CHAPTER 5

Management Actions

Chapters 3 and 4 of this recovery plan module identify factors that currently limit salmonids' biological performance in the estuary and the threats that contribute to those limiting factors. Chapter 5 presents 23 management actions that, together, address the range of threats salmonids in the estuary face, from altered habitat-forming processes to structures in the estuary, changes in the food web, and poor water quality. If implemented, the actions presented in this chapter would reduce the impacts of threats to salmonids during their migration and residency in the estuary and plume.

In addition to identifying the management actions, Chapter 5 evaluates them in terms of constraints to implementation, potential improvement in salmonid survival, and cost. More specifically, the chapter discusses each management action's potential benefits and implementation constraints, hypothesizes how benefits could translate into increased survival of salmonids, breaks each action into component projects, and estimates the cost of each project, and thus of each action. Also included is a list of actions that would address threats to salmonids in the estuary but that would need to be implemented outside the estuary, in either estuary tributaries or upstream areas of the Columbia River basin.

As in other chapters of this recovery plan module, the analysis in Chapter 5 does not fully capture the subtleties of the ecological interactions that influence salmonid survival. Despite continuing research, many aspects of the salmonid life cycle are poorly understood, in part because of the sheer complexity of the ecosystems that salmonids transition into and out of during their lives. The actual relationships among threats and management actions are far more intricate than what is described here. Additionally, given the limits in scientific understanding, there is a degree of uncertainty at each step of the analysis in this chapter. Yet the categories, ratings, and associations presented here are useful tools for discussing complex ecological relationships and comparing possible outcomes of different management actions.

Identification of Management Actions

For the purposes of this recovery plan module, a management action is any action that has the potential to reduce the impact of human-caused or naturally occurring threats to salmonids while they migrate or rear in the estuary, plume, and nearshore. Management actions were identified using available literature and input from area experts. Key documents used to identify management actions are the "Mainstem Lower Columbia River and Columbia River Estuary Subbasin Plan" (Northwest Power and Conservation Council 2004) and its supplement; *Role of the Estuary in the Recovery of Columbia River Salmon and Steelhead (*Fresh et al. 2005); *Salmon at River*'s *End* (Bottom et al. 2005); and the *2004 FCRPS Biological Opinion on Remand* (National Marine Fisheries Service 2004). Table 5-1 lists threats to salmonids in the estuary and plume and management actions that would address those threats.

Several of the management actions in Table 5-1 are associated with more than one threat (italics indicate an action's second occurrence in the table). This illustrates the complex interplay of ecological processes in the estuary, particularly those related to flow, sediment, the food web, and water quality, all of which influence salmon survival. Again, given the complexity of the riverine, estuarine, and marine ecosystems that salmon use during their lives, the actual relationships among threats and management actions are more complicated than Table 5-1 suggests.

TABLE 5-1
Management Actions to Address Threats

	Threat	Management Action
Flow-related threats	Climate cycles and global warming[2]	**CRE[1]-1:** Protect intact riparian areas in the estuary and restore riparian areas that are degraded.[2] **CRE-2:** Operate the hydrosystem to reduce the effects of reservoir surface heating, or conduct mitigation measures. [2] **CRE-3:** Establish minimum instream flows for the estuary that would help prevent further degradation of the ecosystem. [2]
	Water withdrawal	***CRE-3:*** *Establish minimum instream flows for the estuary that would help prevent further degradation of the ecosystem.*
	Flow regulation	**CRE-4**: Adjust the timing, magnitude and frequency of flows (especially spring freshets) entering the estuary and plume to provide better transport of coarse sediments and access to habitats in the estuary, plume, and littoral cell.
Sediment-related threats	Entrapment of fine sediment in reservoirs	**CRE-5:** Study and mitigate the effects of entrapment of fine sediment in reservoirs, to improve nourishment of the littoral cell.
	Impaired transport of coarse sediment	**CRE-8:** Remove pilings and pile dikes with low economic value when removal clearly would improve ecosystem health. **CRE-6:** Reduce the export of sand and gravels via dredge operations by using dredged materials beneficially. ***CRE-4:*** *Adjust the timing, magnitude and frequency of flows (especially spring freshets) entering the estuary and plume to provide better transport of coarse sediments and access to habitats in the estuary, plume, and littoral cell.*
	Dredging	**CRE-7:** Reduce entrainment and habitat effects resulting from main- and side-channel dredge activities in the estuary.
Structural threats	Pilings and pile dike structures	**CRE-8:** Remove pilings and pile dikes with low economic value when removal clearly would improve ecosystem health.
	Dikes and filling	**CRE-9:** Protect remaining high-quality off-channel habitat from degradation. **CRE-10:** Breach or lower dikes and levees to improve access to off-channel habitats.
	Reservoir-related temperature changes	***CRE-2:*** *Operate the hydrosystem to reduce the effects of reservoir surface heating, or conduct mitigation measures.*
	Over-water structures	**CRE-11:** Reduce the square footage of over-water structures in the estuary.

Food web-related threats	Reservoir phytoplankton production	***CRE-10:** Breach or lower dikes and levees to improve access to off-channel habitats.*
	Altered predator/prey relationships	**CRE-13:** Manage pikeminnow and other piscivorous fish, including introduced species, to reduce predation on salmonids. **CRE-14:** Identify and implement actions to reduce salmonid predation by pinnipeds. **CRE-15:** Implement education and monitoring projects and enforce existing laws to reduce the introduction and spread of noxious weeds. **CRE-8:** Remove pilings and pile dikes with low economic value when removal clearly would improve ecosystem health. **CRE-16:** Implement projects to redistribute part of the Caspian tern colony currently nesting on East Sand Island. **CRE-17:** Implement projects to reduce double-crested cormorant habitats and encourage dispersal to other locations. **CRE-18:** Reduce the abundance of shad in the estuary.
	Ship ballast practices	**CRE-19:** Prevent new invertebrate introductions and reduce the effects of existing infestations.
Water quality-related threats	Agricultural practices	***CRE-1:** Protect intact riparian areas in the estuary and restore riparian areas that are degraded.* ***CRE-9:** Protect remaining high-quality off-channel habitat from degradation.* **CRE-20:** Implement pesticide and fertilizer best management practices to reduce estuary and upstream sources of toxic contaminants entering the estuary.
	Urban and industrial practices	***CRE-9:** Protect remaining high-quality off-channel habitat from degradation.* **CRE-21:** Identify and reduce industrial, commercial, and public sources of pollutants. **CRE-22:** Monitor the estuary for contaminants and/or restore contaminated sites. **CRE-23:** Implement stormwater best management practices in cities and towns. ***CRE-1:** Protect intact riparian areas in the estuary and restore riparian areas that are degraded.*
Other threats	Riparian practices	***CRE-1:** Protect intact riparian areas in the estuary and restore riparian areas that are degraded.*
	Ship wakes	**CRE-12:** Reduce the effects of vessel wake stranding in the estuary.

[1] CRE = Columbia River estuary.

[2] It is unclear what the regional effects of climate cycles and global warming will be during the coming decades. In the absence of more definitive data on the future effects of climate cycles and global warming in the Pacific Northwest, this recovery plan module takes a conservative approach of assuming reduced snowpacks, groundwater recharge, and stream flows, with associated rises in stream temperature and demand for water supplies. The climate-related management actions in Table 5-1 reflect this assumption. Although the management actions clearly would not change the threat itself, they have the potential to lessen its impact on salmonids in the estuary. Even if climate cycles and global warming have effects different from those assumed in this document, the management actions that Table 5-1 associates with climate would provide benefits to salmonids by addressing other threats, such as water withdrawal, urban and industrial practices, and reservoir heating. All three of the management actions associated with climate in Table 5-1 are associated with other threats listed in Table 5-1.

Note: Italics indicate an action's second occurrence in the table, in connection with a different threat.

The estuary recovery module also identifies specific monitoring, research, and evaluation activities appropriate to the 23 management actions. These activities will provide crucial information on the effectiveness of actions that are implemented in the estuary, associated changes in the ecology of the estuary, and scientific uncertainties that affect implementation of the actions. Monitoring, research, and evaluation activities are presented in Chapter 6.[1]

Other Recommended Management Actions

In many ways, conditions in the estuary are the sum of ecological stressors that exist throughout the Columbia River basin. Although some threats to salmonids in the estuary originate exclusively in the estuary itself (Caspian tern predation is one example), others are the result of activities in estuary tributaries or in upstream areas; examples of such threats are riparian practices and upstream water withdrawals that reduce stream flow in the estuary. Still other threats, such as land use practices that contribute contaminants to the river, originate in all three areas—estuary, estuary tributaries, and upstream. Because of the geographic scope of these threats, fully addressing them will require effort not just in the estuary but throughout the basin.

When it comes to management actions, though, the geographic scope of this estuary recovery plan module is limited. For the most part the module focuses on management actions that can be implemented within the estuary itself and that will address threats that either originate exclusively within the estuary itself or have a significant in-estuary component. The assumption is that threats originating from outside the estuary are affecting local conditions in tributary and upstream areas and that actions to address these threats will be included in recovery plans being developed for upstream salmonid populations.

Even so, the analysis in Chapters 3 and 4 of this recovery plan module and a review of contemporary literature yielded four management actions that would directly affect threats to salmonids in the estuary yet would need to be implemented almost exclusively outside of the estuary:

- Upgrade up-river irrigation structures to reduce evaporation and conveyance losses and improve estuary instream flows.
- Implement public and private water system conservation practices to maximize instream flows entering the estuary.
- Incorporate water availability analysis in land use planning activities to ensure efficient use of water, improve tributary flows, and reduce stream temperatures.
- Protect and restore riparian areas in tributaries to provide shade and future wood sources.

Because these four actions are outside the geographic scope of the estuary recovery plan module, they are not analyzed in this chapter. Nevertheless, implementation of these four out-of-estuary actions is important to improving the survival of salmonids in the estuary, so

[1] Monitoring, research, and evaluation (MR&E) activities appropriate to the 23 management actions are in the process of being identified and will be included in the module at a later date. Some of these activities are already described as part of the draft *Federal Columbia River Estuary Research, Monitoring, and Evaluation Program* (Johnson et al. 2006), while other activities are being identified that are specific to the management actions in the module.

it is recommended that the actions be included in recovery plans being developed for upstream areas of the Columbia River basin.

One factor that is beyond the geographic scope of the estuary recovery plan module but is addressed in the module in a limited manner is hydrosystem operations, which affect water temperature, sediment transport, and various other habitat-forming processes and conditions in the estuary. Although actual operation of the hydrosystem occurs outside the estuary, the system's effects are considered in the module because they are such significant determinants of habitat conditions for juvenile salmonids in the estuary. Also, unlike the recommended out-of-estuary actions listed above, hydrosystem operations that affect estuarine habitat are unlikely to be addressed in recovery plans being developed for upstream areas of the Columbia River basin. For these reasons, the estuary recovery plan module includes two management actions (CRE-2 and CRE-4) that focus specifically on hydrosystem operations.

The recommendation of out-of-estuary actions to improve survival in the estuary is another reflection of the interconnectedness of the various ecosystems salmonids use during their life cycles, the power of the river as a connector, and how the effects of problematic upstream activities are manifested—and sometimes magnified—in the estuary.

Evaluation of Management Actions: Constraints to Implementation

Constraints to implementation are a key factor in evaluating management actions and their likely impacts on salmonids. No management action can benefit salmonids if it cannot be implemented, and in many cases the degree of benefit corresponds to the degree of implementation. For this reason, the 23 management actions identified above are evaluated in terms of the constraints to their implementation, which yields information about the actions' likely outcomes and starts to provide a basis for comparing the probable effectiveness of different actions.

For each management action, Table 5-2 summarizes the primary threat and limiting factors that the action addresses and expresses the significance of those threats and limiting factors in terms of a threat index. (The threat index indicates whether the threat is a major contributor to a significant limiting factor or a minor contributor to a minor limiting factor. The index is useful in distinguishing those actions that, even if they were successful, would affect a relatively small number of fish from those actions that, even if they were only partially implemented or partially successful, would have more profound benefits because they would affect a larger number of fish.) Table 5-2 also provides a score for the potential benefit to salmonids in the estuary if implementation of the action were completely unconstrained, plus a brief rationale for the score.

Assigning a score for potential benefit with unconstrained implementation is just the first step in evaluating management actions. In fact, decisions about management actions will be made within a complex social and political context that includes a wide variety of interests, and it is likely that many of the actions will not be able to be implemented fully because of various technical, financial, political, or social obstacles. To address this issue Table 5-2 assigns an implementation constraints score to each management action and briefly explains how implementation of the action could be constrained by various factors. By design, the estuary recovery module takes a relatively optimistic view about what is possible in terms of reducing the constraints to implementation of management actions. This means that even the score in Table 5-2 for constrained implementation of an action may represent a higher degree of implementation than is likely to actually occur. However, some constraints may be reduced over time, such as through technology advances or changes in economic sectors; as a result, some actions may have greater potential for implementation than is represented in this recovery plan module.

The table concludes with a score for potential benefit of each action assuming that implementation of the action is constrained. This score is an attempt to identify more realistically what the results of an action would be given the social, political, and financial climate in which management actions will be decided on, but it also assumes that considerable effort is made to reduce constraints to implementation. Also, the difference in Table 5-2 between potential benefit with unconstrained implementation of an action and potential benefit with constrained implementation is helpful in identifying where it might be worthwhile to expend effort to reduce constraints because the benefits would be great. This topic is discussed more fully in Chapter 7.

Some measure of caution should be exercised when viewing the results of this evaluation. In particular, scientific literature generally falls short of prescribing discrete actions to address threats, and the literature is even less robust when it comes to evaluating constraints to the implementation of actions.

TABLE 5-2
Constraints to Implementation of Management Actions

Management Action CRE-1:
Protect intact riparian areas in the estuary and restore riparian areas that are degraded.

Primary threat this action would address		**Riparian Practices.** Riparian areas provide key ecological functions that affect water temperature, the availability of insects, and macrodetrital inputs to the ecosystem. Riparian areas in the lower Columbia River have been degraded by a number of factors, including shoreline modifications, diking and dike maintenance practices, and activities related to the disposal of dredged material.
Associated limiting factors		Water temperature, reduced macrodetrital inputs, and exotic plants.
Threat index[1]	10	This threat is a secondary contributor to two top-priority limiting factors (water temperature and reduced macrodetrital inputs) and a tertiary contributor to one additional limiting factor.
Potential benefits with unconstrained implementation of action [2]	4	Protecting intact riparian areas and restoring degraded riparian areas in priority reaches would provide significant benefits to salmonids by reducing water temperatures and increasing macrodetrital inputs to the system.
Affected salmonids		Ocean-type salmonids; stream-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings).
Implementation constraints[3]	3	Levels of protection vary across the lower Columbia region. In some cases, riparian areas in cities and counties are protected through regulatory mechanisms such as growth management or shoreline rules. Regulatory tools such as buffer zones along streams can be effective but require broad public support over time. Restoration projects are expensive and can take decades to provide their full benefit to tributaries directly entering the estuary.
Potential benefits with constrained implementation of action	2	

[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.

[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.
1 = very low benefits.
5 = very high benefits.

[3] Indicates the feasibility of implementing the action.
1 = Current constraints to implementation are minimal.
5 = Current constraints to implementation are significant.

Management Action CRE-2: Operate the hydrosystem to reduce the effects of reservoir surface heating, or conduct mitigation measures.		
Primary threat this action would address		**Reservoir-related temperature changes.** Low-velocity flows and broad surface area exposure in reservoirs increase the temperature of flows in the estuary. Salmonids are cool-water fish that need stream temperatures of 20º C or lower for normal metabolism, growth, disease resistance, and timing of important life functions such as smoltification and adult migration. Salmonids in the estuary are experiencing water temperatures at the upper limit of their tolerance for longer periods and more frequently than they did historically.
Associated limiting factors		Water temperature.
Threat index[1]	10	This threat is a secondary contributor to a top-priority limiting factor.
Potential benefits with unconstrained implementation of action [2]	3	Given that at many times during the year water temperatures in the estuary are at or above the upper limits of salmonids' thermal tolerance, any lowering of water temperature could provide significant survival benefits. Water temperatures of below 20º C throughout the year would aid salmonids in carrying out essential physiological processes and life functions.
Affected salmonids		Ocean-type salmonids; stream-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings).
Implementation constraints[3]	3	Elevated temperatures that result from reservoir heating are difficult to reduce. Temperatures may be influenced by the volume and speed of flows through the hydrosystem and the source of those flows (some impoundments have cooler water than others do). International treaties, conflicting fish management objectives systemwide, the need for flood control, power management, and other factors constrain management of the hydrosystem to allow cooler flows to enter the estuary.
Potential benefits with constrained implementation of action	2	

[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.

[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.
1 = very low benefits.
5 = very high benefits.

[3] Indicates the feasibility of implementing the action.
1 = Current constraints to implementation are minimal.
5 = Current constraints to implementation are significant.

Management Action CRE-3: Establish minimum instream flows for the estuary that would help prevent further degradation of the ecosystem.		
Primary threat this action would address		**Water withdrawal.** Instream flows in the estuary are important for salmonids because they maintain habitat-forming processes and conditions in the estuary and plume. Although some instream flows have been established in the Columbia River basin tributaries, others are needed, especially with the growing human population in the basin.
Associated limiting factors		Flow-related estuary habitat changes, flow-related changes in access to off-channel habitat, flow-related plume changes, and reduced macrodetrital inputs.
Threat index[1]	10	This threat is a secondary contributor to four top-priority limiting factors.
Potential benefits with unconstrained implementation of action [2]	2	Instream flow laws legally protect tributary and mainstem flows. These water rights have legal standing and are senior to predecessor water rights. Establishing legal instream flows for the estuary would protect minimum flow levels in the estuary and plume and support associated habitat-forming processes.
Affected salmonids		Ocean-type salmonids; stream-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings); stream-type salmonids in the plume.
Implementation constraints[3]	5	The process of setting instream flows is challenging, often takes years, and is not always successful. Implementation of this action would require the involvement of multiple stakeholders, including irrigation, hydrosystem operation, commercial, industrial, tribal, federal, state, and local interests, plus a significant amount of public involvement.
Potential benefits with constrained implementation of action	1	

[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.

[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.
1 = very low benefits.
5 = very high benefits.

[3] Indicates the feasibility of implementing the action.
1 = Current constraints to implementation are minimal.
5 = Current constraints to implementation are significant.

Management Action CRE-4:

Adjust the timing, magnitude and frequency of flows (especially spring freshets) entering the estuary and plume to improve access to habitats and provide better transport of coarse sediments in the estuary, plume, and littoral cell.

Primary threats this action would address		**Flow regulation and impaired transport of coarse sediment.** The magnitude, frequency, and timing of flows are an important determinant of habitat opportunity for salmonids in the estuary. Salmonids have adapted to historical flows and depend on them to complete their life cycles. The transport of sand and gravel from upstream and estuary sources helps maintain salmonid habitats, contributes to turbidity that shelters salmonids from predation, and influences food sources in the plume. Spring freshets are important habitat-shaping events for the estuary, plume, and littoral cell.
Associated limiting factors		Flow-related estuary habitat changes, flow-related changes in access to off-channel habitat, flow-related plume changes, reduced macrodetrital inputs in the estuary, and sediment/nutrient-related estuary habitat changes.
Threat index[1]	15	This threat is a primary contributor to several top-priority limiting factors.
Potential benefits with unconstrained implementation of action [2]	5	Return to a more natural flow regime would have significant ecosystem benefits and would affect all facets of salmonid life histories expressed in the estuary and plume. Adjustments to the timing, magnitude, and frequency of flows entering the estuary would be likely to have synergistic effects that would increase the benefit of many of the other actions.
Affected salmonids		Ocean-type salmonids; stream-type salmonids displaying less dominant life history strategies; stream-type juveniles rearing in the plume.
Implementation constraints[3]	5	Constraints on hydrosystem operations prevent the return to a natural flow regime in the estuary. Implementation of this action would be limited by international treaties, the need for flood control, fish management objectives systemwide, and power production.
Potential benefits with constrained implementation of action	3	

[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.

[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.
1 = very low benefits.
5 = very high benefits.

[3] Indicates the feasibility of implementing the action.
1 = Current constraints to implementation are minimal.
5 = Current constraints to implementation are significant.

Management Action CRE-5: Study and mitigate the effects of entrapment of fine sediment in reservoirs, to improve nourishment of the littoral cell.		
Primary threat this action would address		**Entrapment of fine sediment in reservoirs.** Fine sediments originating from upstream sources are trapped in low-velocity impoundments in the Columbia River, and their movement into the estuary, plume, and littoral cell has been reduced. This alters processes that form shallow-water habitats, affects food sources, and reduces turbidity that otherwise would shelter salmonids from predation.
Associated limiting factors		Flow-related plume changes and sediment/nutrient-related estuary habitat changes.
Threat index[1]	8	This threat is a secondary contributor to several high-priority limiting factors.
Potential benefits with unconstrained implementation of action [2]	2	Fine sediment transport processes are important determinants of estuary and plume habitats. Effective mitigation of this threat would reduce predation of salmonids in the main channel and plume and strengthen habitat-forming processes.
Affected salmonids		Ocean- and stream-type salmonids.
Implementation constraints[3]	5	There are no apparent technical solutions to this threat at this time. Mitigation is recommended, but research is needed to identify the magnitude of the threat and potential solutions or mitigation measures.
Potential benefits with constrained implementation of action	1	

[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.

[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.
1 = very low benefits.
5 = very high benefits.

[3] Indicates the feasibility of implementing the action.
1 = significant potential for implementation.
5 = Current constraints to implementation are significant.

Management Action CRE-6: Reduce the export of sand and gravels via dredge operations by using dredged materials beneficially.		
Primary threat this action would address		**Impaired transport of coarse sediment.** The transport of sand and gravel from upstream and estuary sources is a primary force that influences the creation, maintenance, and distribution of salmonid habitats in the estuary. While there are many potential beneficial uses of dredged materials—including enhanced nourishment of the littoral cell, land creation, property stabilization, and out-of-stream uses—there is also an important ecological need to retain coarse sediments in the estuary for habitat creation and maintenance.
Associated limiting factors		Sediment/nutrient-related estuary habitat changes and flow-related plume changes.
Threat index[1]	12	Although impaired transport of coarse sediment is a primary contributor to a top-priority limiting factor (flow-related plume changes), this management action is likely to have its greatest effect in addressing sediment/nutrient-related estuary habitat changes, a high-priority limiting factor; thus it has a threat index of 12.
Potential benefits with unconstrained implementation of action[2]	2	The beneficial use of sand resulting from dredge activities could play an important role in restoring habitat capacity and habitat opportunity in the estuary, plume, and littoral cell. The beneficial use of dredged materials to provide sand nourishment could reduce the effects of ship wake stranding, improve habitat for *Corphium* (a food source for salmonids), and be beneficial in the development of intertidal swamps and marshes and other salmonid habitat features. Sand entering the littoral cell could also have important ecological benefits.
Affected salmonids		Ocean-type salmonids; stream-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings). This particularly applies to ocean-type juveniles because of their significant use of shallow-water habitats and the nearshore environment.
Implementation constraints[3]	3	Beneficial uses of dredged materials, such as through littoral cell sand nourishment and direct beach nourishment, are currently receiving significant attention, The most obvious constraint to implementation is identifying funding sources to pay for activities beyond the minimum required by law.
Potential benefits with constrained implementation of action	1	

[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.

[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.
1 = very low benefits.
5 = very high benefits.

[3] Indicates the feasibility of implementing the action.
1 = Current constraints to implementation are minimal.
5 = Current constraints to implementation are significant.

Management Action CRE-7: Reduce entrainment and habitat effects resulting from main- and side-channel dredge activities in the estuary.		
Primary threat this action would address		**Dredging**. Annual dredge operations maintain a navigational channel that concentrates flows, alters tidal influences, reduces circulation patterns around the estuary, and releases toxic contaminants from substrates. Dredging activities can result in deposited contaminants being disturbed and redistributed throughout the estuary and littoral cell.
Associated limiting factors		Sediment/nutrient-related estuary habitat changes, native birds, and sediment/nutrient-related plume changes.
Threat index[1]	8	As it relates to this action, dredging is a secondary contributor to a high-priority limiting factor (sediment/nutrient-related estuary habitat changes) and thus has a threat index of 8.
Potential benefits with unconstrained implementation of action[2]	2	Continued dredge operations represent a physical change to the Columbia River estuary. However, reducing or mitigating the effects of dredging would improve habitat-forming processes that would benefit salmonids.
Affected salmonids		Ocean-type salmonids; stream-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings).
Implementation constraints[3]	2	Dredging activities have been occurring since the 1870s to provide sufficient draft for ships entering the Columbia River and will continue into the foreseeable future. Ongoing maintenance is needed to keep the channel to specifications for ships, and additional dredging will be conducted in the estuary as part of the channel deepening process. Maintaining the navigation channel requires dredging and disposal of large volumes of material (4 to 5 million cubic yards) each year. Changing dredging equipment and practices to reduce entrainment and habitat effects would be expensive.
Potential benefits with constrained implementation of action	1	

[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.

[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.
1 = very low benefits.
5 = very high benefits.

[3] Indicates the feasibility of implementing the action.
1 = Current constraints to implementation are minimal.
5 = Current constraints to implementation are significant.

Management Action CRE-8: Remove pilings and pile dikes with low economic value when removal clearly would improve ecosystem health.		
Primary threat this action would address		**Pilings and pile dike structures**. Extensive use of pilings and pile dikes has altered sediment accretion and erosion processes and reduced flow circulation through shallow-water habitats in the estuary. Pilings, pile dikes, and similar structures also have created favorable conditions for predators of salmonids, such as pikeminnow and cormorants. Pile dikes can reduce physical access to low-velocity juvenile salmonid habitats. In some cases, treated pilings may release toxic contaminants, including PAHs.
Associated limiting factors		Sediment/nutrient-related estuary habitat changes, sediment/nutrient-related plume changes, exotic fish, native birds, and bioaccumulation toxicity.
Threat index[1]	12	This threat is a primary contributor to a high-priority limiting factor (altered predator/prey relationships), a secondary contributor to a high-priority limiting factor (sediment/nutrient-related estuary habitat changes) and two low-priority limiting factors.
Potential benefits with unconstrained implementation of action [2]	4	Removing many instream structures would improve circulation in shallow-water habitats and eliminate some salmonid predator habitats.
Affected salmonids		Ocean-type salmonids; stream-type salmonids (yearlings) leaving the heavier flows to forage in shallow waters downstream of pilings and pile dikes; stream-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings);
Implementation constraints[3]	2	Only some of the thousands of pilings, pile dikes, and similar structures in the Columbia River estuary are necessary to maintain the shipping channel, protect property, or serve their intended economic use. Removal of superfluous structures generally is restricted only by cost and would be unlikely to affect property rights or the shipping industry. In cases where pile dikes that do aide in navigation are removed, constraints to implementation would include the cost for additional dredging to maintain the channel.
Potential benefits with constrained implementation of action	2	

[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.

[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.
1 = very low benefits.
5 = very high benefits.

[3] Indicates the feasibility of implementing the action.
1 = Current constraints to implementation are minimal.
5 = Current constraints to implementation are significant.

***Management Action CRE-9*:**
Protect remaining high-quality off-channel habitat from degradation.

Primary threat this action would address		**Dikes and filling.** High-quality off-channel habitat provides crucial feeding, rearing, and refuge opportunities for juvenile salmonids and supplies macrodetrital inputs to the estuarine food web. Reduced floodplain inundation has limited juvenile salmonids' access to historical wetland and swamp habitat, much of which has been converted to other land uses. Protecting remaining intact and accessible off-channel habitats is critical to maintaining key habitats and food sources for juvenile salmonids.
Associated limiting factors		Reduced macrodetrital inputs, sediment/nutrient-related estuary habitat changes, bankfull elevation changes, sediment/nutrient-related plume changes, and exotic plants.
***Threat index*[1]**	15	This threat is a primary contributor to both top-priority and high-priority limiting factors.
***Potential benefits with unconstrained implementation of action*[2]**	5	Protection of high-quality off-channel areas would help maintain important wetland habitats and supply macrodetrital inputs to the food web and insect food sources for juvenile salmonids—a main component of their diet.
Affected salmonids		Ocean-type salmonids; stream-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings).
***Implementation constraints*[3]**	4	Regulatory programs often do not effectively protect floodplains from conversion to other uses. The acquisition of land for habitat protection remains controversial in the estuary. Rural county governments see land disappearing off tax rolls and also listen to citizen disapproval of public ownership of land. Land acquisition is expensive and depends on the willingness of landowners to sell. The fact that many habitats already have been converted to other land uses limits opportunities to protect high-quality off-channel habitat.
Potential benefits with constrained implementation of action	3	

[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.

[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.
1 = very low benefits.
5 = very high benefits.

[3] Indicates the feasibility of implementing the action.
1 = Current constraints to implementation are minimal.
5 = Current constraints to implementation are significant.

Management Action CRE-10:

Breach or lower dikes and levees to improve access to off-channel habitats.

Primary threat this action would address		**Dikes and filling.** Many juvenile salmonids rely on off-channel habitats for feeding and refuge opportunities. Historically, insects and macrodetritus from these habitats were important inputs to the estuarine food web. Dikes, levees, tide gates, and filling have limited the amount and accessibility of key off-channel habitats by reducing floodplain inundation and allowing conversion of land to agricultural, residential, and industrial uses.
Associated limiting factors		Reduced macrodetrital inputs, sediment/nutrient-related estuary habitat changes, bankfull elevation changes, sediment/nutrient-related plume changes, and exotic plants.
Threat index[1]	15	This threat is a primary contributor to both top-priority and high-priority limiting factors.
Potential benefits with unconstrained implementation of action[2]	5	Restoring off-channel areas would reclaim habitat that is important to salmonids. In most cases, project benefits would accrue over relatively long periods of time.
Affected salmonids		Ocean-type salmonids; stream-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings).
Implementation constraints[3]	3	Opportunities to restore off-channel habitats are limited because many such habitats already have been filled with dredged materials. Breaching or lowering dikes and levees or removing tide gates often requires the cooperation of multiple landowners and may fundamentally alter land uses. The associated habitat restoration is expensive.
Potential benefits with constrained implementation of action	4	

[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.

[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.
1 = very low benefits.
5 = very high benefits.

[3] Indicates the feasibility of implementing the action.
1 = Current constraints to implementation are minimal.
5 = Current constraints to implementation are significant.

Management Action CRE-11: Reduce the square footage of over-water structures in the estuary.		
Primary threat this action would address		**Over-water structures.** Over-water structures may provide habitats for predators and affect instream and shoreline plant communities. However, the total surface area of over-water structures in the estuary has not been quantified and the structures' case-by-case functions have not been analyzed.
Associated limiting factors		Sediment/nutrient-related estuary habitat changes and exotic fish.
Threat index[1]	4	This threat is a tertiary contributor to a high-priority limiting factor (habitat changes) and a secondary contributor to one of the lowest priority limiting factors (exotic fish).
Potential benefits with unconstrained implementation of action [2]	3	Given the uncertainty about how much of a threat over-water structures actually pose to salmonids, the potential improvement in survival must be considered low pending additional research and analysis.
Affected salmonids		Ocean-type salmonids (because of their preference for the shallow-water habitats where most structures are located); stream-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings).
Implementation constraints[3]	3	It is assumed that some over-water structures are more important than others and that removing superfluous or less useful structures would not have deleterious effects on adjacent land uses. Removal of over-water structures that are in currently use would likely require compensation. In some cases, structures such as log rafts could be relocated.
Potential benefits with constrained implementation of action	1	

[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.

[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.
1 = very low benefits.
5 = very high benefits.

[3] Indicates the feasibility of implementing the action.
1 = Current constraints to implementation are minimal.
5 = Current constraints to implementation are significant.

Management Action CRE-12: Reduce the effects of vessel wake stranding in the estuary.		
Primary threat this action would address		**Ship wakes.** Wakes from deep-draft vessels traveling through the estuary wash subyearling salmonids onto shore, leaving them stranded. Factors that affect stranding include beach slope and time of day as well as vessel draft, speed, and hull design.
Associated limiting factors		Stranding.
Threat index[1]	6	This threat is a primary contributor to a low-priority limiting factor.
Potential benefits with unconstrained implementation of action [2]	2	The extent of mortality caused by ship wake stranding is unknown. Studies in 1977 and 1994 (Bauersfeld 1977, Hinton and Emmett 1994) reached different conclusions, using different approaches. A soon-to-be-released study by the University of Washington and U.S. Army Corps of Engineers may provide further clarification of the issue.
Affected salmonids		Ocean-type salmonids (because of their longer estuarine residency times, their relatively small size, and the habitats they prefer); stream-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings).
Implementation constraints[3]	3	Options for reducing the effects of vessel wake stranding are limited. Ship traffic through the estuary will continue, ship hull design is unlikely to change, and the speed of ships traveling the estuary may be difficult to alter. Modification of some habitats may be necessary to reduce this threat and would likely be expensive.
Potential benefits with constrained implementation of action	1	

[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.

[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.
1 = very low benefits.
5 = very high benefits.

[3] Indicates the feasibility of implementing the action.
1 = Current constraints to implementation are minimal.
5 = Current constraints to implementation are significant.

Management Action CRE-13: Manage pikeminnow and other piscivorous fish, including introduced species, to reduce predation on salmonids.		
Primary threat this action would address		**Altered predator/prey relationships.** Pikeminnows have always been a significant source of mortality for juvenile salmonids in the Columbia River, but changes in physical habitat, such as the addition of in-water structures, have created more favorable conditions for predation. Introduced species such as smallmouth bass, walleye, and channel catfish also prey on juvenile salmonids, primarily in the freshwater reaches of the estuary.
Associated limiting factors		Native fish and exotic fish.
Threat index[1]	12	This threat contributes to many limiting factors, although the management action addresses only the native and exotic fish limiting factors, which have threat indexes of 12 and 3, respectively.
Potential benefits with unconstrained implementation of action [2]	4	Ecosystem alterations in the estuary as a result of pikeminnow, smallmouth bass, walleye, and channel catfish are uncertain. Scientists speculate that pikeminnow may be preying on both ocean- and stream-type juveniles. Stream-type juveniles may be affected significantly more than previously thought because recent evidence suggests that they forage in shallow areas downstream of piling structures.
Affected salmonids		Ocean-type salmonids; stream-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings).
Implementation constraints[3]	2	Pikeminnow are a far greater threat to juvenile salmonids than bass, walleye, and channel catfish, at least at this time. Implementation activities to reduce pikeminnow predation are constrained by the challenge of reducing their preferred slack-water habitats. Bounty programs can be effective at removing older pikeminnow, which represent the largest threat to salmonids. Although the introduction of exotic fish to the estuary may be irreversible, there are viable tools for managing smallmouth bass, walleye, and channel catfish; these include habitat management and less restricted harvest management. It is likely that warm-water fishers would actively support maintaining the abundance of these species at current—rather than reduced—levels.
Potential benefits with constrained implementation of action	2	

[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.

[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.
1 = very low benefits.
5 = very high benefits.

[3] Indicates the feasibility of implementing the action.
1 = Current constraints to implementation are minimal.
5 = Current constraints to implementation are significant.

Management Action CRE-14: Identify and implement actions to reduce salmonid predation by pinnipeds.		
Primary threat this action would address		**Altered predator/prey relationships.** Pinniped predation on salmonids at Bonneville Dam has been estimated at from 0.5 percent to 3.4 percent of the spring chinook and winter steelhead runs. Estuarywide estimates are unsubstantiated, but it is likely that losses exceed 10 percent of the runs each spring. The extent of predation needs further study and documentation.
Associated limiting factors		Native pinnipeds.
Threat index[1]	12	This threat contributes to many limiting factors, although the management action relates only to native pinnipeds.
Potential benefits with unconstrained implementation of action[2]	3	Actions to reduce predation by pinnipeds would be likely to have only minor impacts on salmonid survival, depending on how many adults are actually being eaten by pinnipeds—a question that remains controversial.
Affected salmonids		Ocean- and stream-type salmonids.
Implementation constraints[3]	4	Methods for reducing salmonid predation by pinnipeds are limited because pinnipeds are protected under the Marine Mammal Protection Act. It could take years to amend the act to allow additional pinniped management tools. Non-lethal methods have been only minimally successful, although it is possible that additional testing would identify effective non-lethal methods.
Potential benefits with constrained implementation of action	2	

[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.

[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.
1 = very low benefits.
5 = very high benefits.

[3] Indicates the feasibility of implementing the action.
1 = Current constraints to implementation are minimal.
5 = Current constraints to implementation are significant.

Management Action CRE-15: Implement education and monitoring projects and enforce existing laws to reduce the introduction and spread of noxious weeds.		
Primary threat this action would address		**Altered predator/prey relationships.** Exotic plants in the estuary often out-compete native plants and change the structure of plant communities. The resulting habitat frequently does not provide the same food or shelter that other species, including salmonids, have adapted to over time.
Associated limiting factors		Exotic plants.
Threat index[1]	3	This threat contributes to many limiting factors, although the management action relates only to exotic plants, one of the lowest priority limiting factors.
Potential benefits with unconstrained implementation of action [2]	2	Preventing and controlling noxious weeds would help maintain the estuarine food web and habitats that juvenile salmonids rely on.
Affected salmonids		Ocean-type salmonids; stream-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings).
Implementation constraints[3]	4	Controlling existing infestations of certain species is functionally impossible once the species are established. Although landowners are the most important agents in preventing and controlling exotic plant infestations, landowner education is a significant task that requires a large effort.
Potential benefits with constrained implementation of action	1	

[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.

[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.
1 = very low benefits.
5 = very high benefits.

[3] Indicates the feasibility of implementing the action.
1 = Current constraints to implementation are minimal.
5 = Current constraints to implementation are significant.

Management Action CRE-16: Implement projects to redistribute part of the Caspian tern colony currently nesting on East Sand Island.		
Primary threat this action would address		**Altered predator/prey relationships.** Caspian tern predation represents a significant source of mortality for stream-type juveniles migrating to saltwater. Stream-type salmonids are particularly vulnerable because of the timing of their out-migration (during tern nesting season) and their preference for deep-channel habitats near tern nesting sites.
Associated limiting factors		Native birds.
Threat index[1]	12	This threat contributes to many limiting factors, although the management action relates only to Caspian terns.
Potential benefits with unconstrained implementation of action [2]	5	Reducing tern predation could have significant effects on the survival of stream-type salmonids, as terns have been documented to consume as much as 3 percent of stream-type juveniles migrating through the estuary.
Affected salmonids		Stream-type salmonids; ocean-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings).
Implementation constraints[3]	2	Recent management efforts have helped reduce mortality by relocating terns to nearby habitats. Long-term solutions will require habitat improvements elsewhere for Caspian terns.
Potential benefits with constrained implementation of action	3	

[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.

[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.
1 = very low benefits.
5 = very high benefits.

[3] Indicates the feasibility of implementing the action.
1 = Current constraints to implementation are minimal.
5 = Current constraints to implementation are significant.

Management Action CRE-17: Implement projects to reduce double-crested cormorant habitats and encourage dispersal to other locations.		
Primary threat this action would address		**Altered predator/prey relationships.** Predation by double-crested cormorants represents a significant source of mortality for stream-type juveniles migrating to saltwater.
Associated limiting factors		Native birds.
Threat index[1]	12	This threat contributes to many limiting factors, although the management action relates only to double-crested cormorants.
Potential benefits with unconstrained implementation of action[2]	4	Recent studies indicate that double-crested cormorants prey on salmonid juveniles in the estuary at a rate equal to or greater than the rate by Caspian terns. In some years cormorants may consume as many as 6 million juveniles.
Affected salmonids		Ocean- and stream-type juvenile salmonids are preyed upon by double-crested cormorants with some fluctuation from year to year. In 2004 double-crested cormorants consumed approximately 4 million subyearling chinook.
Implementation constraints[3]	4	Double-crested cormorants are more difficult to relocate than Caspian terns. Techniques such as the use of decoys and audio playback have not been as effective compared to terns. Perch habitats are plentiful enough in the estuary that removal of pile dikes and other structures may not be an effective tool.
Potential benefits with constrained implementation of action	2	

[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.

[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.
1 = very low benefits.
5 = very high benefits.

[3] Indicates the feasibility of implementing the action.
1 = Current constraints to implementation are minimal.
5 = Current constraints to implementation are significant.

Management Action CRE-18: Reduce the abundance of shad in the estuary.		
Primary threat this action would address		**Altered predator/prey relationships.** Shad returns to the Columbia River number approximately 4 million annually. Shad's effects on the estuary ecosystem and salmonids are poorly understood. However, shad are an introduced species and their biomass alone represents a threat to trophic relationships in the Columbia River.
Associated limiting factors		Exotic fish.
Threat index[1]	3	This threat contributes to many limiting factors, although the management action relates only to shad.
Potential benefits with unconstrained implementation of action [2]	2	The impacts of shad in the estuary are unclear. However, it is likely that reducing shad numbers would have some benefits for salmonids.
Affected salmonids		Ocean-type salmonids; stream-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings).
Implementation constraints[3]	5	Shad are thought to have permanently altered the estuary ecosystem, and their complete removal from the estuary is neither practical nor feasible. Effective management tools to limit shad productivity in the Columbia River basin currently are not available. Research is needed in the near term to determine the significance of this threat and identify potential management actions to manage the abundance of shad.
Potential benefits with constrained implementation of action	1	

[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.

[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.
1 = very low benefits.
5 = very high benefits.

[3] Indicates the feasibility of implementing the action.
1 = Current constraints to implementation are minimal.
5 = Current constraints to implementation are significant.

Management Action CRE-19: Prevent new introductions of invertebrates and reduce the effects of existing infestations.		
Primary threat this action would address		**Ship ballast practices.** Ship ballast water is responsible for the introduction of exotic invertebrates in the estuary. The effects of these introductions are poorly understood, but it is likely that exotic invertebrates disrupt food webs and out-compete juvenile salmonids' native food sources.
Associated limiting factors		Introduced invertebrates.
Threat index[1]	3	This threat is a primary contributor to one of the lowest priority limiting factors.
Potential benefits with unconstrained implementation of action [2]	2	Reducing the impacts of exotic invertebrates would help maintain traditional salmonid food sources and the trophic relationships that salmon have adapted to.
Affected salmonids		Ocean-type salmonids; stream-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings).
Implementation constraints[3]	5	Improvements in ship ballast practices have already been implemented by the industry as a result of new regulations, and stricter regulations are currently being debated at the federal level. However, there are inherent challenges in managing ballast water that contains organisms from other ecosystems. Also, once exotic invertebrates have been introduced, they represent a permanent alteration of the ecosystem and opportunities to reduce their effects may be few. Current understanding of how the estuary ecosystem is affected by introductions of exotic invertebrates is very limited.
Potential benefits with constrained implementation of action	1	

[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.

[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.
1 = very low benefits.
5 = very high benefits.

[3] Indicates the feasibility of implementing the action.
1 = Current constraints to implementation are minimal.
5 = Current constraints to implementation are significant.

Management Action CRE-20: Implement pesticide and fertilizer best management practices to reduce estuary and upstream sources of toxic contaminants entering the estuary.		
Primary threat this action would address		**Agricultural practices.** Water-soluble contaminants such as simazine, atrazine, chlorpyrifos, metolachlor, diazinon, and carbaryl enter the estuary as a result of tributary and upstream agricultural practices. DDT and PCBs have been detected at elevated levels in the estuary. These and other agricultural contaminants can cause salmonid mortality through bioaccumulation or short-term toxicity.
Associated limiting factors		Short-term and bioaccumulative toxicity.
Threat index[1]	12	This threat is a primary contributor to a high-priority limiting factor (short-term toxicity) and a medium-priority limiting factor.
Potential benefits with unconstrained implementation of action [2]	3	Reducing the level of pesticides and herbicides in the estuary would improve survival by reducing ocean-type salmonids' acute and chronic exposure to toxic contaminants and stream-type salmonids' acute exposure.
Affected salmonids		Ocean- and stream-type salmonids.
Implementation constraints[3]	4	Impacts from pesticides and fertilizers have lessened dramatically since the 1950s as a result of new application technologies, new products, and better understanding and regulation of these toxins. Best management practices offer additional ways to reduce the impacts of pesticides and fertilizers. The integration of new practices can be expensive and time-consuming and also can influence the economics of a particular crop.
Potential benefits with constrained implementation of action	1	

[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.

[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.
1 = very low benefits.
5 = very high benefits.

[3] Indicates the feasibility of implementing the action.
1 = Current constraints to implementation are minimal.
5 = Current constraints to implementation are significant.

Management Action CRE-21: Identify and reduce industrial, commercial, and public sources of pollutants.		
Primary threat this action would address		**Urban and industrial practices.** The estuary has been affected by historical and current releases of toxic contaminants, including industrial and commercial pollutants such as PCBs and PAHs. These substances have been found near Portland, Vancouver, Longview, and Astoria. Recent studies have demonstrated significant juvenile mortality in the estuary as a result of toxic contaminants.
Associated limiting factors		Short-term toxicity and bioaccumulation toxicity.
Threat index[1]	12	This threat is a primary contributor to high- and medium-priority limiting factors.
Potential benefits with unconstrained implementation of action [2]	4	Reducing sources of pollutants would lower water temperature, nutrient loading, and the amount of toxic contaminants in the estuary. This would improve both habitat capacity in the estuary and the fitness level of salmonids.
Affected salmonids		Ocean- and stream-type salmonids (particularly ocean types because of their longer residency in the estuary).
Implementation constraints[3]	4	While some discharges of industrial and commercial pollutants are permitted, others are not. Efforts to reduce industrial and commercial pollutants are already under way, and there is potential to reduce point-source emissions. Efforts to reduce sources of pollutants are expensive and time-consuming and often have a negative economic effect on operations.
Potential benefits with constrained implementation of action	3	

[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.

[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.
1 = very low benefits.
5 = very high benefits.

[3] Indicates the feasibility of implementing the action.
1 = Current constraints to implementation are minimal.
5 = Current constraints to implementation are significant.

Management Action CRE-22: Monitor the estuary for contaminants and/or restore contaminated sites.		
Primary threat this action would address		**Urban and industrial practices.** The estuary has been affected by historical and current releases of toxic contaminants, including industrial and commercial pollutants such as PCBs and PAHs. These substances have been found near Portland, Vancouver, Longview, and Astoria. Recent studies have demonstrated significant juvenile mortality in the estuary as a result of toxic contaminants. The action is intended to address the need to monitor the entire estuary for contaminants; however, actual restoration activities are feasible only in specific reaches.
Associated limiting factors		Short-term toxicity and bioaccumulation toxicity.
Threat index[1]	12	This threat is a primary contributor to high- and medium-priority limiting factors.
Potential benefits with unconstrained implementation of action [2]	5	Reducing toxic contaminants in the estuary would improve both habitat capacity and the fitness level of salmonids.
Affected salmonids		Ocean- and stream-type salmonids (particularly ocean types because of their longer residency in the estuary).
Implementation constraints[3]	3	Monitoring activities are already occurring; however, actual restoration of contaminated sites is expensive and technically challenging in many cases. In some cases, restoration may not be feasible or practical.
Potential benefits with constrained implementation of action	3	

[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.

[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.
1 = very low benefits.
5 = very high benefits.

[3] Indicates the feasibility of implementing the action.
1 = Current constraints to implementation are minimal.
5 = Current constraints to implementation are significant.

Management Action CRE-23: Implement stormwater best management practices in cities and towns.		
Primary threat this action would address		**Urban and industrial practices.** Municipal stormwater runoff can convey toxic contaminants to the estuary, reduce groundwater recharge, and increase the "flashiness" of stream flows. Although cities and towns in the Columbia River basin generally have programs to reduce the impacts of stormwater runoff, stormwater best management practices have not been universally implemented throughout the basin.
Associated limiting factors		Short-term toxicity and bioaccumulation toxicity.
Threat index[1]	9	This threat is a secondary contributor to a medium-priority limiting factor as it relates to this management action.
Potential benefits with unconstrained implementation of action [2]	2	Implementing stormwater best management practices would markedly improve conditions and provide a net benefit to salmonids in the estuary through a more normal flow regime, reduced exposure to contaminants, and lower water temperatures.
Affected salmonids		Ocean- and stream-type salmonids (particularly ocean types because of their longer residency in the estuary).
Implementation constraints[3]	2	Some cities lack the resources or will to implement or enforce stormwater best management practices. The benefits of improved stormwater practices generally are associated only with new development and do not offset the full impact of the impervious surfaces in those developments, or the existing impervious surfaces in areas that have already been developed.
Potential benefits with constrained implementation of action	1	

[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.

[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.
1 = very low benefits.
5 = very high benefits.

[3] Indicates the feasibility of implementing the action.
1 = Current constraints to implementation are minimal.
5 = Current constraints to implementation are significant.

Table 5-2 estimates the potential of each management action to benefit salmonids under two different implementation scenarios. Assuming that implementation of most actions is significantly constrained, which management actions would be likely to result in the greatest survival improvements?

In partial answer to this question, Table 5-3 summarizes the potential benefits of each action under both unconstrained and constrained implementation scenarios. It is tempting to sort the actions in Table 5-3 by potential benefit with constrained implementation and view the sorted list as a prioritized list of management actions, with the actions at the top being those predicted to have the greatest benefits.

However, Table 5-3 is misleading as a tool for guiding recovery actions because the potential benefit scores it uses do not accurately account for the magnitude of impact of an action—in other words, the number of fish that could be affected by the action. For example, a given management action could be fully implemented yet result in the survival of only hundreds of additional juvenile salmonids because the threat and limiting factors that the action addresses are relatively minor. Implementation of another action could be significantly constrained but result in many thousands of additional juveniles surviving because the threat and limiting factors the action addresses are so great.

This consideration of magnitude of impact is important and calls for development of a second analysis of potential benefits of management actions: survival improvement targets, which are presented in the next section of this document.

TABLE 5-3
Summary of Constraints to Implementation of Management Actions

Number	Action Description	Benefit with Unconstrained Implementation of Action[1]	Benefit with Constrained Implementation of Action[2]
CRE-01	Protect intact riparian areas in the estuary and restore riparian areas that are degraded.	4	2
CRE-02	Operate the hydrosystem to reduce the effects of reservoir surface heating, or conduct mitigation measures.	3	2
CRE-03	Establish minimum instream flows for the estuary that would help prevent further degradation of the ecosystem.	2	1
CRE-04	Adjust the timing, magnitude and frequency of flows (especially spring freshets) entering the estuary and plume to improve access to habitats and provide better transport of coarse sediments in the estuary, plume, and littoral cell.	5	3
CRE-05	Study and mitigate the effects of entrapment of fine sediment in reservoirs, to improve nourishment of the littoral cell.	2	1
CRE-06	Reduce the export of sand and gravels via dredge operations by using dredged materials beneficially.	2	1

CRE-07	Reduce entrainment and habitat effects resulting from main- and side-channel dredge activities in the estuary.	2	1
CRE-08	Remove pilings and pile dikes with low economic value when removal clearly would improve ecosystem health.	4	2
CRE-09	Protect remaining high-quality off-channel habitat from degradation.	5	3
CRE-10	Breach or lower dikes and levees to improve access to off-channel habitats.	5	4
CRE-11	Reduce the square footage of over-water structures in the estuary.	3	1
CRE-12	Reduce the effects of vessel wake stranding in the estuary.	2	1
CRE-13	Manage pikeminnow and other piscivorous fish, including introduced species, to reduce predation on salmonids.	4	2
CRE-14	Identify and implement actions to reduce salmonid predation by pinnipeds.	3	2
CRE-15	Implement education and monitoring projects and enforce existing laws to reduce the introduction and spread of noxious weeds.	2	1
CRE-16	Implement projects to redistribute part of the Caspian tern colony currently nesting on East Sand Island.	5	3
CRE-17	Implement projects to reduce double-crested cormorant habitats and encourage dispersal to other locations.	4	2
CRE-18	Reduce the abundance of shad in the estuary.	2	1
CRE-19	Prevent new introductions of invertebrates and reduce the effects of existing infestations.	2	1
CRE-20	Implement pesticide and fertilizer best management practices to reduce estuary and upstream sources of toxic contaminants entering the estuary.	3	1
CRE-21	Identify and reduce industrial, commercial, and public sources of pollutants.	4	3
CRE-22	Monitor the estuary for contaminants and/or restore contaminated sites.	5	3
CRE-23	Implement stormwater best management practices in cities and towns.	2	1

[1]Estimate of potential benefit if action is fully implemented, with no constraints.
1 = very low benefits.
5 = very high benefits.

[2]Estimate of potential benefit assuming that implementation is constrained.
1 = very low benefits.
5 = very high benefits.

Evaluation of Management Actions: Survival Improvement Targets

The Columbia River estuary and plume are only two of many ecosystems that salmonids travel in their complex and lengthy journey from headwaters to ocean and back again. Mortality occurs at every stage of this journey. Each year, NOAA Fisheries scientists estimate the number of juvenile salmonids that enter the estuary from upstream of Bonneville Dam and from estuary tributaries. For 2006, NOAA Fisheries scientists estimated that about 168 million juvenile salmonids (both wild and hatchery) would enter the estuary (Ferguson 2006b). Some years later, the surviving fish return to the estuary in varying numbers, with the average return in the last 10 years being approximately 1.7 million fish; roughly 65 to 75 percent of those fish are of hatchery origin.[2] This means that less than 1 percent of the juveniles that enter the estuary are returning as adults.

Estimating Juvenile Mortality in the Estuary and Plume

How much juvenile mortality is occurring in the estuary and plume? The answer to this question is fundamental to developing an understanding of the role the estuary will play in the recovery of salmonid populations basinwide. The answer also is critical in evaluating the benefits and costs of potential management actions because it helps establish the level of effort needed to offset threats to salmonids in the estuary. Unfortunately, determining how much juvenile mortality is occurring in the estuary and plume is challenging for scientists. Counting juveniles in the Columbia River estuary and plume is problematic because available tracking technologies are limited, and it is difficult to monitor juveniles—which tend to move in and out of saltwater—in large, high-energy sites such as the mouth of the Columbia River.

However, some efforts have been made to separate mortality that occurs in the estuary and plume from mortality that occurs in the ocean. One such effort has been the underlying assumptions in the Ecosystem Diagnosis and Treatment (EDT) model, which is used extensively throughout the Columbia River basin. For juveniles entering the estuary from tributaries to the lower Columbia River, EDT assumes mortality rates in the estuary and plume of between 18 and 58 percent, depending on the salmonid species and the amount of time juveniles spend in the estuary (Lower Columbia Fish Recovery Board 2004). In a study of juvenile mortality in the estuary, Schreck et al. (2006) estimated spring/summer mortality at between 11 and 17 percent, largely from avian predation.

In addition, new research is currently under way by NOAA Fisheries, the U.S. Army Corps of Engineers, and Battelle Laboratories to estimate the survival rate of juvenile salmonids in the lower Columbia River. This research involves new technologies for miniaturizing acoustic tags to a size capable of tracking yearling and subyearling juveniles. Current technology developed for the project allows for the tracking of subyearlings of sizes down to approximately 90 mm. Results for the first year (2005) have not been formally released; however, preliminary data indicate an approximate range of survival of 65 to 75 percent for subyearlings and yearlings during their residency in the estuary (Ferguson 2006a). It is probable that actual survival rates are lower than these preliminary estimates suggest because the research did not address mortality among juveniles smaller than 90 mm or

2 This is an informal estimate made by several knowledgeable experts; determining the ratio of hatchery-origin fish with more certainty would require stock-by-stock run calculations averaged over many years.

mortality occurring in the plume and nearshore. The studies above have not conclusive, and separating estuarine and ocean mortality for juvenile salmonids in the Columbia River remains significant challenge.

Some specific estimates of salmonid mortality are known in the estuary; they include estimates for double-crested cormorants and Caspian terns. For other threats to salmonids, such as toxic contamination, ship wake stranding, and pinniped predation, information on mortality in the estuary is incomplete or relatively new in the literature. Still other threats, especially those related to the food web, are poorly understood and have no mortality estimates associated with them, although in some cases the change in conditions from the historical template to the present has been well documented.

Establishing Survival Improvement Targets

An important goal of this estuary recovery plan module is to estimate the potential benefits—in terms of increased survival of salmonids in the estuary—that could result from the implementation of different management actions. To accomplish this goal, the estuary recovery plan module uses what is known about limiting factors, threats, and constraints to the implementation of management actions to assign benefits that could possibly result from different actions.

If scientific understanding of the relationships between ecological conditions and biological responses in estuarine systems were robust, it would be attractive to assign specific mortality rates to each of the factors limiting salmonids' biological performance in the Columbia River estuary. Then one could follow a deterministic logic path that associates mortality rates with specific threats, relates the mortality rates to management actions, and ultimately arrives at an estimate of the survival improvement that would be likely to result from each action. This is not possible at this time, and it will likely not be possible until there have been significant advances in scientific understanding of the complex estuarine environment.

To compensate for the lack of detailed information on mortality in the estuary, this recovery plan module establishes targets for improved survival of wild ESA-listed salmonids rearing and migrating in the estuary and plume, assuming that the implementation of management actions is constrained to the degree indicated in Table 5-2. These survival targets are intended to serve as a planning tool useful in characterizing the potential results of actions and describing the level of effort needed to recover salmonids.

The primary purpose of the survival improvement targets is to help compare the potential benefits of different management actions, particularly actions that partially address major limiting factors versus actions that fully address minor limiting factors. Assigning survival improvement targets to management actions is necessary because most other evaluation techniques (such as high, medium, and low type ratings) lack the specificity to indicate that, in some cases, even constrained implementation of an action that addresses a very important limiting factor could result in large survival improvements.

The survival improvement targets in this chapter were based on an estimate of the number of wild, ESA-listed ocean- and stream-type juvenile salmonids entering the estuary. The total number of wild, ESA-listed juvenile salmonids estimated to enter the estuary in 2006 was approximately 39 million (Ferguson 2006b).[3] Of these, approximately 25 million were estimated to be ocean type and 14 million were estimated to be stream type.

To establish survival improvement targets, some assumptions were made about the overall mortality of juvenile salmonids during estuary and plume residency. Ocean-type juveniles were assumed to have an overall mortality rate of 50 percent during their estuary residency; this includes the 35 percent mortality suggested by the unpublished micro-acoustic tagging research (Ferguson 2006a) plus an additional 15 percent to account for juveniles too small to be tracked. Stream-type juveniles were assumed to have an overall mortality rate of 40 percent during estuary and plume residency. This rate was based on the 25 percent mortality found in the micro-acoustic tagging research (Ferguson 2006a) plus an additional 15 percent to account for mortality occurring in the plume, which was not part of study. These assumptions about estuary mortality are based on best professional judgment after a review of pertinent literature and discussions with subject matter experts, including scientists at NOAA/NMFS's Northwest Fisheries Science Center.

Table 5-4 shows the number of wild, ESA-listed ocean- and stream-type juveniles thought to be entering the lower Columbia estuary and plume, their estimated mortality and survival rates based on the assumptions above, and the number of juveniles estimated to survive their journey through the estuary and plume—again, based on the assumptions above.

TABLE 5-4
Estimated Mortality Rates, Survival Rates, and Survival Improvement Targets for Wild, ESA-Listed Juveniles

Type	Juveniles Entering Estuary*	Assumed Mortality Rate	Assumed Survival Rate	Estimated Number of Juveniles Exiting Estuary and Plume*	Survival Improvement Target (20 percent)**
Ocean Type	25 million	50%	50%	12.5 million	2.5 million
Stream Type	14 million	40%	60%	8.4 million	1.68 million

* = Wild, ESA-listed juveniles.

** = Twenty percent of the estimated number of juveniles exiting the estuary and plume; this target represents additional fish surviving their estuary and plume residency.

Table 5-4 also presents survival improvement targets for ocean- and stream-type salmonids in the estuary and plume. For planning purposes only, this estuary recovery plan module selects 20 percent as a target for improvement in the survival rate of wild, ESA-listed ocean- and stream-type juveniles in the estuary and plume. Twenty percent represents a hypothetical level of improvement that might be realized through the implementation of the management actions, assuming that considerable effort is expended to help offset constraints to implementation, such that threats and limiting factors are reduced. For ocean types, increasing survival by 20 percent would result in a total of 15 million juveniles exiting the estuary and plume—2.5 million more juveniles than the current estimate of 12.5 million. For stream types, a 20 percent improvement would equal 10.08 million—1.68 million additional juveniles beyond the current 8.4 million that are estimated to exit the estuary and plume. Thus the survival improvement targets for ocean- and stream-type salmonids are 2.5

[3] Approximately 98.9 million ESA-listed juveniles (wild and hatchery) are estimated to enter the estuary in 2006. This estuary recovery plan module uses only the wild fraction of these ESA-listed fish.

million and 1.68 million, respectively, as shown in Table 5-4. Targets for both types were set at 20 percent to avoid the appearance of a false level of precision in establishing them. Ocean-type juveniles were assumed to incur more mortality in the estuary and nearshore compared to stream types. Stream types were assumed to incur less mortality in the estuary than ocean types but significantly more mortality in the plume.

The 20 percent survival improvement number for ocean- and stream-type juvenile salmonids was selected based on a qualitative analysis of the level of improvement that reasonably and plausibly might be expected if the 23 management actions were implemented. PC Trask & Associates reviewed existing management plans, the *2004 FCRPS Biological Opinion on Remand* (National Marine Fisheries Service 2004), other literature sources, and the constraints analysis in Table 5-2 in establishing the 20 percent target. However, setting 20 percent as the target for improvement, rather than 15 or 30 percent, is inherently subjective and relies in part on the following assumptions:

- That estuary mortality for juveniles (currently between 40 and 50 percent, depending on population) can be reduced by initiating restoration projects and reducing uncertainties through research and monitoring
- That mortality rates associated with certain threats, such as Caspian terns and cormorants, are well understood and will be lessened through actions specified in management plans that are reasonably likely to be implemented
- That all of the actions identified in this chapter are implemented to a reasonable degree and historical and current constraints to action implementation are thoroughly challenged

Actual improvements in survival will depend on which management actions are implemented, how fully they are implemented, and their efficacy—factors that at this point are open to interpretation and can be qualitatively estimated only. Although the 20 percent targets for ocean- and stream-type salmonids are intended to be reasonable and plausible given the information available to date, open technical, political, and social discussion could refine the targets until science can substantiate them.

The survival improvement targets in Table 5-4 were developed using ocean- and stream-type life history strategies to characterize the 13 ESUs in the Columbia River basin. As a result, the survival improvement targets do not account for important variations found at the ESU, population, and subpopulation scales. For example, not all ocean-type ESUs in the Columbia River basin exhibit the same run timing, size at estuary entry, or use of particular habitats (Fresh et. al 2005). In fact, this variability in estuarine use by the ESUs is fundamental to the member/vagrant theory proposed by NOAA/NMFS's Northwest Fisheries Science Center and a central premise of the estuary recovery plan module (see Chapter 2 for more information on the member/vagrant theory). Although genetic and spatial diversity are not explicitly accounted for in survival improvement targets, the suite of management actions identified in the estuary recovery plan module is intended to collectively address all life history strategies historically expressed in the estuary and plume. This further emphasizes that the survival improvement targets are best viewed as a planning tool only. In reality, there will significant variability among ESUs, populations, and subpopulations in how much additional survival might result from improvements in estuary and plume habitat.

Assigning Survival Improvement Targets to Recovery Actions

The usefulness of the 20 percent target lies not in the 20 percent number itself, but in the distribution of the targets (2.5 million ocean-type juveniles and 1.68 million stream-type juveniles) across the various management actions, as a way of characterizing where survival improvements would need to be realized given the various constraints to action implementation.[4] Table 5-5 shows this allocation of survival improvement targets to the 22 management actions for juvenile salmonids. In cases where there is good scientific literature that supports the allocation of survival targets, as with terns and cormorants, that information has been used as a basis for the analysis in Table 5-5. In other cases, such as reservoir-related temperature changes, an estimate was made by PC Trask & Associates based on literature discussion of related limiting factors and threats. The resulting survival improvement targets should be viewed as the product of a planning exercise, not a representation of deterministically based estimates. (More information about how survival improvement targets were allocated to the different actions is presented in Appendix B.)

Although the survival improvement targets in Table 5-5 are estimates only, they complement the analysis summarized in Table 5-3. In addition, they provide a useful way to show the potential magnitude of juvenile survival at the action scale relative to other actions. The survival improvement targets illustrate how a small increment of implementation of a far-reaching action could offer significantly more potential for recovery than full implementation of an action that is more limited in scope. Comparison of Tables 5-3 and 5-5 and the cost estimates that are developed in the next section form the basis for prioritization of actions in Chapter 7, "Perspectives on Implementation."

A special case in assigning survival improvement targets to actions are those actions (CRE–01 and CRE–09) that use land protection as a means of achieving the target. In theory, protection projects contribute only to maintenance of baseline conditions and not to recovery. However, the estuary recovery plan module does assign a portion of the survival improvement targets to protection projects. The reasoning here is that without protection of baseline environmental conditions, significantly more effort would be required in restoration projects to offset the continued loss of functioning habitat that would result from increases in the human population and corresponding conversion of habitats to economically beneficial land uses. Thus, assigning survival improvement targets to protection projects reflects the value of avoiding the additional effort that would be required to restore functioning habitats lost because they were not protected.

Uses of the Survival Improvement Targets

The survival improvement targets in Table 5-5 were developed to address a particular planning challenge in the estuary module: how to compare the potential benefits of management actions that are disparate in their scope and feasibility, especially when scientific information about the causes of salmonid mortality in the estuary is incomplete. In the absence of comprehensive scientific data, the targets provide a useful framework for evaluating the relative merits of different actions. However, survival improvement targets should not be understood to represent actual numbers of fish, especially when considered in isolation.

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[4] Although for the purposes of this analysis 20 percent is considered a hypothetical number, it is a plausible number. The 20 percent figure is based on overall estimates of juvenile mortality in the estuary, known mortality that can be attributed to specific threats, and professional judgment regarding the efficacy of the different management actions and the likelihood that constraints to their implementation can be overcome.

For example, it would be inappropriate to use the survival improvement targets to estimate total juvenile mortality in the estuary, attribute a level of mortality to a specific limiting factor or threat, or calculate “per-fish” costs of actions. Because the survival improvement targets are not scientifically derived, they have limited use for life-cycle modeling. On the other hand, the targets could serve as a starting point for life-cycle modeling in the absence of rigorous data.

It also would be unwise to predict specific outcomes of an action or suite of actions based solely on the survival improvement targets. Although the targets could appropriately be used to guide expenditures and the selection of individual projects that are consistent with the module’s management actions, any implementation of those projects should be accompanied by monitoring to evaluate the projects’ effectiveness, test the assumptions underlying the targets, and provide a basis for refining them.

Because the survival improvement targets are a tool for comparing the relative benefits of actions, they are particularly useful in weighing the trade-offs involved in implementing some actions but not others, or implementing actions only partially. For example, in theory, if a certain action were implemented partially or not at all, the potential 20 percent gain in the number of wild, ESA-listed juveniles leaving the estuary and plume could not be achieved unless other actions were implemented to a greater extent than envisioned in the module, to compensate. Survival improvement targets provide a way of evaluating various scenarios for implementation. This is critical because the implementation of every action already is constrained (often significantly) and, in most cases, the opportunities to remove constraints and implement actions more fully are limited.

TABLE 5-5
Survival Improvement Targets Allocated to Management Actions[1]

Number	Action Description	Survival Improvement Target[1] with Constrained Implementation (numbers of wild, ESA-listed fish)			
		Ocean Type[1]	% of Total Improvement Target	Stream Type[1]	% of Total Improvement Target
CRE-01	Protect intact riparian areas in the estuary and restore riparian areas that are degraded.	150,000	6%	100,000	6%
CRE-02	Operate the hydrosystem to reduce the effects of reservoir surface heating, or conduct mitigation measures.	100,000	4%	30,000	2%
CRE-03	Establish minimum instream flows for the estuary that would help prevent further degradation of the ecosystem.	25,000	1%	20,000	1%
CRE-04	Adjust the timing, magnitude and frequency of flows (especially spring freshets) entering the estuary and plume to improve access to habitats and provide better transport of coarse sediments an the estuary, plume, and littoral cell.	250,000	10%	150,000	9%
CRE-05	Study and mitigate the effects of entrapment of fine sediment in reservoirs, to improve nourishment of the littoral cell.	5,000	<1%	5,000	<1%
CRE-06	Reduce the export of sand and gravels via dredge operations by using dredged materials beneficially.	50,000	2%	15,000	<1%
CRE-07	Reduce entrainment and habitat effects resulting from main- and side-channel dredge activities in the estuary.	8,000	<1%	10,000	<1%
CRE-08	Remove pilings and pile dikes with low economic value when removal clearly would improve ecosystem health.	175,000	7%	115,000	7%
CRE-09	Protect remaining high-quality off-channel habitat from degradation.	350,000	14%	100,000	6%
CRE-10	Breach or lower dikes and levees to improve access to off-channel habitats.	450,000	18%	100,000	6%

CRE-11	Reduce the square footage of over-water structures in the estuary.	30,000	1%	5,000	<1%
CRE-12	Reduce the effects of vessel wake stranding in the estuary.	55,000	2%	2,000	<1%
CRE-13	Manage pikeminnow and other piscivorous fish, including introduced species, to reduce predation on salmonids.	140,000	6%	125,000	7%
CRE-14	Identify and implement actions to reduce salmonid predation by pinnipeds.	500[2]	N/A	4,500[2]	N/A
CRE-15	Implement education and monitoring projects and enforce existing laws to reduce the introduction and spread of noxious weeds.	20,000	<1%	15,000	<1%
CRE-16	Implement projects to redistribute part of the Caspian tern colony currently nesting on East Sand Island.	2,000	<1%	350,000	21%
CRE-17	Implement projects to reduce double-crested cormorant habitats and encourage dispersal to other locations.	2,000	<1%	250,000	15%
CRE-18	Reduce the abundance of shad in the estuary.	5,000	<1%	5,000	<1%
CRE-19	Prevent new introductions of invertebrates and reduce the effects of existing infestations.	8,000	<1%	2,000	<1%
CRE-20	Implement pesticide and fertilizer best management practices to reduce estuary and upstream sources of toxic contaminants entering the estuary.	55,000	2%	44,000	3%
CRE-21	Identify and reduce industrial, commercial, and public sources of pollutants.	275,000	11%	72,000	4%
CRE-22	Monitor the estuary for contaminants and/or restore contaminated sites.	300,000	12%	150,000	9%
CRE-23	Implement stormwater best management practices in cities and towns.	45,000	2%	15,000	<1%
	Total	2.5 million		1.68 million	

[1] Appendix B presents more information on how survival improvement targets were developed.

[2] The survival improvement targets are assigned for juvenile salmonids only. Although CRE-14 relates specifically to adult salmonids, the survival numbers for CRE-14 are not included in the 20 percent survival improvement targets for juvenile salmonids.

Evaluation of Management Actions: Costs and Schedule

Implementing recovery actions in the estuary will be expensive and require a long-term commitment by many entities. In Tables 5-2 and 5-5, two approaches were used to portray the potential survival improvements associated with implementing actions. In Table 5-6, each action is broken down into one or more projects that can be considered elements of that action.

For some management actions, the first project involves conducting a study or establishing a forum to assemble existing technical information. There are several reasons for this. In some cases, existing information about how to reduce the associated threat to salmonids is limited, and additional study is needed to identify and pilot-test possible actions to determine which ones would be most effective. This is particularly important when funds for implementing management actions are limited. Additionally, conducting a study or establishing a forum involves stakeholders who may have local knowledge about the threat or will be responsible for implementing projects. Lastly, studies and forums provide an opportunity to understand the constraints of management actions, to reexamine assumptions about what is and is not possible, and to explore the lengths to which, as a society, we are willing to go to implement actions that will contribute to the recovery of salmon and steelhead in the Columbia River basin. The intent of including studies and forums in the management actions, when appropriate, is not to postpone taking on-the-ground action but to ensure that any actions that are taken are truly effective, that stakeholders are involved in the process, and that important dialogue occurs about the value of reducing constraints and implementing management actions as fully as possible, even in situations where implementation is highly constrained.

Each project in Table 5-6 has a corresponding unit and cost, and the project costs are summed to produce a total cost. The costs identified in this section do not represent a detailed economic analysis; in fact, they are not economic costs and have not been discounted across time. Instead, the cost estimates are in constant dollars over a 25-year period—the minimal amount of time that will be needed for the management actions in this recovery plan module to be implemented. A 25-year period was selected for several reasons: many of the actions identified in the estuary module have not yet been implemented, in many cases programs to implement the actions are not in place, and some actions are highly uncertain. (As an example, the removal of pile structures to help recover salmonids and improve ecosystem health is largely untested.) In addition, given the complex life cycle of salmonids, it likely will take many cycles to realize the benefits of implementation of these actions.

For many projects, the estimates are general because of the speculative nature of the level of effort that will be applied to implement them. Also, the projects and cost estimates attempt to establish a reasonable cost for recovery—they are not a detailed "wish list" of projects that are waiting to be completed. This point is important in the estuary because many of the actions and their component projects do not lend themselves to the type of discrete restoration projects that might occur in a small tributary, like adding large woody debris. In the future, as restoration and protection actions in the estuary occur, this more detailed level of cost estimates may be possible.

The estuary recovery plan module addresses habitat conditions for all Columbia River basin ESUs during a single stage of their life cycle, but many additional management actions—

including actions in the tributaries—will be needed to achieve recovery of any particular ESU. Because the management actions in the module are only a subset of all the actions needed for recovery of an ESU, the costs in Table 5-6 do not reflect the total costs to achieve recovery. Total costs for recovery are more appropriately represented in the recovery plans for each ESU, as these plans deal with multiple life stages for a specific ESU.

In most cases, the project costs in Table 5-6 are direct costs, meaning out-of-pocket costs that a public or private interest would pay to initiate and complete the action. Action implementation costs should be viewed from a level-of-effort perspective. In most cases, the degree to which actions can be implemented is speculative. This is true for a variety of reasons, but economic, social, political, scientific, and public safety constraints often limit an action's potential for implementation.

Table 5-6 establishes costs for each of the 23 actions in the estuary recovery plan module. It may be determined that not all actions or their corresponding projects should be implemented. On the other hand, new actions or projects may emerge. Most importantly, the development of costs for this suite of actions and projects is an optimistic view of the potential to overcome constraints. This is partly because constraints often represent past societal choices that are virtually impossible to reverse. The costs identified in Table 5-6 were developed by PC Trask & Associates with input from jurisdictions and agencies. It is anticipated that these estimates will be refined as larger societal decisions are made.

Each action in Table 5-6 includes a proposed schedule for implementation. The schedule is designed to place projects in a logical order and spread costs over a long period of time when possible. Costs are identified over a 25-year span, with some projects being implemented once over a relatively short period and others continuing over the entire 25 years.

Other elements contained in Table 5-6 include the association of actions to specific geographical reaches, key assumptions about actions, a list of potential implementers,[5] and notes that help explain how costs were developed. The relationship of actions to the eight geographic reaches and the plume helps to define the breadth of the action and may also indicate which jurisdictions may implement actions in the future. Key assumptions relate primarily to implementation and provide insight into the level of effort reflected in the action costs. Notes are specific information that helps clarify a particular unit or cost.

[5] The list of potential implementers is intended only to indicate entities that *may* have a role in implementation and to serve as a guide to begin discussion of implementation roles. It does not imply any budgetary, regulatory, or other responsibility for implementation.

TABLE 5-6
Estimated Cost and Schedule

Management Action CRE-1:
Protect intact riparian areas in the estuary and restore riparian areas that are degraded.

Project	Unit	Cost	Schedule
1. Educate landowners about the ecosystem benefits of intact riparian areas and the costs of degraded riparian areas.	20 years @ $100,000/year	$2 million	2008 - 2028
2. Encourage and provide incentives for local, state, and federal regulatory entities to maintain, improve (where needed), and enforce consistent riparian area protections throughout the lower Columbia region.	5 years @ $200,000/year	$1 million	2008 - 2013
3. Actively purchase riparian areas from willing landowners in urban and rural settings when the riparian areas cannot be effectively protected through regulation or voluntary or incentive programs and (1) are intact, or (2) are degraded but have good restoration potential.	Rural: 3,500 acres at $5,000/acre[1] Urban: 100 acres at $75,000/acre	$25 million	2007 - 2031
4. Restore and maintain ecological benefits in riparian areas; this includes managing vegetation on dikes and levees to enhance ecological function.	14 miles @ $500,000/mile	$ 7 million	2006 - 2031

Total costs: $35 million

Geographical extent: Reaches A, B, C and H.

Key assumptions: (1) New homes, businesses, and industry will increase with population growth in the basin. (2) Some intact riparian areas are not adequately protected. (3) Protecting intact riparian areas would be cheaper than restoring degraded areas. (4) Some degraded riparian areas could be restored and gain ecological function, with associated downstream benefits. (5) Comprehensive protection and restoration of riparian habitats would occur concurrently with population growth, which will continue at a high rate.

Potential Implementers:
- U.S. Army Corps of Engineers
- Bonneville Administration
- Washington Department of Fish and Wildlife
- Oregon Department of Fish and Wildlife
- Counties
- Cities
- Port Districts
- Conservation districts
- Columbia Land trust
- The Wetlands Conservancy
- The Nature Conservancy
- Ducks Unlimited
- National Fish and Wildlife Foundation
- Oregon Watershed Enhancement Board
- Salmon Recovery Funding Board
- Lower Columbia River Estuary Partnership
- NOAA Fisheries
- Columbia River Estuary Study Taskforce
- Utility districts
- Watershed councils

Notes:
[1] Acreage amounts are 25-year targets that depend on willing sellers and funding.

Management Action CRE-2:

Operate the hydrosystem to reduce the effects of reservoir surface heating, or conduct mitigation measures.

Project	Unit	Cost	Schedule
1. Conduct a reservoir heating study to determine the extent of the issue and identify hydrosystem operational changes that would reduce effects and/or mitigate downstream temperature issues.	1 study	$2.5 million	2007 - 2013
2. Implement hydrosystem operational changes to reduce temperature effects; if no change is possible, mitigate effects through restoration of tributary riparian areas.	25 years @ $700,000/year[1]	$17.5 million	2010 - 2032

Total costs: $20 million

Geographical extent: All reaches (A-H), including the plume and nearshore.

Key assumption: (1) Either there is potential to alter management practices in the hydrosystem to reduce flow temperatures or a commensurate level of mitigation in tributaries would reduce temperatures in the estuary. (2) If temperatures continue to increase above 19° C, the estuary could become completely lethal for salmonids and other native species.

Potential Implementers:

- Bonneville Power Administration
- U.S. Army Corps of Engineers
- Utility districts
- Oregon Department of Environmental Quality
- Washington State Department of Ecology

Notes:

[1] Assumes that some level of improvement is possible, but that the level of possible improvement is likely to be minor because of complexities of the hydrosystem; assumes that mitigation will be needed to offset temperature increases.

Management Action CRE-3:

Establish minimum instream flows for the estuary that would help prevent further degradation of the ecosystem.

Project	Unit	Cost	Schedule
1. Establish a forum to explore options and develop policy recommendations on instream flows.	5 years @ $1 million/year[1]	$5 million	2007 - 2015
2. Implement instream flow regulations in accordance with the policy recommendations in Project No. 1.	5 years @ $1 million/year[2]	$5 million	2015 - 2023

Total costs: $10 million

Geographical extent: All reaches, including the plume and nearshore.

Key assumptions: (1) Demand for water for human use will grow as the human population in the basin increases. (2) Additional legal instream flows in the Columbia River mainstem and tributaries could be established through the efforts of affected parties basinwide. (3) Establishing a legal instream flow would protect flows entering the estuary in the future. (4) An instream flow law would help develop additional water conservation efforts and guide land use development in concert with water availability.

Potential Implementers:

- States (Washington, Oregon, Idaho, Montana)
- Canada
- U.S. Army Corps of Engineers
- Bonneville Power Administration
- U.S. Bureau of Reclamation

Notes:
[1]Costs are associated with developing the planning capacity (i.e., staff, office, technical support) to support the basinwide entity.
[2]Costs are associated with staffing the law-making activities needed to implement basinwide instream flow.

Management Action CRE-4:

Adjust the timing, magnitude and frequency of flows (especially spring freshets) entering the estuary and plume to improve access to habitats and provide better transport of coarse sediments in the estuary, plume, and littoral cell.

Project	Unit	Cost	Schedule
1. Conduct a flood study to determine the risks and feasibility of returning to more normative flows in the estuary.	2 years @ $500,000/year	$1 million	2009 - 2010
2. Conduct a study to determine the habitat effects of increasing the magnitude and frequency of flows (i.e., how much access of river to off-channel habitats would increase).	3 years @ $500,000/year	$1.5 million	2009 - 2011
3. Conduct additional studies to determine the extent of other constraints, including international treaties, systemwide fish management objectives, and power management.	4 years @ $500,000/year	$2 million	2010 - 2014
4. Make policy recommendations to action agencies on flow, taking into consideration beneficial estuary flows, flood management, power generation, irrigation, water supply, fish management, and other interests.	25 years @ $100,000/year	$2.5 million	2010 - 2035
5. Implement modified estuary flow regime annually in concert with other interests, including hydroelectric, flood control, and water withdrawals.	25 years @ $1.5 million/year[1]	$37.5 million	2011 - 2036

Total costs: $44.5 million

Geographical extent: All reaches (A-H), the plume, and the Columbia River littoral cell.

Key assumptions: (1) Even incremental changes in the magnitude and frequency of flows would improve salmonid habitat opportunity and food inputs, which would have benefits throughout the ecosystem. (2) Studies of flood risk and the effect of flow changes on estuarine habitat would provide data useful in modifying hydrosystem operations to benefit salmonids. (3) Studies of constraints to implementation would identify some obstacles that could be overcome. (4) Small to moderate changes in the magnitude, frequency, and timing of flows would improve sediment transport-related habitat opportunity in the estuary. (5) Increased spring freshets would yield greater sediment transport-related benefits than would other flow modifications.

Potential Implementers:

- Bonneville Power Administration
- U.S. Army Corps of Engineers
- U.S. Bureau of Reclamation

Notes:

[1] Assumes a $1.5 million per year cost of decreased hydrosystem generation revenues to compensate for hydrosystem impacts to fish and wildlife; also assumes that flood risk associated with beneficial estuary flows does not increase significantly.

Management Action CRE-5:

Study and mitigate the effects of entrapment of fine sediment in reservoirs, to improve nourishment of the littoral cell.

Project	Unit	Cost	Schedule
1. Identify the effects of reservoir sediment entrapment on economic and ecological processes; this includes effects on ship channels, turning basins, port access, jetty activities, littoral cell erosion and accretion, and habitat availability.	1 study	$2 million	2008 - 2011
2. Establish a forum to develop a regionwide sediment plan for the estuary and littoral cell.	10 years at $100,000/year	$1 million	2006 – 2031
3. Implement projects recommended in the plan to mitigate the effects of sediment entrapment.	5 projects @ $1 million/project	$5 million	2010 - 2020

Total costs: $8 million

Geographical extent: All reaches (A-H), including the plume and littoral cell.

Key assumptions: (1) Sediment entrapment in reservoirs will continue. (2) Sediment entrapment has negative effects, both ecologically and economically. (3) The extent of these effects warrants exploration and implementation of potential mitigation measures. (4) Studying potential mitigation measures would identify some actions that would be effective and could be implemented.

Potential Implementers:

- U.S. Army Corps of Engineers
- Bonneville Power Administration

Management Action CRE-6:

Reduce the export of sand and gravels via dredge operations by using dredged materials beneficially.

Project	Unit	Cost	Schedule
1. Establish a forum to develop a regionwide sediment plan for the estuary and littoral cell.	See CRE-5.	See CRE-5.	See CRE-5.
2. Identify and implement demonstration projects designed to assess ecosystem beneficial uses of dredged materials.	10 projects @ $100,000/project	$1 million	2006 - 2012
3. Dispose of dredged materials using techniques identified through the demonstration projects and regionwide planning.	10 years @ $500,000/year[1]	$5 million	2008 - 2033

Total costs: $6 million

Geographical extent: Reaches A, B, C and the plume and nearshore.

Key assumptions: (1) Dredging activities will continue or increase over time. (2) Opportunities to beneficially use dredged materials for habitat can be identified. (3) Beneficial use of dredged material would have a positive effect on sediment transport and habitat-forming processes in the estuary, plume, and littoral cell.

Potential Implementers:

- U.S. Army Corps of Engineers
- Port districts
- Lower Columbia River Solutions Group
- Oregon Department of Environmental Quality
- Oregon Department of State Lands
- Oregon Department of Fish and Wildlife
- Oregon Department of Land Conservation and Development
- Washington Department of Ecology
- Washington Department of Fish and Wildlife

Notes:

[1]Unit cost is funding to pay for activities beyond the minimum required by law, to achieve regional-scale ecosystem benefits.

Management Action CRE-7:

Reduce entrainment and habitat effects resulting from main- and side-channel dredge activities in the estuary.

Project	Unit	Cost	Schedule
1. Identify and evaluate dredge operation techniques designed to reduce entrainment and other habitat effects.	1 project	$500,000	2008 - 2010
2. Initiate demonstration projects designed to test and evaluate dredge operations.	5 projects @ $200,000/project	$1 million	2009 - 2012
3. Implement best management techniques.	10 years @ $250,000/year[1]	$2.5 million	2011 - 2036

Total costs: $4 million

Geographical extent: Reaches B, C, D, E and F.

Key assumptions: (1) Improved best management practices can be identified that would help reduce the impact of dredging. (2) Mitigation activities would help offset changes to the estuary caused by dredging.

Potential Implementers:

- U.S. Army Corps of Engineers
- Port districts
- Private entities, such as ports and sand and gravel dredgers
- Counties and cities

Notes:

[1]This is an estimate of the incremental cost above permitted dredge activities. Cost may vary significantly depending on site-specific conditions.

Management Action CRE-8:

Remove pilings and pile dikes with low economic value when removal clearly would improve ecosystem health.

Project	Unit	Cost	Schedule
1. Inventory, assess, and evaluate in-channel pile dikes for their economic value and their impact on the estuary ecosystem; develop criteria for establishing project priority.	1 plan	$250,000	2007 - 2009
2. Remove priority pilings and pile dikes.	25 years @ $1.2 million/year	$30 million	2008 - 2033
3. Monitor the physical and biological effects of pile dike removal.	10 years @ $25,000/year	$250,000	2010 - 2020

Total costs: $30.5 million

Geographical extent: Reaches A, B, C, D, E, F, G and H.

Key assumption: (1) Many pilings, pile dikes, and similar structures could be removed without compromising the shipping channel or protection of property. (2) Over time, the removal of superfluous pile dikes would improve conditions for salmonids and the ecosystem.

Potential Implementers:

- U.S. Army Corps of Engineers
- Bonneville Power Administration
- Washington Department of Natural Resources
- Oregon Department of Lands
- Lower Columbia River Estuary Partnership
- Counties and cities

Notes:
[1]A set is a logical grouping of a large number of priority pile dikes targeted for removal.

Management Action CRE-9:

Protect remaining high-quality off-channel habitat from degradation.

Project	Unit	Cost	Schedule
1. Educate landowners about the ecosystem benefits of protecting and stewarding intact off-channel areas and the costs of restoring degraded areas.	15 years @ $250,000/year	$3.75 million	2007 - 2032
2. Encourage and provide incentives for local, state, and federal regulatory entities to maintain, improve (where needed), and enforce consistent riparian area protections throughout the lower Columbia region.	10 years @ $1 million/year	$10 million	2007 - 2032
3. Actively purchase off-channel habitats in urban and rural settings that (1) cannot be effectively protected through regulation, (2) are degraded but have good restoration potential, or (3) are highly degraded but could benefit from long-term restoration solutions.[1]	Rural: 5,000 acres at $5,000/acre Urban: 150 acres at $100,000/acre	$40 million	2007 - 2031

Total costs: $53.75 million

Geographical extent: Reaches A, B, and C.

Key assumptions: (1) Protection opportunities can be increased over the next decade through public awareness, education, regulatory, and acquisition programs. (2) Protection of off-channel habitats is less expensive than restoration. (3) High-quality off-channel habitats offer benefits to salmonids that cannot be provided in other ways. (4) Protection will be needed to off-set increasing threats resulting from human population increases in the estuary and basin.

Potential Implementers:

- U.S. Army Corps of Engineers
- Bonneville Power Administration
- Columbia Land Trust
- The Wetlands Conservancy
- Ducks Unlimited
- Columbia River Estuary Study Taskforce
- The Nature Conservancy
- Lower Columbia River Estuary Partnership
- Watershed councils
- Oregon Watershed Enhancement Board
- Oregon Department of Fish and Wildlife
- Washington Department of Ecology
- Port districts
- Cities
- Conservation districts
- Other special districts

Notes:

[1]Assumes purchases are made over a 25-year period with willing sellers.

Management Action CRE-10:

Breach or lower dikes and levees to improve access to off-channel habitats.

Project	Unit	Cost	Schedule
1. Breach or lower the elevation of dikes and levees; create and/or restore tidal marshes, shallow-water habitats, and tide channels.	5,000 acres[1] @ $10,000/acre	$50 million	2006 - 2031
2. Remove tide gates to improve the hydrology between wetlands and the channel and to provide juveniles with physical access to off-channel habitat; use a habitat connectivity index to prioritize projects.	2,000 acres[1] @ $10,000/acre	$20 million	2006 - 2031
3. Upgrade tide gates where (1) no other options exist, (2) upgraded structures can provide appropriate access for juveniles, and (3) ecosystem function would be improved over current conditions.	1,000 acres[1] @ $5,000/acre	$5 million	2006 - 2031

Total costs: $75 million

Geographical extent: Reaches A, B, C, E, F, and G.

Key assumptions: (1) Additional opportunities to restore off-channel habitats can be developed through long-term outreach and improved landowner relationships. (2) Restoration of sites, including elevation restoration, would yield broad-scale ecosystem benefits over time. (3) A habitat connectivity index would help target efforts toward the projects that would provide the greatest benefits. (4) Restoration of highly degraded sites may be necessary to yield long-term benefits.

Potential Implementers:

- U.S. Army Corps of Engineers
- Bonneville Power Administration
- U.S. Fish and Wildlife Service
- Oregon Watershed Enhancement Board
- Oregon Department of Fish and Wildlife
- Columbia Land Trust
- Columbia River Estuary Study Taskforce
- Salmon Recovery Funding Board
- Conservation districts
- Other districts
- Cities
- Counties
- Lower Columbia River Estuary Partnership
- Lower Columba Fish Recovery Board
- Watershed councils

Notes:

[1]Acreage equals amount of affected area. Costs include those associated with protecting other land uses from renovated hydrology (i.e., moving dikes and levees).

Management Action CRE 11:

Reduce the square footage of over-water structures in the estuary.

Project	Unit	Cost	Schedule
1. Inventory over-water structures and develop a GIS layer with detailed metadata files.	2 projects @ $150,000/project	$300,000	2007 - 2009
2. Initiate a planning process to evaluate existing and new over-water structures for their economic, ecological, and recreational value.	2 phases[1] @ $100,000/phase	$200,000	2009 - 2013
3. Remove over-water structures that no longer serve a functional use and/or reduce the footprint of viable structures when appropriate.	10 projects @ $500,000/project[2]	$5 million	2012 - 2037
4. Establish criteria for new permit applications to consider the cumulative impacts of over-water structures.	1 project	$300,000	2008 - 2010

Total costs: $5.8 million

Geographical extent: Reaches D and G.

Key assumptions: (1) Over-water structures pose some threat to salmonids. (2) A fair number of over-water structures are no longer in use or have relatively minor value to owners. (3) An inventory of over-water structures would aid in assessing individual structures' economic, ecological, and recreational value.

Potential Implementers:

- U.S. Army Corps of Engineers
- Washington Department of Natural Resources
- Oregon Department of Land Conservation and Development
- Oregon Department of State Lands

Notes:

[1]The first phase is technical and the second phase is policy.

[2]A project is defined as a set of structures that have been identified for removal; cost is level of effort.

Management Action CRE-12:

Reduce the effects of vessel wake stranding in the estuary.

Project	Unit	Cost	Schedule
1. Use existing and new research results documenting stranding by ship wakes to estimate juvenile mortality throughout the estuary. Modeling could use newly emerging Light Detection and Ranging (LIDAR) satellite imagery to conduct analyses.	1 study	$500,000	2007
2. Analyze factors contributing to ship wake stranding to determine potential approaches to reducing mortality in locations where juveniles are most vulnerable. Design and implement demonstration projects and monitor their results.	1 three-phase study @ $500,000/phase	$1.5 million	2007 - 2010
3. Implement projects identified in Project No. 2 that are likely to result in the reduction of ship wake stranding events.	10 projects @ $1.3 million/project[1]	$13 million	2011 - 2026

Total costs: $15 million

Geographical extent: Reaches C, D, E and F.

Key assumptions: (1) Vessel wake stranding is a significant issue for ocean- and stream-type salmonids employing the fry life history strategy in the estuary.

Potential Implementers:

- U.S. Army Corps of Engineers
- Columbia River pilots
- Ports
- US Coast Guard
- River and bar pilots

Notes:

[1] This is a level-of-effort cost approach that will require information generated in Projects No. 1 and 2.

Management Action CRE-13:

Manage pikeminnow and other piscivorous fish, including introduced species, to reduce predation on salmonids.

Project	Unit	Cost	Schedule
1. Monitor the abundance levels of pikeminnow, smallmouth bass, walleye, and channel catfish.	5 monitoring events @ $10,000/event (every 5 years)	$50,000	2006 - 2031
2. Implement actions as necessary to prevent population growth (i.e., modify habitat); increase the northern pikeminnow bounty program.	25 years @ $600,000/year	$15 million	2006 - 2031

Total costs: $15.05 million

Geographical extent: Reaches D, E, F, G and H.

Key assumption: Management techniques would maintain populations at levels that would maintain or reduce predation impacts to salmonids.

Potential Implementers:

- U.S. Army Corps of Engineers
- Washington Department of Fish and Wildlife
- Oregon Department of Fish and Wildlife
- Bonneville Power Administration

Notes:
[1] It is unknown whether projects will be needed to manage warm-water fish. In some cases, there may be warm-water habits close to juvenile habitat, in which case site-specific action would be required.

Management Action CRE-14:

Identify and implement actions to reduce salmonid predation by pinnipeds.

Project	Unit	Cost	Schedule
1. Expand federal and state activities at Bonneville Dam to test non-lethal and potentially lethal methods of reducing pinniped populations throughout the estuary. This includes efforts to manage pinnipeds through the Marine Mammal Protection Act.	3 projects @ $500,000/project	$1.5 million	2007 - 2011
2. Implement actions likely to reduce pinniped predation on adult salmonids.	25 years @ $500,000/year[1]	$12.5 million	2007 - 2032

Total costs: $14 million

Geographical extent: All reaches (especially H).

Key assumptions: (1) Mortality from pinnipeds may be a larger source of salmonid mortality than previously understood. (2) Further study would clarify the impact of pinniped predation on salmonids; recent studies by the U.S. Army Corps of Engineers at Bonneville Dam represent a good start on this task. (3) Mortality from pinniped predation could be reduced through non-lethal and lethal methods. (4) The Marine Mammal Protection Act could be modified over time to allow more tools for managing pinnipeds in the estuary. In December 2006, NMFS received an application under Section 120 of the Marine Mammal Protection Act from the states of Oregon, Washington, and Idaho requesting authorization to intentionally take, by lethal methods, individually identifiable California sea lions that prey on Pacific salmon and steelhead (Federal Register 2007)

Potential Implementers:

- U.S. Army Corps of Engineers
- Bonneville Power Administration
- NOAA Fisheries
- Oregon Department of Fish and Wildlife
- Washington Department of Fish and Wildlife

Notes:

[1] Units are years; given legal constraints, it is likely that ongoing efforts to prevent predation will continue over the next 25 years.

Management Action CRE-15:

Implement education and monitoring projects and enforce existing laws to reduce the introduction and spread of noxious weeds.

Project	Unit	Cost	Schedule
1. Increase public awareness of exotic plant species and proper stewardship techniques.[1]	10 years @ $100,000/year	$1 million	2008 – 2018
2. Inventory exotic plant species infestations and develop a GIS layer with detailed metadata files.	5 phases @ $200,000/phase	$1 million	2007 – 2012
3. Implement projects to address infestations on public and private lands.	13 years @ $1 million/year	$13 million	2008 – 2021
4. Monitor infestation sites.	20 years @ $25,000/year	$500,000	2010 - 2030

Total costs: $15.5 million

Geographical extent: All reaches (A-H).

Key assumptions: (1) Aquatic noxious weeds have a negative effect on the estuary ecosystem and affect juvenile salmonids by altering habitat and causing food webs to deteriorate. (2) Additional information is needed on the location, extent, and type of infestations and their effects on the estuary ecosystem. (3) Because introductions of noxious weeds can permanently alter the estuary ecosystem, prevention activities are crucial. (4) Education, outreach, and monitoring would help prevent further introductions of exotic plants.

Potential Implementers:

- U.S. Army Corps of Engineers
- Bonneville Power Administration
- US Fish and Wildlife Service
- State agencies
- Conservation districts
- Noxious weed districts
- Counties
- Cities
- Watershed councils
- Lower Columbia River Estuary Partnership

Notes:

[1]This project is recommended for upstream mainstem and tributaries, but the costs presented here are for activities in the estuary only. Many exotic plants have established themselves upstream and represent a constant downstream threat to the estuary.

Management Action CRE-16:

Implement projects to redistribute part of the Caspian tern colony currently nesting on East Sand Island.

Project	Unit	Cost	Schedule
1. Enhance or create tern nesting habitat at alternative sites in Washington, Oregon, and California.	3 sites @ $1 million/site	$3 million	2008 - 2012
2. Reduce tern nesting habitat on East Sand Island to 1 to 1.5 acres.	1 project @ $4.5 million/project	$4.5 million	2007 - 2010
3. Monitor the regional tern population.	25 years @ $100,000/year	$2.5 million	2010 - 2035

Total costs: $10 million

Geographical extent: Reaches A and B.

Key assumption: Ongoing and new management actions directed to Caspian tern nesting habitat would continue to reduce salmonid mortality from tern predation.

Potential Implementers:

- U.S. Army Corps of Engineers
- U.S. Fish and Wildlife Service
- Oregon Department of Fish and Wildlife
- Washington Department of Fish and Wildlife

Management Action CRE-17:

Implement projects to reduce double-crested cormorant habitats and encourage dispersal to other locations.

Project	Unit	Cost	Schedule
1. Identify, assess, and evaluate methods of reducing double-crested cormorant abundance numbers.	1 multiphase study	$2.5 million	2007 - 2011
2. Implement demonstration projects resulting from Project No. 1 (i.e., decoys and audio playback methods).	5 pilot projects @ $500,000/project	$2.5 million	2010 - 2015
3. Implement projects resulting in reduced predation by cormorants.[1]	10 years @ $700,000/year	$7 million	2013 - 2023

Total costs: $12 million

Geographical extent: Reaches A and B.

Potential Implementers:

- U.S. Army Corps of Engineers
- U.S. Fish and Wildlife Service
- Oregon Department of Fish and Wildlife
- Washington Department of Fish and Wildlife

Notes:

[1]This is a level-of-effort cost estimate; efforts to manage cormorants in the estuary are significantly lagging Caspian tern management efforts.

Management Action CRE-18:

Reduce the abundance of shad in the estuary.

Project	Unit	Cost	Schedule
1. Initiate a planning process to organize technical information about shad and identify potential control methods.	2 phases @ $250,000/phases	$500,000	2007 - 2011
2. Implement demonstration projects to evaluate effective management methods.	4 projects @ $500,000/project	$2 million	2008 - 2015
3. Implement shad population management techniques.[1]	10 years @ $250,000/year	$2.5 million	2010 - 2015
4. Monitor and evaluate management techniques.	10 years @ $50,000/year	$500,000	2011 - 2021

Total costs: $5.5 million

Geographical extent: All reaches (A-H).

Key assumptions: (1) Shad have negative affects on salmonids in the estuary. (2) Additional research would shed light on how shad affect salmonids and suggest new management techniques. (3) New management techniques would be unlikely to cause significant change.

Potential Implementers:

- U.S. Army Corps of Engineers
- Oregon Department of Fish and Wildlife
- Washington Department of Fish and Wildlife

Notes:

[1]This is a level-of-effort cost estimate; currently there are no plans to manage shad abundance levels in the Columbia River.

Management Action CRE-19:

Prevent new introductions of invertebrates and reduce the effects of existing infestations.

Project	Unit	Cost	Schedule
1. Establish a forum to (1) assemble existing technical information on introduced invertebrates in the estuary, and (2) develop a plan for managing existing infestations.	2 phases @ $250,000/phase	$500,000	2007 - 2010
2. Implement recommendations from the plan for managing existing infestations (Project No. 1, above).[1]	5 projects @ $500,000/project	$2.5 million	2008 - 2013

Total costs: $3 million

Geographical extent: All reaches (A-H).

Key assumptions: (1) Ship ballast practices could be improved to help prevent further degradation of the estuary ecosystem. (2) Additional research would help scientists understand the effects of exotic invertebrates on the ecosystem. (3) Because the effects of exotic invertebrates on the ecosystem usually cannot be reversed, it is important to prevent introductions when possible.

Potential Implementers:

- Port districts
- Oregon Department of Fish and Wildlife
- Washington Department of Fish and Wildlife
- U.S. Fish and Wildlife Service
- Oregon Department of Agriculture
- Washington State Department of Agriculture
- Portland State University
- Oregon State Marine Board
- Washington State Parks and Recreation Commission

Notes:

[1]This is a level-of-effort cost estimate.

Management Action CRE-20:

Implement pesticide and fertilizer best management practices to reduce estuary and upstream sources of toxic contaminants entering the estuary.

Project	Unit	Cost	Schedule
1. Increase funding for education and outreach programs targeted to professional and leisure agricultural activities so as to promote reduced use of toxic materials.	10 years @ $1.2 million/year[1]	$12 million	2008 - 2018

Total costs: $12 million

Geographical extent: All reaches (A-H).

Key assumptions: (1) Some users of pesticides and fertilizers are not adequately informed about best management practices for these toxic contaminants. (2) Additional benefits to salmonids could be realized through continued efforts by farmers, chemical manufacturers, and regulatory programs to reduce impacts from fertilizers and pesticides. (3) Benefits to salmonids would increase over a relatively long period time as agricultural practices improve.

Potential Implementers:

- Washington Department of Agriculture
- Oregon Department of Agriculture
- Conservation districts
- U.S. Environmental Protection Agency
- Washington Department of Ecology
- Oregon Department of Environmental Quality
- Lower Columbia River Estuary Partnership
- Natural Resources Conservation Service

Notes:
[1]Unit cost includes estimates for the estuary and estuary tributaries only; the action recommends similar upstream activities.

Management Action CRE-21:

Identify and reduce industrial, commercial, and public sources of pollutants.

Project	Unit	Cost	Schedule
1. Identify non-permitted point-source pollutant discharge sites and take enforcement action where necessary.	8 years @ $150,000/year	$1.2 million	2007 - 2014
2. Provide cost-share incentives for National Pollution Discharge Elimination System (NPDES) permit holders to upgrade effluent above their permit requirements.	10 years @ $2 million/year	$20 million	2010 - 2020
3. Study and establish threshold treatment standards for pharmaceuticals and other unregulated substance discharges; update existing NPDES permits to reflect the new standards.	5 years @ $2 million/year	$10 million	2007 - 2012
4. Provide grants and low-cost loans to permit holders required to treat effluent to standards established in Project No. 3.	10 years @ $2 million/year	$20 million	2012 - 2017

Total costs: $51.2 million

Geographical extent: Reaches D and G.

Key assumptions: (1) Non-permitted discharges that currently are occurring would be identified and curtailed. (2) Financial incentives or support would motivate NPDES permit holders to raise their effluent treatment levels above permit requirements. (3) Releases of industrial and commercial pollutants into the estuary would be reduced over time.

Potential Implementers:

- U.S. Environmental Protection Agency
- Washington Department of Ecology
- Oregon Department of Environmental Quality
- Trade groups such as the Oregon Association of Clean Water Agencies that represent wastewater dischargers

Management Action CRE-22:

Monitor the estuary for contaminants and/or restore contaminated sites.

Project	Unit	Cost	Schedule
1. Implement contamination monitoring recommendations identified in the *Federal Columbia River Estuary Research, Monitoring, and Evaluation Program* (Pacific Northwest National Laboratory 2006).	TBD	TBD[1]	2006 - 2031
2. Develop criteria and a process for evaluating contaminated sites to establish their restoration potential.	1 phase @ $500,000/phase	$500,000	2007 - 2017
3. Develop an integrated multi-state funding strategy to address contamination cleanup in the estuary from non-identifiable upstream sources.	Out-of-Estuary[2]	n/a	2007 - 2012
4. Restore those contaminated sites that will yield the greatest ecological and economic benefits.	20 years @ $3 million/year	$60 million	2007 - 2027

Total costs: $60.5 million

Geographical extent: Reaches A, B, C, D, E, F, G, and H.

Key assumptions: (1) Monitoring will continue to provide vital data needed to understand the toxic contaminant problem and identify potential solutions. (2) Monitoring will identify hot spots of contamination. (3) Contamination sites will be identified for which responsible parties cannot be determined. (4) Additional analysis would identify contamination sites whose restoration would yield significant ecological and economic benefits. (5) Restoration of contaminated sites would benefit salmonids and the ecosystem over time.

Potential Implementers:

- Lower Columbia River Estuary Partnership
- Columbia River Estuary Study Taskforce
- Conservation districts
- Oregon Department of Environmental Quality
- Washington State Department of Ecology
- Federal regulatory agencies such as NOAA Fisheries and U.S. Geological Survey
- Port districts
- U.S. Geological Survey

Notes:

[1] Monitoring costs to be developed through the estuary/ocean subgroup established in response to the Federal Columbia River Power System (FCRPS) Biological Opinions.

[2] Cost is considered to be outside the purview of estuary-specific projects.

Management Action CRE-23:

Implement stormwater best management practices in cities and towns.

Project	Unit	Cost	Schedule
1. Monitor stormwater outputs to measure treatment compliance with existing local and state regulations throughout the basin.	10 years @ $200,000/year	$2 million	2007 - 2015
2. Establish a fund source for regulatory agencies to use when insufficient resources are available to (1) access best available science, (2) develop standards beyond requirements, or (3) adequately enforce regulations.	3 years @ $2 million/year	$6 million	2009 - 2011

Total costs: $8 million

Geographical extent: Reaches D and G.

Key assumptions: (1) Population growth in the Columbia River basin will continue to influence the hydrology and water quality in the estuary. (2) Stormwater practices could be improved by monitoring and enforcing compliance with existing regulations, making best scientific information available, and developing higher standards. (3) The resulting improvements in hydrology and contaminant exposure in the estuary would occur slowly over time. (4) This action is protective in nature; costs are not associated with retrofitting existing stormwater facilities.

Potential Implementers:

- Cities and counties
- Washington Department of Ecology
- Oregon Department of Environmental Quality
- U.S. Environmental Protection Agency
- Lower Columbia River Estuary Partnership

Notes:

This project is recommended for upstream mainstem and tributaries, but the costs presented here are for activities in the estuary only.

Table 5-7 is a summary of costs for the 23 management actions. The total estimated budget for implementation of the actions at this level of effort approaches is approximately $500 million over 25 years. This number contrasts with the $1.1 billion estimated to help restore salmon in Puget Sound tributaries over a 10-year period. Other major ecosystem restoration efforts across the United States, including San Francisco Bay, Chesapeake Bay, the Everglades, and the Louisiana Coast, are estimated to cost several billion dollars apiece.

TABLE 5-7
Summary of Costs of Management Actions

Number	Action Description	Cost for Constrained Implementation	%*
CRE-01	Protect intact riparian areas in the estuary and restore riparian areas that are degraded.	$35 million	7%
CRE-02	Operate the hydrosystem to reduce the effects of reservoir surface heating, or conduct mitigation measures.	$20 million	4%
CRE-03	Establish minimum instream flows for the estuary that would help prevent further degradation of the ecosystem.	$10 million	2%
CRE-04	Adjust the timing, magnitude and frequency of flows (especially spring freshets) entering the estuary and plume to improve access to habitats and provide better transport of coarse sediments in the estuary, plume, and littoral cell.	$44.5 million	9%
CRE-05	Study and mitigate the effects of entrapment of fine sediment in reservoirs, to improve nourishment of the littoral cell.	$8 million	2%
CRE-06	Reduce the export of sand and gravels via dredge operations by using dredged materials beneficially.	$6 million	1%
CRE-07	Reduce entrainment and habitat effects resulting from main- and side-channel dredge activities in the estuary.	$4 million	1%
CRE-08	Remove pilings and pile dikes with low economic value when removal clearly would improve ecosystem health.	$30.5 million	6%
CRE-09	Protect remaining high-quality off-channel habitat from degradation.	$53.75 million	10%
CRE-10	Breach or lower dikes and levees to improve access to off-channel habitats.	$75 million	14%
CRE-11	Reduce the square footage of over-water structures in the estuary.	$5.8 million	1%
CRE-12	Reduce the effects of vessel wake stranding in the estuary.	$15 million	3%
CRE-13	Manage pikeminnow and other piscivorous fish, including introduced species, to reduce predation on salmonids.	$15.05 million	3%
CRE-14	Identify and implement actions to reduce salmonid predation by pinnipeds.	$14 million	3%

CRE-15	Implement education and monitoring projects and enforce existing laws to reduce the introduction and spread of noxious weeds.	$15.5 million	3%
CRE-16	Implement projects to redistribute part of the Caspian tern colony currently nesting on East Sand Island.	$10 million	2%
CRE-17	Implement projects to reduce double-breasted cormorant habitats and encourage dispersal to other locations.	$12 million	2%
CRE-18	Reduce the abundance of shad in the estuary.	$5.5 million	1%
CRE-19	Prevent new introductions of invertebrates and reduce the effects of existing infestations.	$3 million	1%
CRE-20	Implement pesticide and fertilizer best management practices to reduce estuary and upstream sources of toxic contaminants entering the estuary.	$12 million	2%
CRE-21	Identify and reduce industrial, commercial, and public sources of pollutants.	$51.2 million	10%
CRE-22	Monitor the estuary for contaminants and/or restore contaminated sites.	$60.5 million	12%
CRE-23	Implement stormwater best management practices in cities and towns.	$8 million	2%
	Total	$514.3 million	

*Column shows the relative percentage of each action to the total cost. Percentages do not add up to 100 percent because of rounding.

Summary

The estuary and plume ecosystems are especially vulnerable to threats because these ecosystems are affected by factors across a wide geographic range—from upstream to the estuary itself, and even well out in the Pacific Ocean. A set of actions has been identified to help address threats to salmonids in the estuary, plume, and nearshore. Other recovery venues must also address upstream threats to effectively improve degraded habitats in the estuary. It is difficult to characterize these estuary actions in terms of their effectiveness because overall salmonid mortality in the estuary and specific mortality rates related to certain threats are only beginning to be understood. This estuary recovery plan module uses survival improvement targets to help characterize the level of effort required and the costs of that effort.