same as those to deposit feeders. (See Section 6.1.17, Deposit Feeders, for analysis). The Corps' proposed monitoring program, which will include a post-project survey of ecosystem conditions, will specifically address suspension feeders in shallow water areas (see Section 7).

6.1.22 Tidal Marsh Macrodetritus

Tidal marsh and swamps are shown to be highly important habitat for juvenile salmonids that feed both epibenthically and in the water column. Small fish forage at edges of marsh channels for insects and benthic crustaceans. Production of prey resources is partially supported by marsh detritus.

6.1.22.1 Decrease in Tidal Marsh Macrodetritus

Riverine Reach

No changes are anticipated to occur within the riverine reach that would alter the amount or distribution of tidal marsh macrodetritus.

Estuary

Deepening the lower Columbia River channel is not likely to have a direct effect on the amount or productivity of tidal marsh macrodetrius. No dredging within the tidal marsh and swamp habitat is planned. Likewise, no filling of tidal marsh and swamp habitat is proposed as a part of the Project.

Tidal marsh and swamp habitat may increase slightly in area as a result of the channel deepening. The slight decrease in water surface elevation may provide more area that is at the appropriate depth for tidal marsh to develop (see Section 6.1.7, Bathymetry). This would allow marshes to expand and lead to an increase in tidal marsh and swamp macrodetritus.

River Mouth

See Estuary, above.

6.1.22.2 Conclusion

The amount and characteristics of tidal marsh and swamp habitat could potentially be slightly affected along the shallow water margins of the lower river and estuary through expansion. However, the potential changes are anticipated to be too small to be measurable. Nonetheless, the Corps' proposed monitoring, which will include a post-project survey of ecosystem conditions, will include estimates of tidal marsh macrodetritus (see Section 7).

6.1.23 Resident Microdetritus

Resident microdetritus, which is derived from benthic and planktonic algal production, is important to suspension feeders and suspension/deposit feeders. The primary potential for change to resident microdetritus would occur from changes caused by salinity intrusion.

6.1.23.1 Decrease of Resident Microdetritus

Riverine Reach

No changes are anticipated to occur within the riverine reach that would alter the amount or distribution of resident microdetritus.

Estuary

Because salinity may marginally intrude farther into the estuary as a result of the deeper channel,the spatial distribution of resident microdetritus may change slightly. However, as discussed in Section 6.1.5 Salinity, modeling results for potential changes in salinity associated with deepening the channel are anticipated to be minimal and are well within the natural variability of the system.

River Mouth

See Estuary, above.

6.1.23.2 Conclusion

There may be a small shift in the location of where resident microdetritus dies. This shift of the ETM is very difficult to predict because of the dynamic tidal and river hydraulics. It is not expected to affect salmonids.

6.1.24 Imported Microdetritus

Imported microdetritus is mostly derived from algal production upriver, including that produced above dams, and is important for suspension feeders and suspension/deposit feeders. Changes in the zone of contact between imported microdetritus and the salt wedge would occur in the estuary.

6.1.24.1 Reduction of Imported Microdetritus

Riverine Reach

No changes from current conditions are expected to occur to imported microdetritus upstream of the estuary.

Estuary

It is expected that no direct impacts will occur from the proposed Project to imported phytoplankton. Because salinity may intrude farther into the estuary as a result of the deeper channel depth, the point where imported phytoplankton contact dilute seawater will be farther upstream from current conditions. Specifics regarding changes in salinity are discussed in Section 6.1.5, Salinity.

River Mouth

See Estuary, above.

6.1.24.2 Conclusion

There may be a small shift in the location of where imported phytoplankton die. This shift is difficult to predict because of the dynamic tidal and river hydraulics. It is not expected to affect the overall amount of microdetritus.

6.1.25 Reduction or Increase of Habitat Complexity, Connectivity, and Conveyance

Tidal marsh and swamps and shallow water areas provide important habitats for juvenile salmonids. During reconsultation, consideration was given to whether the proposed Project has the potential to either increase or decrease the complexity, connectivity, or conveyance capability of these habitats.

Riverine Reach

See Estuary, below.

Estuary

No activities proposed for the Project would directly affect the complexity and connectivity of habitats within the estuary, riverine, or river mouth reaches. However, the primary concern for reconsultation is whether changes to habitat-forming processes will ultimately result in long-term changes to habitat complexity, connectivity, or conveyance. In particular, the potential effects from lowering the water surface elevation and changing salinity intrusion were considered.

As discussed in previous sections, OHSU/OGI and WES modeling results indicate slight changes to water surface elevation and salinity intrusion (see Sections 6.1.7, Bathymetry, and 6.1.5, Salinity, respectively). However, these slight changes are not anticipated to result in discernible changes to tidal marsh or shallows distribution or function because the changes are negligible compared to the natural variability of the system. In fact, OHSU/OGI modeling results indicate that channel deepening will result in almost no change in habitat opportunity hours, based on the depth criterion (see Section 6.1.7, Bathymetry).

River Mouth

See Estuary, above.

6.1.25.1 Conclusion

While the project is not anticipated to have a discernible effect on the location, function, or accessibility of tidal marsh or shallows habitat, the Corps is proposing to monitor any potential changes to the ecosystem from deepening of the navigation channel. The proposed monitoring programs are discussed in Section 7. Although the monitoring is not specifically targeted to habitat complexity, connectivity, and conveyance, it will provide information that will be useful for tracking these conditions in the future.

6.1.26 Velocity Field

Velocity field describes the speed and direction of fluid motion throughout the river system. As described in the conceptual model, the velocity field is an important indicator of salmonid growth because of its impact on refugia and feeding habitat opportunity. Changes in bathymetry from dredging and disposal that may change river velocity, and thereby affect habitat opportunity, were assessed as part of this analysis.

6.1.26.1 Effects on Habitat Opportunity Caused by Velocity Changes Resulting from Alteration of Bathymetry

Effects on habitat opportunity resulting from changes in water surface elevation are discussed generally in Section 6.1.7, Bathymetry. WES and OHSU/OGI both considered velocity specifically in their modeling analysis (see Appendices F and G).

Riverine Reach

Based on the predicted water surface changes (see Section 6.1.7, Bathymetry), velocity field changes are expected to be correspondingly small and have an insignificant effect on habitat opportunity.

Estuary

The WES model is three-dimensional, with model results for velocity averaged separately for the bottom and for the surface regions of the water column. Modeling results indicate that average velocity differences with the Project are small, ranging from approximately -0.2 foot per second to 0.2 foot per second. The largest differences are in the navigation channel. Differences in the shallow regions outside the navigation channel range from approximately -0.05 to 0.05 foot per second.

OHSU/OGI modeling supports the results of the WES model. The OHSU/OGI model presents velocity magnitude differences in terms of hours of habitat opportunity. Habitat opportunity, as defined by Bottom, et al. (2001), considers water depth and velocity conditions that provide favorable habitat for subyearling salmonids during their outmigration. In terms of velocity magnitude, habitat opportunity is defined as slow-moving environments with a velocity of less than 30 centimeters per second (approximately 1 foot per second). Using this definition of habitat opportunity, Table 6-1 shows the average number of hours in which the velocity criterion is met (over a 168-hour week) for the Cathlamet Bay region of the Columbia River estuary.

Modeling results were done for vertically averaged water column velocities and for minimum and maximum water column velocities. Both the spatial distributions and the area-weighted averages were similar for base and plan, indicating that channel deepening will have no effect on velocity magnitude. Maximum differences in average hours of approximately 10 to 15 percent (increase and decrease) between base and plan were predicted for model runs at both low and high flow. In these cases, the model runs for the Project scenario estimated higher habitat opportunity hours than the current situation.

Based on physical model results, the proposed Project will not cause significant changes to velocity in the shallow habitat areas of the lower Columbia River. WES modeling indicates base versus plan differences of less than 0.05 foot per second outside the navigation channel. The small computed differences in velocity for shallow areas between base and plan are much smaller than natural variations in velocity in these areas resulting from variations in freshwater flow and tidal dynamics. Furthermore, the computed differences in velocity between base and plan are smaller than the differences between computed velocity and observed velocity determined during model calibration.

River Mouth

Not applicable.

6.1.26.2 Conclusion

Based on modeling results, the proposed Project will not cause significant changes to velocity in the shallow habitat areas of the lower Columbia River. WES modeling indicates base versus plan differences of less than 0.05 foot per second outside the navigation channel. OHSU/OGI modeling actually indicates slight increases in habitat opportunity based on velocity. The small computed differences for both models are much smaller than natural ranges in velocity resulting from variations in freshwater flow and tidal dynamics. Furthermore, the computed differences in velocity between base and plan are smaller than the differences between computed velocity and observed velocity determined during model calibration. Velocity fields will be monitored as part of the Corps' monitoring plan (see Section 7).

6.1.27 Bathymetry and Turbidity (as Related to Salmonid Growth Opportunities)

The relevant aspects of bathymetry and turbidity in this section are the part they play in growth opportunities for salmonids. In the context of growth opportunity, this indicator refers to the ability of salmonids to see their prey. Because salmonids are visual predators, turbid waters may limit their ability to see prey, while uneven bathymetry may hide the prey from their sight.

6.1.27.1 Changes in Bathymetry

Riverine Reach

Changes to bathymetry could result to changes in the river level in this reach ranging from zero to 0.18 foot (approximately 2 inches) (see Section 6.1.7, Bathymetry). The analysis presented under Estuary, below, applies to this reach as well.

Estuary

As stated in Section 6.1.7, Bathymetry, the proposed Project could lead to changes in river bathymetry a number of ways, including:

- Dredging of material will directly increase water depth in dredged areas of the navigation channel by lowering the sediment bed elevation.
- Disposal of dredged material in-river will also affect water depth in some locations.
- The changes to channel geometry and river hydraulics can potentially alter the sediment dynamics in the system (see Section 6.1.2, Bedload, for discussion).

The primary changes to bathymetry will occur within the navigation channel. However, most salmonid feeding occurs in shallow water habitat areas. WES modeling indicates that areas outside of the navigation channel will undergo changes in water depth of less than 0.02 foot (approximately 1/4 inch). These small computed differences in water depth between base and plan are smaller than natural variations in water depth in the system that result from variations in freshwater flow and tidal dynamics. OHSU/OGI modeling supports the WES results and indicates that channel deepening will result in almost no change in habitat opportunity hours based on the depth criterion (number of hours that the water depth is between 4 inches and 6 feet for a given area). These changes are not anticipated to affect the ability of salmonids to find prey.

River Mouth

See Estuary, above.

6.1.27.2 Changes in Turbidity

As stated previously in Section 6.1.4, Turbidity, dredging and disposal operations are anticipated to increase turbidity in their immediate vicinity, at the time of their occurrence. These temporary increases could be several times background levels (for example, 25 NTU versus a background of 5 NTU). Dredging and disposal operations will occur at different times throughout the estuarine and riverine areas of the Project; disposal will also occur at the deep water site beyond the river mouth. Turbidity increases will be attenuated by turbulent mixing in riverine regions and by electrostatic effects caused by salinity in estuarine regions. In riverine and estuarine areas where neither dredging nor disposal is occurring, there will be no observable increase in turbidity.

Riverine Reach

See Estuary, below.

Estuary

Turbidity within the river will have short-term localized increases associated with dredging and disposal activities. As noted in Section 6.1.4, Turbidity, increases in turbidity levels from proposed activities are expected to be no more than 26 NTUs. Turbidity increases downstream of the activities will not exceed 1 NTU. As discussed in Section 4.1.1, these levels of turbidity are not sufficient to adversely affect salmonids.

River Mouth

See Estuary, above.

6.1.27.3 Conclusion

Riverine Reach

See Estuary, below.

Estuary

Changes to bathymetry and turbidity from proposed project activities will be minimal, localized around the actual navigation channel, and, in the case of turbidity, are anticipated to be only short-term changes. These changes are not anticipated to impair conditions that influence the ability of fish to locate their prey.

River Mouth

See Estuary, above.

6.1.28 Feeding Habitat Opportunity

The natural variability in the physical characteristics of lower Columbia River habitats affects the amount of total habitat available for use by young salmonids. The species/life stage most sensitive to changes in feeding habitat opportunity is ocean-type salmonids, which tend to feed near the shoreline and within zero to 2 meters of the surface. Generally the smaller ocean-type juveniles have the capacity to maintain sustained swimming speeds of 0.4 meter per second or greater over periods of hours (Davis, et al., 1963). For this reason, they can resist only relatively weak currents.

Yearling and older salmonids have less restrictive habitat requirements than juveniles and are consequently less susceptible to changes in feeding habitat opportunity. Generally, yearlings are not strongly shoreline-oriented, although some are found in shoreline areas. Yearlings tend to be surface-oriented, but feed over a relatively wide range of depths, from the surface up to 5 to 10 meters deep. Yearlings are commonly found in areas of both low and relatively high current speeds as they rapidly migrate downstream.

The only proposed action with the potential to affect feeding habitat opportunity is the dredging of the navigation channel. To have an effect, the dredging would need to cause substantial changes in water surface elevation, velocity (current speeds), salinity, or temperature. As discussed above and further below, the project is not expected to cause such changes.

6.1.28.1 Change in Water Surface Elevation, Velocity, or Salinity

Changes in water surface elevation, current speeds, or salinity resulting from the Project should not alter the location or amount of feeding habitat available to ocean-type juvenile salmonids. As discussed in Section 6.1.26 (Velocity Field), the anticipated change in velocity from the proposed action is expected to be minimal. In addition, the change in surface water elevation is expected to range from zero to 0.18 foot. and should not affect access to shallow water habitats (see Sections 6.1.5, Salinity, and 6.1.7, Bathymetry). Changes in salinity intrusion are also expected to be miniscule and are not expected to affect habitat opportunity (see Section 6.1.5, Salinity).

6.1.28.2 Change in Temperature

Temperature changes could occur within the estuary for a number of reasons, including salinity changes, depth changes, and velocity changes. Modeling results indicate that these potential factors for changing temperature conditions are not significantly altered by the proposed project activities. Model results indicate a negligible change in salinity for base versus plan conditions in all areas (see Section 6.1.5, Salinity). Model results also indicate negligible or no changes in depth and velocity for base versus plan conditions in all areas outside of the navigation channel (see Sections 6.1.7, Bathymetry, and 6.1.26, Velocity Field). Accordingly, changes in feeding habitat opportunity that result from temperature changes are not expected to occur.

6.1.28.3 Conclusion

Based on modeling results, the predicted changes in water surface elevations, velocities, salinity, and temperature are not enough to measurably change feeding habitat opportunity for young salmonids. However, as noted previously, the Project is expected to have no discernible effect on salmonid feeding habitat opportunity, but the Corps is proposing to monitor the variables that affect habitat opportunity to verify this conclusion (see Section 7).

6.1.29 Refugia

Refugia is a habitat function important to young salmonids because of their vulnerability to predators and need to escape currents in the river that exceed their swimming capacity (see Section 6.1.26, Velocity Field). Changes in refuge functions could occur through alteration of water surface elevation or flow velocity along shoreline habitats used by young salmonids during their rearing in the riverine and estuarine portions of the action area.

6.1.29.1 Changes in Water Surface Elevation

Riverine Reach

Shallow water and gently sloping shorelines are considered to provide refuge from fish predators; however, these same conditions increase exposure to some bird predators. This function is closely related to feeding habitat opportunity (see Section 6.1.28, Feeding Habitat Opportunity). Substantial changes in water depths in the range of several tenths of a meter or more might alter the amount or quality of shallow-water refugia available to juvenile salmonids. Within the estuarine and riverine reaches of the action area, water depths vary in the range of 2 to 9 feet within hours as a result of tidal forces. Seasonal changes in river discharge produce effects that increase this range by several meters. However, the modeling results indicate that changes in the surface water elevation caused by the Project are anticipated to be zero to 0.18 foot (approximately 2 inches).

Estuary

See Riverine Reach, above.

River Mouth

See Riverine Reach, above.

6.1.29.2 Changes in Velocity

Refugia functions as an escape from environmental conditions that exceed the normal physical capacities of young salmonids, including ability to swim against currents.

Riverine Reach

Currents (Section 6.1.26, Velocity Field) are the environmental condition most commonly exceeding the swimming capacity of young salmonids in the lower Columbia River riverine and estuarine habitats. Side channels, bays, islands, and fixed structures such as piers and piles provide refuge from strong riverine and tidal currents that could potentially displace young salmonids. Generally the smaller ocean-type juveniles have the capacity to maintain sustained swimming speeds of 1.5 feet per second or greater over periods of hours (Davis, et al., 1963). These ocean-type juveniles have the capacity to resist only relatively weak currents. Substantial increases in riverine or tidal currents (more than 10 decimeters per second) within the shoreline habitat juveniles commonly occupy would alter the amount or location of the refuge available to them. However, the modeling results from WES and OHSU/OGI show that changes in velocity caused by the Project are anticipated to be no more than 0.05 foot per second in shallow areas.

Estuary

See Riverine Reach, above.

River Mouth

See Riverine Reach, above.

6.1.29.3 Conclusion

The changes in water surface elevations projected within the estuarine and riverine reaches are not likely to alter the amount or location of refugia. In addition, changes to river current velocity from the proposed dredging are anticipated to be negligible (particularly in the side channels and shallow water areas that provide the refugia) and will not affect the function of the available refugia. The proposed monitoring program, which will include a post-project survey of habitat conditions, will specifically address refugia (see Section 7).

6.1.30 Habitat-Specific Food Availability

Young salmonids migrating through the lower Columbia River and estuary are rearing as they move. Ocean-type juveniles, in particular, spend prolonged periods rearing in shallow water areas within the estuary. Prey available to young salmonids rearing in the action area varies between freshwater and saltwater influenced areas, as well as between open water and shallow benthic areas. Prey also varies with seasons.

Prey availability is potentially influenced by changes in the physical habitat that alter the amount or distribution of shallow water habitats used by young salmonids. Three potential sources of effect have been assessed to determine whether changes to habitat-specific food availability will occur:

- Loss of shallow water area from side-slope adjustment
- Loss of shallow water and flats area from lowering of surface water elevations
- Changes in habitat-specific food availability as a result of changes in salinity

The first two sources of effect have already been dealt with in Sections 6.1.2, Bedload and 6.1.7 Bathymetry, respectively. Accordingly, the analysis in this section focuses on potential changes in food sources that may result from anticipated changes in salinity.

6.1.30.1 Changes in Habitat-Specific Food Availability as a Result of Changes in Salinity

Minor changes in salinity are not likely to produce changes in the shallow water and flats habitat that affect salmonids, including habitat-specific food availability. Existing salinity conditions within the estuary vary daily with tide condition and seasonally with changes in river discharge. Daily changes at specific locations can vary from low salinities of less than1 ppt to as high as 15 to 20 ppt. Modeling (see Section 6.1.5, Salinity) indicates an increase in salinity of from 0.1 to 0.15 ppt in shallow areas of the estuary, such as Cathlamet and Grays Bays.

Riverine Reach

The riverine reach is freshwater and is not affected by salinity.

Estuary

A review of salinity tolerances of *Corophium salmonis*, a major benthic invertebrate prey item for juvenile salmonids (Weitkamp, 1994), indicated a tolerance to salinity variations and the ability to recover following major perturbations in salinity conditions. However, changes in the range of 1 ppt may influence the distribution of *Corophium* at the extremes of its range at the downstream and upstream edges of its distribution (Holton, 1984). *Corophium* may not occur as far downstream as they currently do in the deeper portions of the river channel. However, most *Corophium* consumed by young salmonids are likely produced in the shallow habitats where the young salmonids feed. Salinity changes of 0.1 to

0.15 ppt in the surface water within these habitats are unlikely to affect the distribution of *Corophium* in areas where salmonids feed.

The change in shallow water salinity, in view of the much greater natural variation caused by tides and river flow, is unlikely to result in a measurable change in the species distribution of various shallow water and flats species within the estuary. Also, the extent of salinity distribution within the action area is unlikely to change within the shallow water and flats habitat areas.

River Mouth

See Estuary, above.

6.1.30.2 Conclusion

Prey resources for larger juvenile salmonids occupying the water column are not likely to be altered by the slight physical changes resulting from the Project. Physical changes within the shallow water areas where juvenile salmonids feed are not measurable and are not expected to affect juvenile food availability. However, the Corps' proposed monitoring program, which will include a post-project survey of ecosystem conditions, will address food availability (see Section 7).

6.1.31 Contaminants

This section examines whether the proposed Project adds to existing risks posed by bioaccumulative contaminants to juvenile salmonids that feed on epibenthic invertebrates when they are present in the action area. The contaminants examined focused on compounds that are environmentally persistent and bioaccumulate in fish and invertebrates, namely total polychlorinated biphenyls (ΣPCBs), total DDT and metabolites (ΣDDT), and total polyaromatic hydrocarbons (ΣPAHs). Because of the contaminants' physical properties, juvenile salmonids bioaccumulate them principally from food rather than from water. For hatchery fish, a key contaminant source is the hatchery food. For both hatchery and naturally produced stocks, key sources are areas where the sediments are highly contaminated by point sources of pollution.

6.1.31.1 Increase in Availability of Contaminants

In sediments, contaminants are absorbed to the organic carbon in silt, which is part of the fine particulate fraction (less than 0.064 micron in size). The microbial biofilm that accumulates on the surface of organic particles constitutes the food of certain types of epibenthic invertebrates; together, they make up the pathway by which these contaminants enter food chains involving juvenile salmonids. Preliminary evidence obtained by NMFS suggests that some salmonids may be at risk of being stressed by contaminants contained in the tissues of their epibenthic prey (L. Johnson, 2000). Dredging and disposal suspends fine particulates, and it has been hypothesized that these particulates may be deposited in an area where epibenthic prey of juvenile salmonids thrive. Within this zone, the contaminants may be more accessible to juvenile salmonid prey. Therefore, there is some potential for risk, and the purpose of this assessment was to examine risks from dredging sediments within the channel. Risks from sediments outside of the channel were examined in comparison to those associated with channel sediments.

A risk-based approach was used to address this question. The entire analysis is described in Appendix B. Figures B-1 through B-3 of that appendix summarize the results of the risk analyses for the lower estuary (RM zero to 40) for all three contaminant classes. These risk estimates are presumed to apply to all salmonids, including hatchery fish and nonendangered species. As can be seen from all three graphs, only negligible risks were predicted for the channel sediments that are proposed for dredging.

ΣPCB risks in the channel are negligible. Likewise, all ΣDDT exposures via channel sediments were below both the regional screening guideline and a lowest observed effect threshold developed from testing of cutthroat trout (Figure B-2). Cutthroat trout appear to be the salmonid most sensitive to DDT, so these results should apply to other juvenile salmonids. Finally, all ΣPAH exposures associated with channel sediments were lower than four effects criteria. For example, channel sediment ΣPAH concentrations were 41 parts per billion (ppb) dry weight or lower, whereas the most conservative effect criterion, proposed by Johnson (2000), was 54 ppb dry weight. Other ΣPAH effect criteria were much higher: 1,000 to 15,100 ppb dry weight (Figure B-3). For all contaminants, risks from shoreline sediments were higher than for channel sediments, and they were higher upstream than in the lower Columbia River.

Risks to the sediment-dwelling invertebrate prey of salmonids in channel sediments also were negligible, and the findings were very similar to those for juvenile salmonids, even though different methods were used to define what contaminant concentrations they might be exposed to and the toxicity of these contaminants.

The potential for cumulative risks appears negligible because all contaminants posed negligible risks. Because their specific modes of action are different and exposures were below effects thresholds, risks from PAHs, PCBs, and the DDT family are not additive. This result supports the overall conclusion concerning negligible risk potential to juvenile salmonids in the lower Columbia River as a result of the proposed Project.

Riverine Reach

Risks associated with Project sediments were negligible. Risks to salmonid juveniles were highest in the shoreline, non-project sediments of the riverine reach because there is a greater concentration of urban and industrial point sources in the Portland-Vancouver-Longview region; however, these levels should not exceed EPA/DMEF screening levels. Project actions will only occur in those areas when berths are being deepened. Sediment samples have shown that the materials to be dredged in these berths are suitable for in-water, unconfined disposal (see Section 3.2.4, Berth Deepening at Lower Columbia River Ports).

Estuary

Navigation channel sediments posed negligible risks. Risks were lower in the estuarine reach as compared with upstream reaches because there are fewer urban and industrial sources and greater, tidally driven dilution of contamination by ocean water.

River Mouth

Contaminant risks appear lowest in the river mouth reach because it is distant from most urban and industrial contaminant sources and its sediments and waters are most diluted tidally by oceanic water.

6.1.31.2 Conclusion

The potential for cumulative risks appears negligible because all contaminant levels posed negligible risks. Because their specific modes of action are different and exposures were below effects thresholds, risks are not additive. This result supports the overall conclusion concerning negligible risk potential to juvenile salmonids in the lower Columbia River as a result of the proposed Project. Monitoring actions for this indicator are addressed in Section 7.

6.1.32 Disease

Disease agents in salmonids of the Columbia River system include parasites, bacteria, and viruses. Many of the parasites and some of the bacteria co-exist with healthy fish, causing no observable decrease in fitness. However, it is possible that stress may induce such symbiotic relationships to become pathogenic by decreasing the immune capacity of the host fish (National Oceanic and Atmospheric Administration [NOAA], 2001) . Stress may be induced by environmental changes that are outside the variations normally experienced by salmonids. Crowding in fish hatcheries, fish ladders, or other areas of restricted habitat causes stress and also increases the chance of transmitting disease agents from sick fish to healthy fish. Increased water temperature, decreased flows, or reduced food availability are other possible stress factors. The preceding analysis of these parameters does not identify changes that are likely to cause immuno- suppression. Likewise, increases in levels of contaminants that may adversely affect the immune system (e.g., dioxins) as a result of this action are not predicted to occur (see Section 6.1.30, Habitat-Specific Food Availability, and Appendix B).

Riverine Reach

See above.

Estuary

See above.

River Mouth

See above.

6.1.32.1 Conclusion

No changes that are likely to substantially increase stressors for salmonids are anticipated. Accordingly, no increases in disease are expected as a result of proposed project activities.

6.1.33 Suspended Solids

Suspended solids are a factor in salmonids survival for a variety of reasons, including:

- The organic matter is a potential source of biological oxygen demand in the water column (addressed in Section 6.1.33, Suspended Solids).
- The organic material may be a pathway of transfer of contaminants to fish (addressed in Section 6.1.31, Contaminants).
- The material may have a detrimental effect on fish through clogging of gills (addressed in Section 6.1.33, Suspended Solids).
- The associated turbidity may impair feeding by reducing the ability of fish to see prey (addressed in Section 6.1.27, Bathymetry and Turbidity).

- Turbidity can also benefit juvenile salmonids by making them less susceptible to predation (addressed in Section 6.1.36, Turbidity).

As discussed in Section 6.1.1, Suspended Sediment, some changes to the sediment portion of suspended solids are expected to occur during construction and maintenance dredging activities at both dredging and disposal locations. Both dredging and disposal will occur in the estuarine and riverine environments, and disposal will also occur in the open ocean beyond the river mouth. The potential effects on salmonid prey and predation from changes in suspended solids are covered in Sections 6.1.27, Bathymetry and 6.1.36, Turbidity respectively. Consideration of changes in levels of the organic component of suspended solids is provided below. In addition, the potential for suspended solids to reach levels necessary to cause gill clogging is also discussed below.

6.1.33.1 Changes to Suspended Solids

Riverine Reach

See Estuary, below.

Estuary

The proposed dredging associated with the Project will occur within the navigation channel and will primarily entail removal of sand and sediments. Disposal activities will involve only those materials removed during dredging. The material at the bottom of the navigation channel is composed of over 99 percent sand and is low in organic content. The organic input to the system comes from both upriver sources and from tidal marsh and swamp areas. The proposed project activities are not anticipated to affect either of these sources (see Section 6.1.8, Tidal Marsh and Swamp Habitat). Accordingly, the proposed activities are not anticipated to alter the concentration or distribution of organic material within the river or estuary.

The likelihood of increased suspended solids causing gill clogging in migrating salmonids depends on a number of factors, including:

- Duration of exposure to suspended solids
- Concentration of suspended solids
- Particle size of suspended solids
- Angularity of suspended solids

The highest increases in suspended solids concentrations are anticipated to be localized and short term, occurring near the dredging and disposal operation (see Section 6.1.1, Suspended Sediments). The likely exposure for salmonids will be to the low concentrations (zero to 2 mg/L increases) that will occur downstream from dredging and disposal operations. In addition, less than 1 percent of dredged material will consist of the fines that are the cause of gill clogging (Sigler, et al., 1984). Accordingly, the anticipated slight increases in suspended solids will not be of a sufficient intensity or nature to cause gill clogging in salmonids.

River Mouth

See Estuary, above.

6.1.33.2 Conclusion

The organic component of suspended solids, which can cause the problems identified above for salmonids, is not expected to increase as a result of the proposed Project. Notable increases in sediments will occur only in localized areas and for short periods. To the extent that there are increases in the sediment portion of suspended solids, the effects are discussed in Section 6.1.1, Suspended Sediment.

6.1.34 Stranding

Subyearling salmonids rearing in water less than 3 feet deep can potentially be stranded by water level fluctuations. The following discussion focuses on whether changes in ship wakes will occur that will change the potential for stranding of salmonids.

6.1.34.1 Stranding Related to Ship Wakes

Fish encounter continuous water fluctuations, with tidally produced declines occurring twice each day. Thus, they appear to be adapted to surviving water level declines of several to many inches per hour. Likewise they commonly encounter storm-induced waves during their estuarine residence period. These waves range in height from 4 inches to several feet, depending on speed, fetch, and duration of the prevailing wind. These storm waves generally build up over short periods of time, likely giving the fish adequate opportunity to detect the worsening condition and move away from shallow areas where they might be stranded.

Unlike storm waves, ship generated waves will reach shoreline rearing areas with little warning. With beach slopes of 0.02to 0.1 foot per feet, these waves hypothetically could deposit fish from very shallow water to the dewatered portion of the beach.

Riverine Reach

The stranding of fish from ship wash is directly related to the size of the waves generated. Wave size is primarily a function of ship speed and is secondarily influenced by channel depth, distance from shore, and vessel draft. This suggests that regulating speeds of commercial marine traffic is one effective way to reduce potential stranding by large draft vessels. However, similar but more recent studies conducted in 1992 and 1993 showed little stranding as a result of wave action generated by large draft vessels. Just five juvenile salmonids were found to have been stranded on shore as a result of wave action (Hinton and Emmett, 1994). A 2001 analysis of whether the deeper draft ships will produce larger waves in a deeper channel indicates that little if any change is expected (Hermans, SEI Presentation, 2001) (see Section 6.1.1.3, Suspended Sediment Caused by Ship Wakes).

In addition to the deeper channel not causing increased wave sizes, it is also not expected to cause more frequent waves. The FEIS found that “channel deepening in itself will not induce additional ship traffic” or “contribute to development of additional ports or port facilities” (Corps, 1999a). This is consistent with historical vessel traffic trends on the Columbia River, as well as the market forces that drive port facility development.

Historical data for the existing 40-foot channel shows that the total tonnage carried by ocean-going vessels calling at the lower Columbia River ports has more than tripled since Congress authorized the deepening from 35 to 40 feet in 1962, while the number of vessel transits has actually decreased slightly. The same trend is expected if the channel is deepened to 43 feet. Regional and national commodity forecasts project cargo volumes transiting the lower Columbia River will double or triple over the next 20 years, but a deeper channel will likely reduce or moderate the volume of vessel traffic relative to a "no channel deepening" scenario.

Estuary

See Riverine Reach, above.

River Mouth

See Riverine Reach, above.

6.1.34.2 Conclusion

The Project is not expected to produce either a direct or an indirect effect on stranding of young salmonids. The Project is designed to provide greater navigation reliability and efficiency with existing vessels – not to increase the number of ships using the channel. In addition, vessel speeds and wakes are not expected to measurably change with the deeper channel. Thus, the stranding conditions are not likely to change with the proposed Project. However, the Corps proposes to conduct field surveys during juvenile outmigration to verify this conclusion (see Section 7).

6.1.35 Temperature and Salinity Extremes (as Related to Salmonid Survival)

Temperature and salinity extremes are important factors affecting juvenile salmonid survival, migration, and ocean entry. Because the Columbia River is water quality limited for temperature, it is particularly important to determine the extent to which the Project might change the temperature profile in the lower Columbia River and estuary system.

The primary project activities that have the potential to change salinity and temperature are dredging and in-water disposal. Although dredging will occur sporadically throughout the navigation channel from RM 3 to RM 106.5, most of the in-water disposal will occur downstream from RM 36.

6.1.35.1 Changes to Salinity

As discussed in Section 6.1.5, Salinity, alteration of the channel bathymetry, resulting from dredging and flowlane disposal, has the potential to change the relative balance between upstream freshwater velocities and ocean tidal forces.

Riverine Reach

Not applicable.

Estuary

Because longitudinal salinity gradients occur in the estuary portion of the system (RM 3 to 40), this is the area of concern with regard to impacts on salinity gradients. However, while salinity changes greater than 1 ppt are predicted to occur at the bottom of the navigation channel, changes at a given location in the shallow embayments of the estuary (especially in Cathlamet Bay) are predicted to be less than 0.1 to 0.15 ppt.

It should also be mentioned that the very small computed differences between base and plan for salinity in shallow areas are much smaller than natural temporal variations in these areas as a result of variations in freshwater flow and tidal dynamics. In other words, while the model predicts that some change is likely, that change will not be discernible given the large daily, monthly, and seasonal variations in the conditions affecting salinity in the estuary (see Section 6.1.5, Salinity).

River Mouth

See Estuary, above.

6.1.35.2 Changes to Temperature

The proposed Project's potential for affecting temperature in the action area is through alteration of tidal intrusion in the estuary. Other possible effects to temperature from the Project are from changes to velocity or depth.

Riverine Reach

Changes in water depth and velocity in this area are two other factors affected by the Project that could potentially affect temperatures. However, model results indicate negligible or no changes in depth and velocity for base versus plan conditions in all areas outside of the navigation channel (see Sections 6.1.7, Bathymetry, and 6.1.26, Velocity Field).

Estuary

Altering bathymetry has the potential to change the relative mix of upstream freshwater and ocean water. This ocean/freshwater mix occurs in the estuary portion of the system (RM 3 to 40); therefore, this is the primary area of concern for affecting temperature gradients.

The primary factor potentially affecting temperatures would be an increased penetration of cooler ocean water under plan conditions. This would reduce rather than increase the temperature of estuarine waters during summer months. However, model results indicate a negligible change in salinity for base versus plan conditions in all areas (See Section 6.1.5, Salinity). Therefore, a change in temperature as a result of increased intrusion is not anticipated.

River Mouth

See Estuary, above.

6.1.35.3 Conclusion

The modeling performed by WES and OHSU/OGI indicate that the physical factors most likely to result in changes in temperature and salinity will not be significantly affected by the proposed Project. Accordingly, no significant change to temperature or salinity is anticipated. However, the Corps proposes to conduct monitoring of temperature and salinity before, during, and after construction to verify this conclusion.

6.1.36 Turbidity

Increases in turbidity can reduce the ability of predators to see salmonids. This could increase survival of salmonids. A complete discussion of increases in turbidity levels is provided in Section 6.1.4, Turbidity. Turbidity aspects related to growth are discussed in Section 6.1.27, Bathymetry and Turbidity.

6.1.36.1 Decreased Predation and Ability to Feed Caused by Turbidity

There is the potential for short-term and localized elevation of turbidity levels during deepening and maintenance dredging activities at both dredging and disposal locations. These activities will occur in both estuarine and riverine environments; disposal will also occur in the open ocean, beyond the river mouth.

Riverine Reach

See Estuary, below.

Estuary

Increases in localized turbidity levels of 5 to 26 NTUs are possible as a result of proposed project activities. These increases will be short term (less than an hour) and confined to areas where dredging and disposal will occur. In riverine and estuarine areas where neither dredging nor disposal is occurring, there could be a zero to 1 NTU increase in turbidity levels.

River Mouth

See Estuary, above.

6.1.36.2 Conclusion

Temporary increases in turbidity are anticipated to occur in localized areas where dredging and disposal will occur. Changes to turbidity levels in shallow water areas outside of the active disposal areas are unlikely to exceed 1 NTU. Therefore, it is not expected that survival of salmonids will change from turbidity caused by the Project.

6.1.37 Predation

Predation is a major cause of the loss of young salmonids during their migration to the ocean. Because historical dredge material disposal practices led to the creation of additional predator habitat within the estuary, the analysis for the currently proposed project activities addresses steps taken to prevent a similar situation. Predation rates on young salmonids are potentially affected by factors that either influence the abundance of predators or the exposure of the young salmonids to predators. Substantial changes in habitat characteristics, not anticipated as a result of this Project, are the most likely cause for these effects.

For a detailed discussion of potential changes to habitats within the action area, see Sections 6.1.8 (Tidal Marsh and Swamp Habitat), 6.1.9 (Shallow Water and Flats Habitat), and 6.1.10 (Water Column Habitat).

Riverine Reach

See Estuary, below.

Estuary

Predation of juvenile salmonids is primarily by avian predators such as Caspian terns and cormorants. Past enhancement of avian predator habitat occurred as a result of creating upland habitat through dredge disposal. To ensure that the proposed Project does not repeat this, no disposal is planned for areas that would create or expand upland habitat areas that could be colonized by these predators. Adult salmonids are preyed on primarily by marine mammals and man during their return migration through the action area. No changes have been identified that are likely to alter the predation rates on adult salmonids.

River Mouth

See Estuary, above.

6.1.37.1 Conclusion

No changes to habitat areas are anticipated that would change the abundance of predators or salmonid exposure to those predators. Accordingly, no effects to predation on salmonids are expected as a result of the proposed Project.

6.1.38 Entrainment

Two potential effects from entrainment have been considered during the reconsultation process. First, the potential for salmonids to be directly entrained during dredge operations has been assessed. Second, the effects of entrainment of salmonid prey species during dredging operations have been considered.

6.1.38.1 Entrainment of Salmonids

The only documented entrainment of salmonids occurred during a study in which the dredge draghead was operated while elevated in the water column instead of on the channel bottom and while pumping (R2 Resource Consultants, 1999). No juvenile salmonids have been entrained during normal dredging operations (Larson and Moehl, 1990).

Dredging procedures call for the draghead to be buried in the sediment of the riverbed during dredging operations or raised no more than 3 feet off the river bottom when the pumps are idling to further reduce the potential for fish entrainment. Adult salmonids have sufficient swimming capacity to avoid entrainment by dredging if they are present in the vicinity of dredges and if the draghead is above the riverbed when operating. As noted in the discussion of pipeline and hopper dredging in Section 3, BMPs for dredging operations require that the dredge pump not be operated when the draghead is raised more than 3 feet above the river bottom.

Riverine Reach

It is not anticipated that any fish will be entrained during dredging operations in this reach.

Estuary

See Riverine Reach, above.

River Mouth

No dredging activities for the Project will occur within this reach.

6.1.38.2 Entrainment of Salmonid Prey

Entrainment of salmonid prey has been assessed to determine the potential to produce indirect impacts to young salmonids through loss of prey resources.

Riverine Reach

It is likely that benthic invertebrate prey such as *Corophium* will be entrained in active dredge areas within the navigation channel. However, the benthic prey consumed by young salmonids come primarily from the large areas of shallow water in the lower Columbia River, where channel dredging will not occur.

Entrainment of planktonic prey also potentially occurs during dredging. Prey resources such as *Daphnia* and similar organisms will be entrained. However, these planktonic invertebrates are numerous throughout the water mass of the lower Columbia River. The portion of the population lost through the small portion of the water mass entrained will be small compared with the amount lost continuously from the lower river in the river's discharge to the Pacific Ocean.

Estuary

See Riverine Reach, above.

River Mouth

No dredging activities for the project will occur within this reach. Also, for a discussion on the potential for entrainment of Dungeness crab, see Section 6.1.18, Mobile Macroinvertebrates.

6.1.38.3 Conclusion

Entrainment is not anticipated to have an effect on salmonids because BMPs will be followed that reduce entrainment of salmonids. In addition, salmonid prey that are entrained in the estuary will be limited to the navigation channel, where benthic productivity is low.

6.2 Effects on Pathways

This section addresses the specific effects of the project on the respective indicators at a broader ecological level of analysis. The effects discussed in Section 6.1 for individual ecosystem indicators are linked to a larger ecosystem scale by addressing how these effects might change pathways. This integrated approach considers the links inherent within the system, analyzing each of the ecosystem pathways identified in the conceptual model (habitat-forming processes, habitat types, habitat primary productivity, food web, growth, and survival).

6.2.1 Habitat-Forming Processes Pathway

Sections 6.1.1 through 6.1.7 discussed potential changes to the seven physical processes that are important to forming the habitats relied on by salmonids. The following potential changes to those processes were identified:

- There will be short-term, localized increases in suspended sediment concentrations in the immediate vicinity of dredging and disposal operations (see Section 6.1.1, Suspended Sediment).
- The Project may temporarily shift the direction of bedload movement along the sides of the navigation channel as a result of side-slope adjustments, which may cause erosion at some previous beach nourishment sites (see Section 6.1.2, Bedload).

- There will be short-term, localized increases in turbidity levels in the immediate vicinity of dredging and disposal operations (see Section 6.1.4, Turbidity).

- Salinity increases of less than 0.5 ppt in the shallow embayments of the estuary (e.g., Cathlamet Bay, Grays Bay) will occur. Salinity increases up to 5 ppt would occur in the bottom of the navigation channel (see Section 6.1.5, Salinity).

- The salinity wedge could potentially be shifted upstream up to a mile (see Section 6.1.5, Salinity), resulting in a possible shift in the ETM location.

- Bathymetric changes will include up to 3 feet of deepening in areas of the navigation channel that are currently shallower than -48 ft CRD and some rise in the riverbed at shoreline and flowlane disposal sites. In addition, there is a potential for zero to 3 feet of deepening along the side slopes adjacent to the dredge cuts (see Section 6.1.2.1, Potential Reduction in Volume of Bedload Caused by Removal of Channel Materials). Water surface elevation could be affected between RM 80 and 146. The decrease could be as much as 0.18 foot at the upstream end of the Project (see Section 6.1.7, Bathymetry).

Individual indicators and their potential effect on habitat-forming processes are discussed in the following paragraphs.

6.2.1.1 Increased Suspended Sediment

Suspended sediments are an important component of the habitat-forming process. There may be as much as a 4.5 percent increase in the total suspended sediment load in the lower Columbia River as a result of the Project. Increased suspended sediment levels would tend to improve habitat-forming processes in the estuary by providing additional materials to form tidal marsh and swamp habitat. However, the increased suspended sediment load is likely too small to have a measurable effect on habitat-forming processes.

6.2.1.2 Side-Slope Adjustment

The proposed Project will result in some side-slope adjustment as a result of altered bedload transport direction within the action area. This process will not affect water column or tidal marsh and swamp habitats. The side-slope adjustment process will take 5 to 10 years. Over that time, shallow water and flats habitat at six historical shoreline disposal sites will tend to move shorewards into former areas of artificial beach that have slowly eroded. All of these shoreline sites have been used in the past for dredge disposal. Two of the six historical shoreline disposal sites (Sand Island, RM 86.2, and Miller Sands, RM 22.5) will be used throughout the life of the Project. Because the bedload transport rate during maintenance sideslope adjustment is the same rate at which normal bedload transport would occur without the Project (just in a different direction), the quantity and quality of shallow water and flats habitat is expected to remain constant in the river and estuary reaches.

6.2.1.3 Increased Turbidity

Short-term localized turbidity levels of 5 to 26 NTUs that might be caused by the proposed action are not likely to produce detectable effects on plant growth in the lower river.

Not only is the amount of increase too low, but it will be localized to areas where dredging and disposal will occur. The highest levels of turbidity will occur in deep water and sandy beach areas that are not salmonid habitat.

6.2.1.4 Salinity Increases

The computed differences in modeling between base and plan for salinity in shallow areas are much smaller than natural temporal variations due to normal variations in freshwater flow and tidal dynamics. Differences computed for the channel bottom are increases up to 5 ppt. This will not affect habitat-forming processes in any of the three habitat types.

6.2.1.5 ETM Shift

The potential shift of the ETM would occur in a relatively small part of the south channel (see Section 6.1.5, Salinity). It would generally remain within the current range or path of the ETM, with up to a 1-mile shift in the upstream boundary. This change is smaller than the existing daily fluctuations caused by flow conditions. The ETM suspends nutrients in the estuary, which are then distributed by tides and currents in the river system. Any fluctuation in the location of the ETM that may result from the Project is not expected to affect the tidal influences and currents that distribute nutrients throughout the estuary. The effect of the potential shift of the ETM on distribution of nutrients in the estuary is expected to be so small that it cannot be measured.

6.2.1.6 Bathymetric Changes

The 3-foot lowering of the channel bathymetry will occur in 56 percent of the navigation channel. This is not expected to directly impair habitat-forming processes because the increase in water depth will be limited to the area of the navigation channel that will add 3 feet to the water column type of habitat. Flowlane disposal will occur in water column habitat. It will not have an effect on habitat-forming processes for any of the habitat types. The potential effects of changes in bathymetry on habitat-forming processes in tidal marsh and swamp and shallow water and flats habitat have been addressed earlier in the discussions of suspended sediment increases, side-slope adjustments, and salinity increases. Habitat opportunity, as defined by Bottom et al. (2001), considers water depth and velocity conditions that provide favorable habitat for juvenile salmonids. Using this definition of habitat opportunity, modeling results are nearly identical for base and plan, indicating that the proposed actions will not have an impact on habitat opportunity as it relates to water depth in the estuary (see Section 6.1.27, Bathymetry and Turbidity). Shoreline disposal will occur in areas where salmonid habitat is not present and will not affect habitat-forming processes (see Section 6.1.9, Shallow Water and Flats Habitat). Finally, bathymetric changes caused by the Project include a potential up to a 0.18-foot decrease in water surface elevation between RM 80 and 146. This is not anticipated to affect habitat-forming processes (see Section 6.1.7, 3, Changes in Water Surface Elevation Resulting from Hydrodynamic Changes).

6.2.1.7 Conclusion

Modeling performed for the proposed Project, as well as analysis provided in this document, indicate that there will not be any significant effect on habitat-forming processes as a result of the proposed Project. The Corps is proposing monitoring to verify this conclusion (see Section 7.3, Monitoring Actions).

6.2.2 Habitat Types Pathway

Sections 6.1.8 through 6.1.10 discussed potential changes to the three primary habitats of juvenile salmonids in the lower Columbia River. The following potential changes to these habitat areas were identified:

- Side-slope adjustments associated with the Project may cause a shift in the location of shallow water habitat-forming processes in areas where the navigation channel is adjacent to previous shoreline disposal sites (see Section 6.2.1.2, Side-Slope Adjustment).

- Shoreline disposal could potentially disturb and shift the location of shallow water habitat at three proposed deposit sites: Sand Island, Miller Sands, and Skamokawa Beach (see Figure 3-4 and Appendix C).

- Water column habitat will be directly affected by the increased depth (approximately 3 feet) of the water column within a portion of the navigation channel in the action area (see Section 6.2.1.6 Bathymetric Changes).

- Water column habitat may be affected by drilling and blasting activities

- Water clarity may be reduced temporarily by the action of the dredge head on the bottom of the navigation channel and by flowlane disposal of dredged material (see Section 6.2.1.1, Increased Suspended Sediment, and Section 6.2.1.3, Increased Turbidity).

- Proposed dredging timelines are consistent with the existing BO for O&M dredging because dredging occurs in areas where salmon are not present at depths greater than 20 feet (see Table 3-1).

As noted, several of these potential effects are discussed in Section 6.2.1, Habitat-Forming Processes Pathway. The possible effects on the Habitat Types Pathway from the other indicator changes are discussed in the following subsections.

6.2.2.1 Shoreline Disposal

While the three identified shoreline disposal sites have the potential to affect salmonid habitat areas, an assessment of the sites concluded that they do not contain many of the important habitat features that shallow water habitats used by salmon typically include, such as low velocity, vegetation, and food sources. These areas likely provide a corridor for migrating salmonids, and, consequently, there is some potential effect from this action.

6.2.2.2 Drilling and Blasting

Blasting will be done during the preferred in-water work window. This is the period when salmonids abundance is lowest and will minimize impacts to the listed stocks. In addition, since there may be some fish in the river, the blasting plan will be designed to further minimize any impacts by keeping over pressures above the blast zone to less than 10 psi. This level is generally believed to be below the level at which salmonids would be adversely affected. A state approved plan for blasting will also be developed to further minimize impacts. Based on the above, the potential impacts to water column habitat will be minimized.

6.2.2.3 Timing Windows

Dredging and disposal during construction will be done year-round for 2 years. Although this is outside of the normal November 1 through February 28 in-water work period for the lower Columbia River it is not anticipated that it will have a significant effects on listed salmonids. Salmonids normally do not occur to any extent in the areas being dredged or the disposal sites (except the three shoreline sites). Juvenile salmonids normally migrate along the channel margins using the side slopes as structure

(Carlson et al., 2001). They occur primarily at depths less than 20 feet and so would not be expected to be affected by dredging and disposal operations. Although they can occur near the three shoreline disposal sites, these sites, are highly erosive and do not provide much, if any, habitat. Based on the above, potential impacts associated with project timing will be minimized.

6.2.2.4 Conclusion

Although none of the identified indicator changes discussed above is believed to have a measurable effect on existing habitat types, the Corps is proposing to implement compliance measures to ensure effects will be minimized and will also monitor to confirm this conclusion.

6.2.3 Habitat Primary Productivity Pathway

Sections 6.1.11 through 6.1.16 discussed potential changes in the six factors that are important to primary productivity within salmonid habitat. The following potential changes to primary productivity were identified:

- Short-term reductions in light may result in localized, short-term reductions in photosynthesis by benthic plants and phytoplankton.
- Change in salinity intrusion may affect the location of resident phytoplankton productivity, the location where imported freshwater phytoplankton contact intolerable salinity extremes, and the location of benthic algae productivity. These productivity changes are anticipated to be undetectable (see Section 6.1.14, Resident Phytoplankton Production, and 6.1.15, Benthic Algae Production).

The potential effects to the Habitat Primary Productivity Pathway resulting from the identified indicator changes are discussed in the following subsections.

6.2.3.1 Light Reduction

While short-term reductions in light may result in short-term reductions in photosynthesis by benthic plants and phytoplankton, these changes are not of sufficient duration to result in a loss of vegetation or measurable biomass production. The ephemeral and transient nature of the activities suggests that a reduction in light penetration would occur for only very short periods of time. In addition, the reductions will occur primarily in deep water areas that do not support large amounts of vegetation other than phytoplankton.

6.2.3.2 Salinity Change

No change in type or quantity of imported phytoplankton within the system is anticipated. In addition, while resident phytoplankton will expand its range in correlation with any upstream expansion of salinity, this effect on phytoplankton will not be measurable because the upstream expansion of salinity is not anticipated to be measurable. There may be a small upstream expansion of benthic algae production, but this is difficult to determine because a myriad of diatom species that make up the flora are euryhaline. None of these slight changes would have a measurable effect on primary productivity within the system.

6.2.3.3 Conclusion

No changes to primary productivity are anticipated as a result of the proposed Project.

6.2.4 Food Web Pathway

Sections 6.1.17 through 6.1.24 discussed potential changes in eight relevant components of the food web in the lower Columbia River. The following potential changes to those eight food web components were identified:

- Limited removal and burying of deposit feeders, suspension/deposit feeders, and suspension feeders will occur in portions of the navigation channel and deep water areas.
- Dredging and disposal actions will result in loss of adult and juvenile mobile macroinvertebrates.
- There may be a slight upstream shift in the ETM, which would be accompanied by a slight shift in the focus of resident and imported microdetritus food web input (see Section 6.2.3.2, Salinity Change).

Potential changes resulting from the shift in the ETM are discussed in Section 6.1.5, Salinity. Potential changes to Dungeness crab populations are discussed below.

6.2.4.1 Effect on Deposit Feeders, Suspension/Deposit Feeders, and Suspension Feeders

Removal and burial effects on these organisms are expected to be relatively short-lived, with dredge and disposal areas being recolonized. These organisms occur in low densities in the navigation channel because the sand waves create unstable habitat conditions. In these and other areas of the river, densities fluctuate as a result of constantly changing environmental conditions. No changes to these organisms are anticipated in shallow water areas, side channels, or embayments, which are the important locations for salmonid feeding opportunities. Regardless, the Corps' proposed monitoring program will include a post-project survey of ecosystem conditions that will address these organisms in shallow water areas.

6.2.4.2 Effect on Mobile Macroinvertebrates

Some mortality of mobile macroinvertebrates by dredging and disposal operations will occur; however, this mortality is expected to have an insignificant effect on these populations in either the estuary or the river mouth. Mobile macroinvertebrates are adapted to respond rapidly to disturbances, and to re-colonize areas following these disturbances. Mobile macroinvertebrates can be an important food item for salmonids in estuaries. Changes in mobile macroinvertebrate populations resulting from project actions are not anticipated to be large enough to affect the salmonid food web.

6.2.4.3 Conclusion

No significant changes to the food web are anticipated as a result of the proposed Project.

6.2.5 Growth Pathway

Sections 6.1.25 through 6.1.30 discuss potential changes in six important factors that can influence the growth of salmonids. No significant potential changes to those six growth factors were identified.

6.2.5.1 Conclusion

No changes to the Growth Pathway are anticipated as a result of the proposed Project.

6.2.6 Survival Pathway

Sections 6.1.31 through 6.1.38 discuss potential changes in eight important factors that can influence the survival of salmonids. The following potential change to those eight important survival factors was identified:

- A turbidity plume associated with dredging and disposal activities could increase salmonid predation. The potential for changes to the turbidity indicator is discussed below.

6.2.6.1 Turbidity Increase

Sediment increases are likely to be localized in deeper water and sandy beach areas and will be of short duration. In particular for juvenile salmonids, the turbidity increase is unlikely to affect survival because juveniles do not use these areas.

6.2.6.2 Conclusion

No changes to the Survival Pathway are anticipated as a result of the proposed Project.

6.3 Project Effects on Listed Species and their Habitat

This section uses the conceptual model to evaluate how identified effects to the ecosystem (as determined from the pathways analysis in Section 6.2) may affect the listed and candidate salmonid species (short-term effects). It also addresses potential effects on the Columbia River ecosystem over the 50-year life of the Project (long-term effects).

6.3.1 Potential Short-Term Ecosystem Effects

The following are the potential ecosystem pathway effects that have been identified through application of the conceptual model:

- There may be a temporary loss of shallow water habitat associated with dredge material disposal at three shoreline disposal sites.

- Water column habitat may be affected by drilling and blasting activities.

- Proposed dredging timelines are consistent with the existing BO for O&M dredging. In addition, dredging will occur in areas that salmonids do not use at depths greater than 20 feet.

6.3.2 Shoreline Disposal of Dredge Material

One shoreline disposal site is located within the riverine reach at Sand Island (O-86.2). The site is a beach nourishment site intended for disposal during both construction and maintenance dredging. Two shoreline disposal sites are located within the estuarine portion of the action area – Miller Sands Island, which is located within the estuary at O-23.5, and Skamokawa Beach, which is located at W-33.4.

A narrow band of shallow water will be affected by disposal at these shoreline disposal sites. However, because there is so little actual habitat within the potential disturbance areas for these three disposal sites, there is very little potential for actual effects on salmonids. To eliminate even this slight potential, the Corps is proposing impact minimization measures that should ensure there be no actual impact to salmonids. These are discussed in Section 7.4, Compliance Actions.

6.3.2.1 Drilling and Blasting

The proposed compliance measures associated with drilling and blasting activities are anticipated to be adequate to prevent effects on listed species. Monitoring will be performed to ensure that this conclusion is accurate. If impacts to listed species are identified by monitoring, then appropriate compensation will be negotiated with the Services (see Section 9).

6.3.2.2 Timing Windows

The compliance measures associated with the proposed project timing are anticipated to be adequate to prevent effects on listed species. Monitoring will be performed to ensure that this conclusion is accurate. If impacts to listed species are identified by monitoring, then appropriate compensation will be negotiated with the Services (see Section 9).

6.3.3 Potential Long-Term Ecosystem Effects

During the reconsultation process, concerns have been identified regarding potential long-term effects of the Project. These have centered on minor changes that may be caused by Project actions that are not detectable in the short term, but may affect listed salmonid habitat over the next 50 years. This could also include ecosystem effects that are not identifiable, given the current understanding of the ecosystem. Areas for which concern has been expressed during this reconsultation include those related to the ETM, formation and preservation of tidal marsh and swamp habitats, habitat opportunity changes in isolated geographic areas, and elimination of connectivity between habitats relied on by juvenile salmonids.

The Corps recognizes that this is an issue that needs to be addressed by this BA. Section 7 contains actions to gather information that will be used to address effects that are not detectable in the short-term (see Table 7-1, Monitoring Actions Associated with Dredging and Disposal). Section 8.3 contains actions that will address ecosystem research that is aimed at advancing the knowledge base for the recovery of the listed salmonids. This research may result in identification of effects that are not currently understood, given the current knowledge of the ecosystem.

6.3.4 Conclusion

None of the identified potential effects are anticipated to measurably affect salmonids; however, there is uncertainty associated with ecosystem processes that warrant implementing specific impact minimization, monitoring, and research actions (see Section 7.3, Monitoring Actions; Section 7.4, Compliance Actions; and Section 8.3, Ecosystem Research Actions).

6.4 Activities Not Included in this BA

Although 11.6 miles of the Willamette River are included in the channel deepening project authorized by Congress, deepening in the Willamette River channel is not analyzed in this BA because intervening events have placed Willamette channel deepening into a separate process and time line.

Concerns over sediment contamination and uncertainty regarding the scope and timing of remedial investigations and actions in the Willamette River led the Sponsor Ports to ask that the Corps delay deepening work on the Willamette channel. Subsequently, EPA designated Portland Harbor, which includes a 5.5-mile portion of the navigation channel, as a federal Superfund cleanup site. The Superfund listing only increases the uncertainty surrounding the timing of any channel improvements in the Willamette River. These intervening events make it impossible to meaningfully analyze potential effects on listed species or critical habitat at this time.

Cleanup under the Superfund program will involve extensive study of the area, evaluation of alternatives, and public involvement in the selection of a final cleanup plan. The final cleanup plan selected by EPA may result in changes to the previously proposed channel improvements for the Willamette River – changes that cannot be anticipated at this time. Any improvements to the channel in the Willamette River will therefore take place under conditions different from those found today – i.e., conditions reflecting the Superfund cleanup. Accordingly, the Sponsor Ports and the Corps will not move forward on deepening in the Willamette River channel until plans are fully in place for the necessary remediation. Further, once remediation plans are in place, the Corps plans on re-evaluating the costs and benefits of the Willamette River reach to ensure that deepening it is still justified. Finally, at such time as the Sponsor Ports and the Corps may proceed with channel improvements activities for the Willamette River, the Corps will review the project through a separate ESA consultation process.

Similarly, with the exception of berth deepening, future development of other port facilities is not analyzed here because such development will be caused by regional market factors such as commodity demand, not by channel deepening. The Corps' NEPA analysis supports the finding that berth deepening constitutes the only anticipated indirect effect of channel deepening.

The FEIS found that channel deepening in itself will not induce additional ship traffic – or contribute to development of additional ports or port facilities (see Corps, 1999a, Section 6.8, Socio-Economic Resources and Section 6.9, Secondary Impacts). This conclusion is consistent with historical vessel traffic trends on the Columbia River and with the market forces that drive port facility development.

Although channel deepening is critical to the Pacific Northwest region's ability to competitively handle the projected increase in cargo, deepening is not dependent on, and is not likely in and of itself to cause development of, additional marine terminal facilities. Separate studies forecast that cargo volumes transiting the Portland/Vancouver harbors will double over the next 20 years (ICF Kaiser et al., 1999), while seaport volumes at the Washington Columbia River ports will increase by 38 percent over the same period (ICF Kaiser, et al., 1999). These are unconstrained projections of cargo demand, which make no assumptions about channel depth or other infrastructure improvements.

The lower Columbia River ports have no plans to build new marine terminals to accommodate or respond to channel deepening. Similarly, there are no known plans by private developers to add terminal capacity as a result of, or contingent on the channel deepening. Sufficient overcapacity exists at the Port of Portland's Terminal 6 container terminal and at the existing grain elevators at the lower Columbia River ports to accommodate increased cargo volumes without requiring immediate new development.

Channel deepening is not likely to induce development of additional ports or port facilities. Future additions to Columbia River marine terminal capacity will be driven by market demand. "More or less demand for goods shipped from the lower Columbia River ports would occur with or without a deeper channel" (Corps, 1999a). However, "a deeper channel would help maintain the competitive position of the Columbia River ports" (Corps, 1999a) by allowing more cargo to be carried on about the same total number of vessels that call at these ports today. Any future terminal development or expansion undertaken to accommodate increased cargo volumes caused by market demand would be subject to separate environmental analysis and regulatory approvals.