11 Habitat Protection, Conservation, And Mitigation Strategies

If the impacts described in Section 7 of this document occur within habitat used by a potentially covered species, the result may be incidental take of aquatic animals through either physical harm to the animals or reduced capacity of the habitat to serve essential life functions, such as reproduction, foraging, and migration. The ESA requires that such impacts be avoided or, if unavoidable, minimized to the maximum extent practicable. Measures for avoiding or minimizing the risk of incidental take are identified below. Mitigation measures to compensate for unavoidable take and management strategies are also provided.

It is difficult to programmatically quantify the risk of incidental take attributable to any structure that modifies hydraulics because of the great variety of site-specific factors at work. However, the reviews performed for these white papers indicate that habitat impacts are approximately defined by the **area of habitat affected**, the **number of species affected**, and the **importance of the habitat** to each species.

The **area of habitat affected** is the area of habitat destruction, which can be determined from project plans, plus the area of habitat subject to embedding, scour, or deposition, which can be determined via hydraulic modeling of the structure using a common sediment transport model (appropriate models are described by Miller et al. 2001). Impacts resulting from rare and unpredictable events such as debris flows may not have to be analyzed in an ESA context, but if necessary could be estimated within a cumulative effects context using landscape-scale studies such as published watershed analyses.

The **number of species** affected can be determined at the site scale via surveys or from an inventory database, such as the Streamnet database, the Priority Habitats and Species database, the distribution maps developed for the WDNR Aquatic Lands HCP effort, or the Forest Practices HCP (WDNR 2005c), Streamnet database, and/or the Priority Habitats and Species database. For certain species, these resources identify species use as well as presence, e.g., spawning, migration, or rearing habitat.

The **importance of a habitat** can be estimated by the principle of limiting factors: The resource that is most limiting to a population's growth will be the principal control on that population. For example, if the fish in a given stream are most limited by insufficient spawning habitat, then a project that destroys spawning habitat will result in greater harm than one that destroys an equivalent area of foraging habitat. Baseline data on limiting factors for some species are available from watershed councils and have been prepared for most WRIAs that contain habitat accessible to anadromous salmonids; a current inventory and summaries of limiting factors are available from the Washington State Conservation Commission website at http://salmon.scc.wa.gov. However, these summaries are rarely informative enough to make a determination about which habitat elements are directly limiting for fish production. For salmonids, quantitative analysis has estimated limiting factors for most streams in Washington using the Ecosystem Diagnosis and Treatment model; further information is available at http://www.mobrand.com/edt/.

WDFW might consider a requirement to assess take risk for each HPA. Estimates of area affected, species affected, and habitat importance would allow unprecedented quantification of habitat impacts on a statewide level and would provide an invaluable tool for adaptive management of the HPA program.

This analysis assumes that all activities and structures permitted under the HPA authority are fully compliant with applicable local, state, and federal regulations, particularly including the *Hydraulic Code Rules* (WAC 220-110).

Measures that could minimize impacts from artificial structures include finding an alternative to building the structure; siting the structure as far as possible outside of the active channel/water body; minimizing the structure's footprint; and generally designing the structure to have the least possible effect on channel hydraulics (Bates 2003).

Additional measures for further avoiding or minimizing the risk of incidental take are identified below. These measures include one that was not specified in any of the documents reviewed for this white paper: modifying in-water work windows to be protective of spawning and incubation by any potentially covered species that could be present in the area affected by a proposed project.

11.1 General Actions Applicable to All Activity Types

11.1.1 Information Gathering Recommendations

1. Establish and implement a plan to address data gaps identified in Section 10.

2. Develop additional information on many of the potentially covered species' life histories, habitat needs, and habitat tolerances.

3. Develop and apply a technique for evaluating cumulative impacts of HPA-permitted projects.

4. Track additional information in the HPMS database.
    - Size of structures
    - Specific type of structures
    - Monitoring requirements
    - Mitigation requirements
    - Summary of monitoring findings.

    This information would be useful for analyses at a variety of scales (e.g., basin, stream, region, state) and for WDFW biologists during their reviews of proposed bank protection projects.

5. Develop WDFW guidelines on a series of topics relevant to designing, constructing, and monitoring bank protection projects, including:
    - Beach nourishment
    - Riparian revegetation
    - Channel dewatering
    - Fish and invertebrate species presence
    - Fish and invertebrate removal

6. Update eelgrass/macroalgae guidelines, possibly to include
    - incorporating technology-based approaches (e.g., towed video with diver-based ground-truthing and density data gathering)
    - standardizing monitoring data delivery to facilitate its incorporation into a statewide database (similar to Ecology's SEDQUAL database).

11.1.2 Enforcement Recommendation

Commit to enforcing applicable regulations and providing sufficient staff to meet enforcement needs.

11.1.3 Education Recommendations

Education recommendations apply to information sharing within WDFW and education of the public, particularly local jurisdictions and shoreline landowners.

Within WDFW:

1. Educate staff through information- and monitoring data-sharing workshops for WDFW biologists.

2. Develop an improved system of using monitoring data and making it more widely available. Presumably the use of data could be improved at both the project-specific level (i.e., monitoring data reviewed and acted upon to ensure project compliance) and more generally (i.e., to guide subsequent proposal reviews).

3. Develop statewide clearinghouse for monitoring data, including aquatic and riparian vegetation, fish use, and physical habitat data.

4. Use statewide clearinghouse of eelgrass data to generate updated geographic information system (also known as GIS) layers.

5. Educate the public on shoreline components, habitat function, and species vulnerabilities.

6. Have staff available to assist in development of project monitoring plans and monitoring oversight, as necessary.

Public education:

1. Educate the public on shoreline components, habitat function, and species vulnerabilities. It is critical that decision makers and the general public be educated about the outcomes of their actions, especially those who have the greatest influence on outcomes (i.e., those who live, work, and play along our shorelines).

2. Have staff available to assist in development of project monitoring plans and monitoring oversight, as necessary.

11.1.4 Conservation Program Recommendations

1. Develop and implement conservation programs. Use ecological principles to guide actions and incorporate multiple functions and processes in developing goals and objectives for conservation actions.

2. Develop incentives for conservation programs. Land acquisition, tax incentives, regulatory incentives, and other measures have been used and should be considered in the development of conservation programs.

11.1.5 Construction Recommendations

11.1.5.1 Construction and Maintenance Best Management Practices

The U.S. Environmental Protection Agency (U.S. EPA) has released a recent publication relevant to the management of construction and maintenance related effects on water quality (U.S. EPA 2007). The report summarized best management practices (BMPs) that are relevant to the construction and maintenance of HPA-permitted activities. The recommended BMPs, which should be applied to hydromodificaton projects to reduce nonpoint source pollution, include:

- Stockpile fertile topsoil for later use for plants
- Use hand equipment rather than heavy equipment
- If using heavy equipment, use wide-track or rubberized tires
- Avoid instream work except as authorized by the local fishery and wildlife authority
- Stay 100 ft away from water when refueling or adding oil
- Avoid using wood treated with creosote or copper compounds
- Protect areas exposed during construction.

Other nonconstruction-related recommendations put forth by U.S. EPA (2007) include:

- Incorporating monitoring and maintenance of structures
- Using adaptive management
- Conducting a watershed assessment to determine project fate and effects
- Focusing on prevention rather than mitigation
- Emphasizing simple, low-tech, and low cost methods.

The National Marine Fisheries Service (NMFS 2001) says that temporary crossings placed in salmonid streams for water diversion during construction activities should meet all fish passage guidelines where fish are expected to be present during the construction window.

In the construction of many kinds of HPA-permitted structures, avoidance or minimization of impacts can be accomplished through proper site selection. For construction and maintenance activities, management strategies can be implemented to minimize underwater noise, project area dewatering, and navigational dredging impacts.

Construction activities should be timed to occur when sensitive life stages (e.g., spawning, incubation, emergence) of potentially covered species are less likely to be present (NMFS 2003a). To minimize effects to aquatic vegetation, they could also be timed to occur at times of the year when aquatic vegetation biomass is at a minimum.

11.1.5.2 Pile Driving

The intensity of underwater noise produced by pile driving varies considerably depending on site characteristics and the type of materials and methods employed. A desirable approach for avoiding underwater noise impacts from pile driving is to conduct this activity within a dewatered exclusion area. This measure may not be practicable in many circumstances. In such cases, a number of BMPs can be used to limit underwater noise impacts.

The following BMPs should be considered to minimize effects related to pile driving on HCP species:

- Use pile caps[1], if feasible and safe, to reduce the sound of pile driving below injury level (Laughlin 2006).

- Use vibratory hammers[2]; the low rise in sound over a longer period of time is less stressful to aquatic animals, and the sound is typically 10 to 20 dB lower than impact hammer pile driving (WSDOT 2006a).

- For projects with pile sizes less than 24 inches in diameter, use the smallest piling size practicable to lower sound pressure levels when driven.

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[1] Pile caps have been shown to effectively reduce underwater sound levels. Laughlin (2006) reduced sound levels by 27 dB with a wood pile cap when driving a 12-inch-diameter steel pile, which would reduce noise levels to below those established for injury (at 33 feet [10 meters]) by NMFS and USFWS. Conbest, Micarta, and Nylon pile caps have also been shown to reduce sound levels (Laughlin 2006).

[2] Under certain conditions, a vibratory hammer can be used to reduce noise impacts. Vibratory hammers vibrate the pile into the sediment by oscillating the pile into the substrate. The vibratory action of this hammer causes the sediment surrounding the pile to liquefy so that the pile can be driven (WSDOT 2006a). Peak sound levels for vibratory hammers can exceed 180 dB; however, the sound from these hammers has a relatively slow rise, produces sound energy that is spread out over time, and is generally 10 to 20 dB lower than pile driving using an impact hammer (WSDOT 2006a). However, it is frequently necessary to proof a piling driven with a vibratory hammer with an impact hammer to ensure the integrity of the piling.

- Use (untreated) wood or concrete piles where practicable, as these also induce lower sound pressure levels. Even though these materials are less strong, increasing the size of the structure would be considered less impactful as long as the structure does not become so large as to produce other hydrogeomorphic impacts (e.g., if the additional wood piles inhibit transport of sediment, water, or groundwater).

- Use air bubble curtains [3]to create a bubble screen (Reyff et al. 2003; Vagle 2003). (Dual layer air bubble curtain or similar[4] noise abatement technology.)

- Maintain the integrity of the air bubble curtain; no boat traffic or other structure or equipment should be allowed to penetrate the air curtain during pile driving activities.

- In marine environments, install geotubes during low tide to minimize the potential for entrapment and stranding of fish within the enclosed area.

- Use fabric barriers and/or cofferdams to create an additional interface to buffer sound transmission into the underwater environment (WSDOT 2006).

- Use helical piles where possible. These piles do not require vibration or hammering. The only noise produced is from the screwing action of the driller.

- To avoid attracting fishes with lights during nighttime pile driving operations, limit pile driving to daylight hours to the extent practicable

11.1.5.3 Channel Dewatering

- Develop guidelines for channel dewatering and stream bypasses. Adopt a protocol for review/approval of proposed dewatering and stream bypass plans. The isolation plan should include information on timing, channel dewatering, and bypass plans. The isolation method should be able to withstand any flows that are encountered during the

[3] Proper design and implementation of a bubble curtain are key factors in the effectiveness of this strategy (WSDOT 2006a). Based on the literature, NMFS and USFWS usually assume there will be a 15 dB_{peak} and RMS reduction in sound levels when using a bubble curtain (WSDOT 2006a). For steel piling 14 inches or less in diameter, as well as concrete and wooden piling, such a reduction would reduce noise levels to below injury thresholds established by NMFS and USFWS at a distance of 33 feet (10 meters).

[4] Fabric barriers and cofferdams are also used to attenuate sound levels from pile driving by creating another interface through which sound travels. The concept is similar to that behind the use of bubble curtains (WSDOT 2006a).

isolaiton period, to avoid flooding and the possibility of fish reoccupying the area prior to dewatering.

- Adopt science-based protocols for fish removal and exclusion activities. An example protocol is provided by WSDOT (WSDOT 2006b). NMFS also provides electrofishing guidelines, which are in common use and are usually required as conditions of NMFS scientific take permits. Recommended guidance/protocols include those for:
  - Fish capture including seining and electrofishing.
  - Fish handling.
  - Tracking and reporting of number and species of fish captured, fish injured, injuries observed, and fish killed.
- Make sure qualified people are available who can perform fish removal, capture, handling, and exclusion.
  - Define the qualifications of a "qualified fish biologist" or "qualified personnel." A qualified biologist needs to be on-site supervising and/or implementing the operation.
  - NMFS often requires a resume from the permittee prior to issuing a take permit.
  - Develop an appropriate training or qualification process for biologists.
  - Maintain a list of qualified fish biologists.
  - If electrofishing, at least two people (an operator and a netter) are required to safely and effectively capture the fish. In larger stream areas, two or more electrofishers operating simultaneously may be necessary to effectively capture all of the fish, as each electrofisher only has a limited range of effectiveness.
- A scientific collection permit from WDFW is required to capture fish.

For fish salvage/electrofishing operations:

- Require slow dewatering and passive fish removal from the dewatered area before initiating active fish-removal protocols. Fish removal by seining is recommended before resorting to electrofishing, which carries a greater risk of mortality (NMFS 2006). Seining alone is not as effective at removing fish as electrofishing, and is likely to miss fish during a salvage operation. Such fish would die when the stream is dewatered. Initially seining and then electrofishing is a more effective way of safely removing fish from the work isolation area.

- Pay attention to timing and conditions during the operation. Perform work during low-flow or dry conditions, and/or during dry weather. With less water in the channel, there are likely to be fewer fish affected by channel dewatering. However, electrofishing may have impacts if sensitive life stages of fish are present, for example adults that are migrating into the system to spawn, or when the eggs and alevin are still in the gravel. Also, during lower flows the water temperature often is elevated. Electrofishing should not be performed when temperatures exceed 64 F or 18 C, as it reduces the oxygen content of the water, affects the conductivity of the water (influencing the effect of the electric current), and fish are often already stressed, which could lead to mortality during electrofishing and handling.

- When electrofishing, use the minimum voltage and duty cycle necessary to effectively capture the fish. Use the lowest power output that provides for effective electrofishing (sufficiently large field for taxis and narcosis). This will be influenced by the conductivity and the temperature of the water, as well as the size of fish expected to be encountered. Fish should recover quickly (within a minute) and should not show any external signs of injury, such as branding or deformation (Snyder 2003). Use the least damaging current available. Most electrofishers now use a pulsed direct current, where the "duty cycle" or pulse length and frequency can be adjusted to minimize impacts on fish. Do not use electrofishers that use alternating current (Snyder 2003).

- Watch for the occurrence of brands (i.e., burn-type marks caused by electrofishing) and extended tetany (tonic spasm of muscles), which indicate harmful effects are still a problem, even when using currents designed to be less harmful (Snyder 2003).

- Backpack electrofishers generally have a circular anode and a cable cathode. Boat-based electrofishers use spherical anodes, but under most circumstances a boat shocker would not be used in a fish salvage operation. The size of anode that is used must be appropriate to the size of the stream. Personal communications cited in Snyder (2003) suggest that while spherical electrodes are theoretically superior to cables, no significant difference in catch rate or the incidence of brands was observed between the two; that spherical anodes and cable cathodes appear to be the best combination; and that anodes should be kept high in the water to draw fish to the surface, where they can be easily netted.

- Species such as lamprey are more effectively captured using non-circular anode rings that direct the current into the substrates. A qualified biologist would know what is appropriate for the conditions.

Minimize channel dewatering impacts on HCP species by taking the following precautions:

- If pumps are used to temporarily divert a stream to facilitate construction, an acceptable fish screen must be used to prevent entrainment or impingement of small fish (NMFS 2001).

- Adhere to performance criteria for fish screens on pumped diversions presented by NMFS (1996a) and WDFW (1998). Compliance will minimize the risk of incidental take due to entrainment.

- Pump sediment-laden water (from the work area that has been isolated from surrounding water) to an infiltration treatment site.

- Dispose of debris or sediment outside of the floodplain.

- Stabilize disturbed areas at the work site with sediment corresponding to the ambient bed to prevent an influx of fine sediment once water is reintroduced to the site. Replace disturbed streambed materials with clean gravel of the appropriate size prior to rewatering to minimize an influx of fine sediment.

- Fish should be kept in the water as much as possible. Minimize exposure to the field and specimen handling by rapidly netting fish before they get too close to the anode and quickly, but gently, placing them in oxygenated holding water. After capture, place fish into a temporary holding bucket to allow recovery prior to transferring the fish to a safe release site. The time in the bucket should be as brief as possible. Process the fish frequently to reduce crowding, and change the water frequently to maintain cool, well-oxygenated water (Snyder 2003).

- The release location should near the capture site, but appropriately located either upstream of the construction activities, or a sufficient distance downstream to avoid increased turbidity from construction activities.

11.1.5.4 Dredging and Fill

Dredging and fill are necessary components of project construction and maintenance for many HPA-permitted activities. The permitted in-water work window for these structures should consider the full range of HCP species likely to occur in the vicinity and should be timed to avoid the presence of sensitive species and/or life-history stages where practicable. In cases where adverse impacts on HCP species cannot be avoided effectively (e.g., a nursery site for buried lamprey amocoetes), alternative designs that avoid dredging and fill impacts should be considered.

Where practicable, dredging and fill activities should be conducted within an exclusion area (dewatered or watered as appropriate) following fish removal. This will help to limit elevated turbidity and sediment impacts. Creation of exclusion areas and fish removal and relocation should be conducted using standardized protocols for these procedures.

A number of techniques have been developed that may be used to avoid or mitigate the effects of dredging (Smits 1998) and placement of fill materials on sensitive ecosystems such as wetlands (Sheldon et al. 2005). Dredging associated with fish screens is typically coupled with the installation and/or maintenance of a water diversion system. Placement of fill material is typically associated with the installation of water diversion system or may be incidental during construction.

General recommendations to avoid and minimize the impacts of dredging are provided in the 2001 Dredging: Marine Issues white paper (Nightingale and Simenstad 2001a) and include:

- Use multiseason pre- and postdredge project biological surveys to assess animal community impacts more extensively;
- Incorporate cumulative effects analysis into all dredging project plans;
- Increase use of landscape-scale planning concepts to plan for beneficial use projects most suitable to the area's landscape ecology and biotic community and food web relationships;
- Further identify turbidity and noise thresholds to assess fish injury risks; and
- Further analyse and synthesize knowledge about the spatial and temporal distribution of fish and shellfish spawning, migration behavior, and juvenile rearing to evaluate environmental windows for dredging on a site-specific basis.

The following recommendations are intended to reduce the effects of dredging on HCP species:

- For new marine, riverine, and lacustrine projects and significant expansions beyond general maintenance dredging, thoroughly assess the large-scale, cumulative impacts of the resulting changes in bathymetry, habitat loss, and change to estuarine/nearshore marine ecosystem dynamics (e.g., salinity intrusion).
- Require hopper dredges, scows, and barges, trucks or any other equipment used to transport dredged materials to the disposal or transfer sites to completely contain the dredged material.
- For long-term projects where continuous dredging and onloading to barges occur, require periodic movement of the barge to reduce shading.
- Modify in-water work windows to take into consideration what is known about site-specific spatial and temporal distribution of fish and shellfish eggs, larvae, and juveniles.
- Evaluate the application of in-water work windows on a site-specific basis based on the location and features of the site, such as sediment composition, plant and animal assemblages, and timing of seasonal and migration patterns.
- Use presampling bathymetric surveys, records from previous dredging events, and best professional judgment to estimate the volume of sediments likely to be dredged; base sampling and testing requirements on this estimated volume.
- Avoid projects and expansions that convert intertidal to subtidal habitat. If such conversion is unavoidable, employ comprehensive, large-scale risk assessment to identify the cumulative effects of site-specific changes to ecosystem dynamics.
- Select dredging equipment types according to project-specific conditions, such as sediment characteristics.

- Base turbidity threshold testing for dredging operations on background site turbidity.
- In areas where dredging is proximal to sensitive habitats (or in projects where sediments both suitable and unsuitable for unconfined open water disposal will be dredged adjacent to each other), use the “Silent Inspector” (a computerized electronic sensor system) to monitor dredging operations. This tool can assist in operational documentation and regulatory compliance by providing record accessibility and clarity. It also offers advantages for planning, estimating, and managing dredging activities.
- Increase the use of multiseason, preproject surveys of benthos to compare with postproject surveys to understand dredging impacts.
- Where applicable and involving uncontaminated sediments, consider beneficial use of dredged materials that can contribute to habitat restoration, rehabilitation, and enhancement, particularly for projects that incorporate a landscape ecology approach.
- Avoid beneficial use projects that impose unnatural habitats and features on estuarine, marine, and riverine landscapes.
- Use hydrodynamic models to predict system-wide changes in salinity, turbidity, and other physicochemical regimes for project assessment planning that avoids or minimizes impacts on aquatic habitat.
- Dredging should be conducted to a depth not greater than a navigation channel depth at the seaward end. If necessary, authorize dredging to depths greater than the navigation channel at the seaward end only in berthing areas and turning basins for commercial shipping purposes.

11.1.5.5 Vessel Activities

Issues related to vessel activities (including barges) during construction include vessel grounding in sensitive habitats (such as eelgrass), the effects of propeller wash, the risk of accidental spills of fuel or other contaminants, the risk of introducing noxious weeds, and noise.

- WDFW’s standard HPA provisions already prohibit vessel grounding in areas of eelgrass, macroalgae, or forage fish spawning (e.g., “Eelgrass and kelp shall not be adversely impacted due to project activities [e.g., vessels shall not ground, anchors and spuds shall not be deployed, equipment shall not operate, and other project activities shall not occur in eelgrass and kelp,” from Marine Boat Ramp Maintenance and Repair provisions in the Hydraulic Pemit Management System]).
- It may be appropriate to require construction vessel operation plans for larger projects or projects located in particularly sensitive habitat to ensure that the potential for vessel and construction activity impacts to sensitive habitats and species is minimized.
- To reduce vessel impacts to the nearshore environment at the Clinton ferry terminal, Thom et al. (1995, in Haas et al. 2002) recommended constructing a longer deck that keeps vessels in deeper water.

- Elevated ambient noise levels are produced when construction vessels are operated continuously around a project site. To protect HCP species from the resulting stressors, operation of vessel engines and motorized equipment should be limited to the extent necessary to support construction work and the working environment. Where available and practicable, vessels with noise-deadening technology should be employed to reduce underwater noise levels produced.

- HPA standard provisions should include:
    - Clean propellers before putting boats into the water to reduce the spread of noxious weeds.
    - File a spill prevention plan.
    - Maintain vessels on a routine basis as well as prior to its use on the construction site.

- Floats should be sited in deeper water to reduce the potential impacts associated with propeller wash.

11.1.6 Aquatic Vegetation Recommendations

HPA-permitted activities can impact aquatic vegetation through altered autochthonous production, habitat complexity, and nutrient cycling. Mitigation of impacts to aquatic vegetation is best achieved through avoidance. To protect and restore aquatic habitat functions, management strategies and development of shoreline regulations should:

- Avoid or minimize the removal or disturbance of aquatic vegetation. Locate facilities in areas that are currently devoid of native aquatic vegetation or in areas that will minimize the potential impacts, such as in deeper water or further offshore.

- Minimize impacts from vessels associated with HPA-permitted structures. The typical effects of vessels on aquatic vegetation vary with both distance and propeller speed, both of which may be important factors in loosening sediment particles and eroding the vegetation.
    - Manage equipment and vessel operations and establish no-construction or no-vessel activity buffers around existing aquatic vegetation to protect this habitat and its contribution to ecological functions.
    - Require the control of turbidity during construction and operation of the facility to minimize prop wash and bubbles, and prevent suffocation or excessive shading of plants.

- Site structures in deeper water to minimize shading and physical impacts on aquatic vegetation.

- Do not allow floats to ground out on low tides.

- Encourage the use of upland boat storage areas and the use of slings to minimize shading of aquatic vegetation.

- Place the potential shade-casting structures perpendicular to the arc of the sun (i.e., north–south placement) to maximize transmission of light under the structure.
- Any walkways should be 100 percent grated; floats and docks should be at least 60 percent grating.
- Orient grating to maximize transmission of light under the structure.
- Minimize the amount of pier area that directly contacts the shoreline, to allow light penetration to the nearshore intertidal and shallow subtidal areas.

11.1.6.1 Eelgrass

If HPA-permitted structures (including “water crossing structures” such as bridges, “overwater structures,” and larger complexes such as marinas) are designed and located so that they do not reduce available light below approximately 325 $\mu M/m^2/sec$, then eelgrass impacts may be avoidable (Thom et al. 1996, in Simenstad et al. 1999).

Where projects result in a direct loss of eelgrass during in-water construction, revegetation can be achieved through natural regrowth or transplanting (Thom et al. 2001); however, transplanting eelgrass is not always successful and the science is still developing. For one project in the San Juan Islands, post-disturbance monitoring of eelgrass beds indicates that where substrate, depth, light availability, and currents are suitable and adjacent eelgrass remains intact, natural revegetation can recolonize disturbed areas at a rate of greater than 1 foot per year (Jones and Stokes 2005).

In Washington, transplanting has been used with some success to revegetate eelgrass beds, although a review of eelgrass restoration projects concluded that eelgrass restoration is “possible, with difficulty” (Thom et al. 2001). New eelgrass beds can be established where conditions that prevent eelgrass from growing (e.g., shade, depth, substrate, or current velocity) are remedied (Thom et al. 2001).

11.1.6.2 Freshwater Aquatic Vegetation

Mitigation of impacts to aquatic vegetation should focus on ecosystem functions (Hruby et al. 1999). Although all non-noxious aquatic plants are considered beneficial, replacement of vegetation lost or disturbed during project installation may be less beneficial than other ecosystem renovation methods, depending on the plant coverage, density, species, and setting involved. For example, guidance on assessing the functions and values of riverine flow through wetlands in Western Washington (Hruby et al. 1999) does not include aquatic vegetation as a variable in evaluating the functions and values to anadromous or resident fish. Likewise, the matrices of ecosystem functions and pathways for making ESA determinations of effect at the watershed scale (NMFS 1996; USFWS 1998) do not include aquatic vegetation as an indicator of ecosystem function. However, this is partly because both of these evaluation systems are largely designed to address salmonid habitat requirements; re-evaluation is warranted for many potentially covered species having a stronger dependence on freshwater aquatic vegetation (e.g., Olympic mudminnow or California floater). In many settings, aquatic vegetation can recolonize through natural seeding and vegetative growth if conditions are suitable. Depth, substrate, shade, and competition among plant species are all factors that determine which species of plants colonize and survive (Chambers et al. 1999).

Using the functional approach to assessing potential impacts to aquatic vegetation (Hruby et al. 1999), which is an important habitat component for many of the potentially covered species (e.g., Olympic mudminnow and California floater), and determining appropriate mitigation for the loss of freshwater aquatic vegetation are likely to result in minimal potential for incidental take related to aquatic vegetation loss.

11.1.7 Riparian and Shoreline Vegetation Recommendations

The following measures could help avoid and minimize incidental take arising from impacts to riparian and shoreline vegetation:

- Avoid and minimize any impacts on riparian, aquatic, and shoreline vegetation by protecting the vegetation.

- Consider whether projects that require extensive in-water work, which may require extensive access and which have high-quality riparian habitat, should have work performed entirely within the wetted channel to avoid impacts to riparian vegetation. The short-term impact to a stream channel may be of less consequence than the long-term impact that may be incurred to riparian vegetation, due to the respective rate of recovery.

- To the extent practicable, do not permit removal or disturbance of riparian vegetation in areas with high erosion hazard (Knutson and Naef 1997).

- Where riparian vegetation has been removed, isolate disturbed areas from aquatic resources using erosion control features until disturbed areas are stabilized.

- Consider all ecological functions when developing a riparian management strategy.

- If it is not possible to leave vegetation, prepare and carry out revegetation plans to restore the riparian vegetation. The revegetation plans should identify areas to be replanted, when construction is complete, with native riparian vegetation endemic to the area. The proximity of the vegetation to the aquatic habitat and the size of the vegetation should be such that it can restore the ecological benefits, such as temperature regulation and allochthonous inputs.

- Replanted vegetation should be monitored [5]. The project proponent should be required to ensure 100 percent of all plantings are viable and healthy at the end of one year and 80

[5] Some of the original white papers recommended a three-year monitoring period, with two monitoring reports; one at the end of the first year, another after three or five years. Other white papers recommended monitoring every other year or every third year for an unspecified period of time.

percent of all plantings are viable and healthy by the end of the three-year monitoring period. These recommendations are based on provisions in WAC 220-110 and on general conditions provided by the Corps, NMFS, and USFWS for Corps ESA Section 7 programmatic consultations.

- Submit monitoring reports to WDFW. Similar to the requirement of the Corps for ESA Section 7 individual and programmatic consultations, the first monitoring report should be submitted one year after project completion. After 3 years, monitoring and reporting should be completed every other year or every third year[6]. The monitoring reports must include information on the percentage of plants replaced, by species. Monitoring reports should also state the cause of any plant failure, a provision generally required by the Corps, NMFS, and USFWS for Corps ESA Section 7 programmatic consultations. In addition, any specific conditions provided by the U.S. Army Corps of Engineers (for project permits) or NOAA Fisheries and USFWS (for ESA Section 7 compliance) must be implemented.

- Save vegetation (specifically large trees and root wads) removed for the project for later use in restoration efforts. This condition has often been required in recent individual and programmatic Section 7 consultations. Even if the material is not specifically useful for the permitted action, a WDFW area habitat biologist will generally know of ongoing or pending restoration projects in need of LWD and root wads.

- Require performance bonds for projects disturbing large areas (e.g., >500 square feet) of riparian vegetation.

- Enforce revegetation requirements.

- Consider establishing buffers and setbacks that protect the functions of the riparian system and its contribution to ecosystem. The term “buffer,”as applied in a specific management context, denotes an area set aside and managed to protect a natural environment from the effects of surrounding land-use or human activities (May 2003; Knutson and Naef 1997). Depending on the context, buffers may be designed to perform a specific function or set of functions, such as filtering pollutants or providing shade (May 2003).

- Establishing buffer areas is an important regulatory tool both to keep development activities in this habitat to a minimum, and (for developed or redeveloping sites) to trigger mitigation sequencing to deal with project impacts on riparian vegetation. May (2003) provides a review of riparian functions as a factor of buffer width. As indicated in May (2003), there is no consensus in the literature recommending a single buffer width for a particular function or to accommodate all functions. Knutson and Naef (1997) resolved the variability in the literature by averaging effective buffers widths reported for specific riparian functions. Knutson and Naef (1997) show that for streams, a buffer

[6] See previous footnote.

width of 147 feet is effective in providing five of the seven riparian functions including: sediment filtration, erosion control, pollutant removal, LWD, and water temperature protection. Table 11-1 provides a summary from the scientific literature of how different riparian habitat widths protect function.

Table 11-1. Riparian buffer functions and widths (widths reported in feet)

Riparian Function	May (2003)			Knutson and Naef (1997)	
	Notes on Function	Range of Effective Buffer Widths	Minimum Recommended Widths	Range of Effective Buffer Widths	Average of Reported Widths
Sediment removal/erosion control	For 80% sediment removal	26 – 600	98		
Erosion control				100 – 125	112
Sediment filtration				26 – 300	138
Pollutant removal	For 80% nutrient removal	13 – 860	98	13 – 600	78
LWD recruitment	1 SPTH based on long-term natural levels	33 – 328	164	100 – 200	147
Water temperature protection	Based on adequate shade	36 – 141	98	35 – 151	90
Wildlife habitat	Coverage not inclusive	33 – 984	328	25 – 984	287
Microclimate	Optimum long-term support	148 – 656	328	200 – 525	412

SPTH = site potential tree height.

Brennan and Culverwell (2004) recommend the following for consideration as part of any coastal management strategy and development of shoreline regulations associated with marine riparian habitat:

- Preventing additional losses of riparian vegetation is both critical and cost-effective. Once riparian functions are lost, they are difficult and expensive to restore, if restoration is possible at all.

- Fill data gaps. The lack of empirical data for Northwest coastal ecosystems and limited recognition of riparian functions have led to poor management practices and protection standards for coastal resources. Research and documentation are critical to establish a scientific foundation for creating adequate policies and practices for protection and restoration.

- Establish appropriate buffers and setbacks. Buffers and setbacks are essential, functional, and cost-effective tools for preserving important processes and functions, preventing environmental degradation, and protecting valuable coastal resources.

- Maintain and/or restore riparian vegetation for human health and safety. Flooding, storm, and erosion hazards are common problems in coastal areas and become a greater threat when shoreline development does not consider the functions and values of maintaining riparian vegetation buffers.

- Identify, evaluate, and incorporate multiple functions into a management strategy. Any management strategy should be based on maintaining all natural processes and functions, determined by an evaluation of the specific requirements for maintaining individual and collective functions over space and time (e.g., LWD recruitment; life history requirements of multiple species of fishes and wildlife).

- Use a multidisciplinary approach in developing riparian management zones. Experts in a wide range of natural sciences should collaborate on an integrated and multidisciplinary assessment.

- Maintain and/or restore riparian vegetation for pollution abatement and soil stability. Vegetative buffers would likely be of benefit by reducing contaminants in runoff and reducing costly reactionary measures to clean up waterways.

- Maintain and/or restore riparian vegetation for fish and wildlife. It is clear that as vegetation is eliminated, the food supply, and thus the carrying capacity of the coastal ecosystem, is reduced.

- Protect marine riparian areas from loss and degradation. Riparian areas provide a wide range of functions that are beneficial to humans, fish, and wildlife. Every effort should be made to preserve remaining marine riparian areas from further degradation, fragmentation, and loss.

11.1.8 Water Quality Recommendations

Based on the findings of Bash et al. (2001) on turbidity effects on salmonids, the following mitigation measures are recommended to avoid direct and indirect effects on HCP species:

- Prior to project construction, determine background suspended sediment concentrations and collect information on particle size and shape, to understand the ambient turbidity to which animals have adapted.
- Review existing watershed assessments to consider pollution loads that may be from sources outside the project to evaluate the project's cumulative effects on turbidity levels.
- Once existing turbidity and sources have been determined, establish acceptable project increases to background turbidity that are similar to those set in the Implementing Agreement between WSDOT and Ecology (WSDOT and Ecology 1998), which states:

  > "All work in or near the water, and water discharged from the site shall meet the State's Water Quality Standards, WAC 173-201A. A mixing zone for turbidity is authorized within WAC 173.201A-030 during and immediately after necessary in-water or shoreline construction activities that result in the disturbance of in-place sediments. Use of a turbidity mixing zone is intended for brief periods of time (such as a few hours or days) and is not an authorization to exceed the turbidity standard for the entire duration of the construction. Use of the mixing zone is subject to the constraints of WAC 173-201A-100(4) and (6), requiring an applicant have supporting information that indicates the use of the mixing zone shall not result in the loss of sensitive or important habitat, substantially interfere with the existing or characteristic uses of the water body, result in damage to the ecosystem, or adversely affect public health. The mixing zone is authorized only after the activity has received all other necessary local and state permits and approvals, and after the implementation of appropriate best management practices to avoid or minimize disturbance of in-place sediments and exceedances of the turbidity criteria. Within the mixing zone, the turbidity standard is waived, and all other applicable water quality standards shall remain in effect. The mixing zone is defined as follows:
  >
  > 1. For waters up to 10 cfs [cubic feet per second] flow at time of construction, the point of compliance shall be 100-feet downstream of project activities.
  > 2. For waters above 10 cfs up to 100 cfs flow at time of construction, the point of compliance shall be 200-feet downstream of project activities.
  > 3. For waters above 100 cfs flow at the time of construction, the point of compliance shall be 300 feet downstream of project activities.
  > 4. For projects working within or along lakes, ponds, wetlands, estuaries, marine waters or other non-flowing waters, the point of

compliance shall be at a radius of 150-feet from the activity causing the turbidity exceedance."

- As an indicator of pre-construction conditions, assess the PAH and metals contamination levels of the water body and sediment prior to construction. Consider the existing watershed condition and account for point and nonpoint source pollution loads from watershed sources other than the project and from legacy impacts of the system when evaluating cumulative impacts from PAHs, metals, and turbidity. Professional experience and information on urban stormwater pollutants presented by Menzie et al. (2002) and numerous others support this measure as reasonable.

- Set stockpile areas back from the bank and include erosion prevention BMPs, such as silt fencing and tarp covers.

- Locate the structure deep enough to avoid prop wash resuspension of sediments and contaminants.

- Given the large size of terminals and the large number of pilings required for marinas, use alternatives to treated wood (e.g., materials such as metal, concrete, plastics, and composites) to avoid potential impacts for both new and/or replacement structures.

- If treated wood is used,
    - it should be encased or sealed to prevent leaching of harmful chemicals.
    - Sawdust, drillings, and trimmings from treated wood should be contained with tarps or other impervious materials and prevented from contact with the bed or waters of the state.
    - Structures built of treated wood should incorporate features such as steel, plastic, or rubber collars, fendering, or other systems to prevent or minimize the abrasion of treated wood by floats, ramps, or vessels.

Many of the following mitigation measures regarding aquatic applications of treated wood are based on those suggested by Poston (2001).

- Use alternative materials such as metal, concrete, or composites, or for temporary projects use untreated wood.

- If possible, install immersed treated wood products when potentially covered species are not present near the site. This measure is based on information on rapidly diminishing leaching rates reported by Poston (2001).

- Pre-soak treated wood in confined water to reduce impacts by capturing the initial surge of most concentrated leachate, particularly in the case of ACZA- and CCA Type C-treated products, for which leaching rates appear to drop dramatically after a few days.

- Phase and stagger the installation of ACZA- and CCA Type C-treated structures by a few weeks or more, which may dramatically reduce the concentration of leached metals in surrounding water and the instantaneous extent of the area of impact. This measure is based on information on rapidly diminishing leaching rates reported by Poston (2001).

- Use semi-transparent, water-repellent stain, latex paint, or oil-based paint on above-water portions of treated wood structures, which may reduce leaching of arsenic, chromium, and copper into stormwater generated by that portion of the structure (Lebow et al. 2004).

Additional mitigation measures for water quality include:

- Require that stormwater runoff be 100 percent contained. Route stormwater from the structure and adjacent impervious surfaces to a treatment system.

- If possible, determine a spatial limit, beyond which no water quality effects will extend. Within this limit, monitoring will be required to ensure that established water quality standards are met. If at any point during construction/dredging/demolition these standards are exceeded, construction/dredging/demolition activities will cease until water quality standards are met.

- Existing Washington State Department of Ecology regulatory requirements for Clean Water Act Section 401 certification and the Hydraulic Code limit the in-water curing of concrete as necessary to avoid pH effects and the use of appropriate BMPs to avoid leakage of concrete leachate to surface waters.

11.1.9 Hydrologic and Geomorphic Recommendations

11.1.9.1 Channel Hydraulics

WDFW could consider requiring that HPAs for any structure that will place fill within the OHWL include a hydraulic model of probable structure effects on sediment transport and channel hydraulics to ensure that impacts such as scour, deposition, and embedding due to fine sediment deposition are avoided or minimized[7].

A modeling requirement would ensure that effects of the structure on the channel, and by extension on potentially covered species, are as well understood as practicable. The results of such studies can be summarized so as to allow monitoring of the quantitative impact of authorized projects on channel hydraulics. Such results would be useful in estimating cumulative impacts of the HPA program, incidental take, and identifying appropriate compensatory mitigation measures.

11.1.9.2 Littoral Drift

Impacts to littoral drift can be avoided or minimized through the following measures:

[7] Some of the original white papers recommended that the hydraulic model provide a summary of effects "to a quantitatively ascertainable degree", while others said that the hydraulic model need not be numerical; conceptual or qualitative models may suffice for some settings.

- Design pile-supported structures with maximum open space between pilings to allow waves, currents, and sediment to pass beneath (MOEE 1995).

- Minimize certain impacts from floating structures placed perpendicular to shorelines, which dampen wave action and prohibit natural shoreline erosional processes, by minimizing the dimensions of these types of structures.

- Utilize floating breakwaters or ramps in place of breakwater walls to reduce effects on littoral drift (Nightingale and Simenstad 2001b).

- Do not allow floats to ground at low tide.

The effects of these measures are site-specific, and thorough study of the littoral drift cell and potential habitat affected should be conducted on projects that could affect the system's littoral currents and wave action. Avoiding or minimizing alterations in littoral processes would allow shoreline sediment conditions to change at the scales and rates that match those that potentially covered species have evolved to adapt to, minimizing the potential for incidental take through alterations in shoreline substrate distribution and consistency.

11.1.10 Artificial Light

Kahler et al. (2000) recommends that to reduce impacts on salmonid predation, additional shoreline or pier lighting on lakes should not be permitted, and Tabor et al. (1998) suggests that reducing artificial light in the Cedar River would benefit emigrating sockeye salmon. Tabor et al. (1998) also observed that any reduction in artificial lighting must be balanced with safety and other public concerns.

11.1.11 Lost Opportunities

The hydraulic and geomorphic modifications induced by many HPA-permitted projects (e.g., dams, weirs, tide gates, beaver dam removal and large woody debris removal) can result in lost-opportunity impacts. Mitigation for lost opportunity requires mitigation for channel processes affected by a project. In some situations, off-site mitigation may be the only option (WDFW 2003). According to WDFW (2003), the concept of mitigation for lost opportunity should only be applied when consistent, acceptable assessment methods or site-specific information is available. More detailed information on mitigation for lost-opportunity is provided in WDFW (2003).

11.2 Activity-Specific Avoidance, Minimization, and Mitigation Actions

The measures for avoiding or minimizing take include conservation measures and best management practices. Many of the activity-specific measures presented below are generally applicable to several types of activities.

Conservation measures are design elements that are intended to avoid or minimize impacts to habitats and species.

Best Management Practices (BMPs) are those measures used during the construction phase to avoid or minimize impacts.

11.2.1 Bank Protection

11.2.1.1 Avoidance and Minimization Techniques

Impact reduction measures for bank protection include both conservation measures and BMPs. Many of these practices have been identified in the published literature as well as guidance documents, and they may be required by regulatory agencies as permit conditions. Table 11-2 summarizes these measures as currently known and practiced, organized by mechanism of impact.

Table 11-2. Bank Protection Conservation Measures and BMPs

Mechanism of Impact	Conservation Measures[ab]	Best Management Practices
Construction	Require construction set-back that will avoid the risks associated with slope retreat (high and low-no-bank sites) (Gerstel and Brown 2006). Manage all surface water to contain and direct it appropriately to the base of the bluff (high-bank sites) (Gerstel and Brown 2006). Develop guidelines for channel dewatering, including a protocol for WDFW review and approval of proposed dewatering plans. Adopt guidance/protocols for fish and invertebrate removal and exclusion. Specifically, this refers to guidance/protocols for fish capture (including seining and electrofishing), fish handling, and reporting on the number and types of fish captured, fish injured, injuries observed, and mortality. An example protocol is provided by the Washington State Department of Transportation (WSDOT 2006b). Define the qualifications of "qualified personnel" who can perform fish capture and handling activities or develop an appropriate training or qualification process for biologists. In addition, maintain a list of qualified fish biologists who can perform fish removal and exclusion activities. Initiate channel dewatering to allow for volitional movement out of area. Then conduct fish and invertebrate removal activities. Have qualified personnel present to survey the area during dewatering and remove any additional fish and invertebrates encountered.	Construction activities should be timed to occur when sensitive life stages of potentially covered species are less likely to be present. As appropriate, species surveys (including forage fish egg surveys) should be conducted at site prior to initiation of construction to ensure no species present or to allow for removal plan to be prepared and implemented. Use temporary erosion control measures, including application of mulch, hydroseeding, geotextiles, or soil stabilizers (Saldi-Caromile et al. 2004). Use temporary soil trapping measures, including silt barriers such as straw bales or silt fences (Saldi-Caromile et al. 2004). Use temporary bank protection techniques during construction (relevant to bank pull-back and revegetation; installation of deformable bank toes) (Saldi-Caromile et al. 2004). The following mitigation measures regarding suspended sediment are based on those proposed by Bash et al. (2001): • Prior to project construction, determine suspended sediment concentrations and collect information on particle size and shape as indicators of the nature of existing turbidity. • When evaluating cumulative impacts from turbidity, consider information from existing assessments of watershed condition to account for point and nonpoint source pollution loads from watershed sources other than the project, as well as legacy impacts of the system. • Set stockpile areas back from the bank and include erosion prevention BMPs, such as silt fencing and tarp covers. Use spill prevention plans and pollution and erosion control plans.

Mechanism of Impact	Conservation Measures[ab]	Best Management Practices
		To minimize noise generation: • Avoid use of impact hammer during any pile installation. • Use air bubble curtains and/or pile caps to attenuate sound pressure waves. • Fabric barriers or cofferdams can also serve to attenuate sound generation. Require that construction vessels and propellers are washed and free of noxious weeds or invasive animals prior to entering water. Avoid barge grounding. Avoid propeller scour. Require a spill prevention plan.
Channel Process Modifications	Adhere to guidelines in *Stream Habitat Restoration Guidelines* (Saldi-Caromile et al. 2004) and *Integrated Streambank Protection Guidelines* (Cramer et al. 2003) for project development and implementation. Minimize structure footprint. Site structure above OHWL and as far outside the active channel as possible. Evaluate fluvial geomorphic processes, and consider natural and locally modified processes in project design and construction. Develop and maintain upland infrastructure carefully and with consideration of potential effects on slope stability (high-bank sites) (Gerstel and Brown 2006). Discourage backshore filling to create new home or other construction sites (Gerstel and Brown 2006).	For activities requiring dewatering, plan for at least a one-year flow event to occur during construction and design dewatering systems accordingly (Saldi-Caromile et al. 2004).

Mechanism of Impact	Conservation Measures[ab]	Best Management Practices
Substrate Modifications	If traditional armoring techniques are used, consider applying measures that reduce substrate and wave impacts (e.g., floating energy attenuators, weir-like revetments, walls open near bottom) (Cox et al. 1994). Minimize area of large substrate placement. Use suitably sized materials to minimize potential for displacement and scatter during high-flow or storm events. Site structure above OHWL and as far outside the active channel as possible. Reduce slope and/or integrate vegetated or riprapped bench areas, supporting sediment retention (Zelo et al. 2000).	Schedule construction for times when project area is dry (or substrate is frozen) (Saldi-Caromile et al. 2004).
Habitat Accessibility Modifications	Locate bank protection structures as far outside of the floodplain as possible to minimize the potential for precluding access to off-channel areas.	No specific best management practices identified.
Aquatic Vegetation Modifications	Avoid impacts by locating structures away from aquatic vegetation, especially eelgrass, whenever possible. This will require a pre-construction survey of vegetation location, species assemblage, and density. Require post-construction monitoring of vegetation for up to 10 years to investigate potential project impacts.	Minimize the area of impact by using land-based construction operations that avoid trampling of aquatic vegetation. Avoid barge grounding. Avoid propeller scour.
Riparian Vegetation Modifications	Promote bank stability by leaving as many existing trees and vegetation in place as possible, early seeding in disturbed areas (Nunnally 1978). Use and/or maintain native plant revegetation as a means to stabilize banks, where possible (Gerstel and Brown 2006; Lund 1976; Knutson and Woodhouse Jr. 1983; Myers 1993; Manashe 1993; MacDonald et al. 1994; Downing 1983; Cox et al. 1994; Zelo et al. 2000).	To protect riparian habitat, construct any necessary access points and roads with the least impact possible, according to several activities listed by Saldi-Caromile et al. (2004) as lower impact:: • Access the site using an existing access point. • Access the site from the opposite bank and cross the stream (if necessary using a floating platform or driving equipment across the channel during low flows).

Mechanism of Impact	Conservation Measures[ab]	Best Management Practices
	Above high-water level, cover riprap with soil and revegetate (Lund 1976). To the extent practicable, do not permit removal or disturbance of riparian vegetation in areas with high erosion hazard (Knutson and Naef 1997). If such removal or disturbance is permitted, require replanting with native riparian vegetation or other appropriate erosion control measures. Prepare revegetation plans for projects that temporarily disturb vegetation during construction. The revegetation plans should identify areas to be replanted with native riparian vegetation when construction is complete. Replanted vegetation should be monitored over several years (up to a 10-year period), and performance standards for plant survival and non-native plant exclusion should be established and required. Submit monitoring reports to WDFW as part of the revegetation plan. Similar to the requirement of the U.S. Army Corps of Engineers (the Corps) for ESA Section 7 individual and programmatic consultations, two monitoring reports should be required, one to be submitted one year after project completion and the other to be submitted after the final required monitoring event. The monitoring reports must include information on the plant survival by species and maintenance activities (including plant replacement) needed during each monitoring cycle in order to meet performance standards. Monitoring reports should also state the cause of plant failure, a provision generally required by the Corps, NOAA Fisheries, and USFWS for Corps ESA Section 7 programmatic consultations. WDFW should prepare or locate a revegetation guidance document that describes appropriate native vegetation to use; water, shade, and soil requirements; time of year most appropriate for planting; and other pertinent information to promote successful revegetation efforts. Suggest that vegetation (specifically large trees and root wads) removed for the project be saved for later use in restoration efforts. This condition has often been required in recent individual and	• Construct any necessary access roads perpendicular to the streambank, implementing a rock work platform as needed and restoring following removal of platform. Other practices regarding access: • Clearly mark access through the riparian area to minimize impacts (Saldi-Caromile et al. 2004). • Use temporary mats to "walk" equipment across sensitive areas, or fit applicable vehicles with extra wide tracks to reduce weight impacts and soil compaction (Saldi-Caromile et al. 2004). • In sensitive landscapes, use track-driven equipment when possible, as opposed to tire-driven, to distribute vehicle weight more evenly across surface (Saldi-Caromile et al. 2004).

Mechanism of Impact	Conservation Measures[ab]	Best Management Practices
	programmatic Section 7 consultations. Even if the material is not specifically useful for the permitted action, a WDFW area habitat biologist will generally know of ongoing or pending restoration projects in need of LWD and root wads.	
Water Quality Modifications	Manage all surface water to contain and direct it appropriately to the base of the bluff (high-bank sites) (Gerstel and Brown 2006). Evaluate and design for surface and groundwater flow issues (Gerstel and Brown 2006). Avoid placing structures in areas that may affect flow connection from cold-water groundwater sources to surface water.	No specific best management practices identified.

Notes: a) In addition to these measures and BMPs, all applicable conservation measures should be applied from the Washington State Department of Ecology's Stormwater Management Manuals for Eastern and Western Washington (Ecology 2002, 2005), and all actions should be in compliance with the Hydraulic Code and its implementing rules.

[b]) Many of the measures discussed in this table are also given in the *Integrated Streambank Protection Guidelines* (Cramer et al. 2003).

11.2.1.2 Mitigation Strategies

Mitigation for bank protection projects may be required by regulatory authorities when it is determined that the project will cause an adverse impact to species, habitats, or conservation values. General strategies may include acreage-based habitat restoration, enhancement, or creation at an on- or off-site location or the acquisition of additional high-quality habitat property for preservation purposes. Because of the long-term positive impact on habitat, many bioengineering and beach nourishment techniques are discussed and referred to in the literature as self-mitigating due to their support of additional habitat and vegetation to the project site (Cramer et al. 2003; Gerstel and Brown 2006). The *Integrated Streambank Protection Guidelines* (Cramer et al. 2003) provides a matrix that identifies the bank protection actions likely to be self-mitigating and to what extent (Chapter 5, Matrix 3 in Cramer et al. 2003). Several specific measures that may be used to mitigate for various impact mechanisms are summarized in Table 11-3.

Table 11-3. Bank Protection-Specific Mitigation Strategies

Mechanism of Impact Impact	Compensatory Mitigation Strategy	Function of Mitigation
Construction Activities	Several of the below strategies are typically used in or combined to mitigate for unavoidable construction impacts. BMPs are also used in conjunction with these measures.	Mitigate for unavoidable construction-related impacts.
Channel Processes and Morphology Modifications	Use energy dissipation structures for wave or flow (Gerstel and Brown 2006).	Reduce wave or flow energy at shoreline to prevent or stem further erosion.
Substrate Modifications	Use soft shore armoring or bioengineered solutions, some of which may be self-mitigating (Chapter 5, Matrix 3, Cramer et al. 2003). Spawning gravel supplementation or beach nourishment (may require periodic supplementation) (Zelo et al 2000; Parametrix 1985; Simenstad et al. 1991).	Reduce impact of armoring on shoreline habitat. Varied functions can be improved (e.g., long-line cabled logs can self-mitigate, contributing to ongoing capture of gravel, increase in local channel roughness and bank complexity, and protection or growth of riparian vegetation [Nichols and Sprague 2003]). Provide additional or higher-quality substrate for forage fish (nearshore marine habitats) and salmonid spawning (freshwater channel habitats).
Habitat Accessibility	Off-site construction of side channel(s) (reconnect side channel or oxbow) (Bonnell 1991; Cowan 1991).	Provide additional rearing and spawning habitat.
Aquatic and Riparian Vegetation	Replace lost aquatic vegetation and re-establish riparian buffer along bank shoreline (Saldi-Caromile et al. 2004). Retain removed vegetation for future restoration or mitigation effort (including LWD). Mitigation to eelgrass and macroalgae is best achieved through avoidance, but if this vegetation is unavoidably impacted, apply natural regrowth or transplant methods (Thom et al. 2001).	Provide additional vegetation for shoreline shading and detritus inputs. Provide additional macroalgae habitats for juvenile salmonid prey production and forage fish habitat.
Water Quality	Stormwater treatment or flow buffering for point sources (Osborne and Kovacic 1993) existing prior to bank protection project.	Improve water quality and quantity of delivery to habitat by buffering of flows and/or reduction of pollutants to the project site.

11.2.1.3 Management Strategies

Management strategies provide the best opportunity for WDFW to guide the construction and design of bank protection structures. These strategies are intended to lead to better information for design and review of projects, enhance the sharing of information, provide additional resources to contribute to lessening potential project impacts, and provide WDFW biologists and the entire department with the legal authority to prohibit activities that are not adequately protective of potentially covered species. Each of the recommendations requires additional WDFW staff availability because additional project oversight is recommended, and existing project oversight is already a significant challenge according to WDFW biologists around the State (Anchor Environmental et al. 2006).

11.2.1.3.1 Regulatory Recommendations

Regulatory recommendations are those changes to the WACs that are recommended in order to avoid, minimize, or mitigate impacts associated with bank protection structures. The WACs establish the rules that WDFW requires for bank protection projects. Many of the conservation measures, BMPs, and mitigation strategies could be incorporated into the WACs. In addition, the following regulatory recommendations have been identified:

- Require pre- and post-construction project monitoring to investigate conditions in the project area and adjacent areas.

- Require inspection during construction to ensure compliance with the HPA and a "sign off" by the inspector. WDFW could hire inspectors or license private engineering/environmental firms to inspect specific construction requirements related to fish habitat. Project components that would most benefit from inspection during construction are structural design, an instream habitat and/or instream mitigation, riparian vegetation, and revegetation progress.

- Prohibit bank protection structures that disconnect sediment sources unless life or property is at risk.

- Allow beach nourishment as a mitigation technique to address impacts of new and existing bank protection structures.

- Establish freshwater construction timing restrictions at the smallest geographic scale possible (ideally, basin-specific) based on species distributions and periodicity. Revisions to the WAC are recommended to address the lack of freshwater construction timing provisions, as well as saltwater timing provisions, based on consideration of the entire potentially covered species list to minimize the risk of take.

- Establish partnerships with other entities (e.g., the Corps and port authorities) to beneficially reuse clean dredged material to nourish beaches and have available as mitigation.

- Provide incentive mechanisms to promote "good" projects. Examples of potential incentives are simplified and accelerated permit review (i.e., "top of the stack") and conducting or funding the monitoring activities required for the project. Such monitoring is envisioned to be conducted by crews (similar to Washington Conservation Corps or Ecology Youth Corps crews) whose sole responsibility is monitoring, rather than by WDFW biologists.

- As incentive, identify grant funding opportunities for projects incorporating habitat restoration components.

- Limit programmatic coverage to certain size, types or locations of bank protection structures. For example, the USACE (2002) Nationwide Permit 13 limits the size of the proposed bank protection structure to 500 feet or less in order to be eligible under the programmatic coverage. Similarly, the USACE (2005) Regional General Permit for Pend Orielle River and Lake Chelan limits the size of a bank protection structure to 250 feet or less.

11.2.1.3.2 Education Recommendations

The recommendations focused on public education specific to bank-protection projects include:

- Educate the public on potential impacts of bank protection projects and alternative techniques available.

- Develop a paper or web-based resource that highlights representative "good" and "bad" bank protection projects to help citizens understand the differences. The resource could consist of concise case studies for a variety of marine, estuarine, and freshwater settings (e.g., Eastern and Western Washington; feeder bluffs and accretion shoreforms; large, moderate, and small systems; high gradient and low gradient).

- Educate the public on the limitations of bank protection projects at providing full protection from extremely high-flow events to discourage construction close to shorelines or bluffs.

- Have staff available to assist in project design and/or implementation of the *Integrated Streambank Protection Guidelines* (Cramer et al. 2003) and the *Stream Habitat Restoration Guidelines* (Saldi-Caromile et al. 2004).

11.2.2 Shoreline Modifications

This section provides recommendations of strategies for the protection, conservation, mitigation, and management of HCP species based on a review of the scientific literature of shoreline modifications. Because of the nature of the scientific literature (i.e., papers are written years after an action has been taken), some of these recommendations may already be commonplace. However, it is important to document support for those activities that have a basis in empirical science. Where citations are not provided, it should be assumed that no direct evidence for that recommendation exists, but the recommendation is based on a reasonable conclusion from the collective information surveyed in preparing this white paper.

11.2.2.1 Jetties

Jetties cause more damage to nearshore ecosystems than any other single shoreline modification measure. They intercept littoral transport, cut off groundwater supply, and disturb natural nearshore circulation. They also encourage vessel traffic. There are two primary ways to reduce major littoral and nearshore circulation impacts from jetties.

One of the easiest means for reducing the impact of littoral drift disruptions is to develop a sediment bypass strategy (see Figure 11-1). The strategy typically consists of collecting sediment on the updrift side of a set of jetties (in the deposition basin in the figure). This sediment is then dredged and piped, trucked, or barged to the downdrift side of the other jetty. Sediment bypass is a common practice along the Gulf Coast (Seabergh and Kraus 2003) but has seen limited application in sheltered settings (NRC 2007) like Puget Sound. Although large tidal fluctuations can complicate the design, a large number of installed systems have indicated that the mean tide level is a reasonable crest elevation (Seabergh and Kraus 2003). In Puget Sound, for example, this would allow much of the sediment to bypass the jetty in the active sediment transport corridor on the upper foreshore (Finlayson 2006).

The alterations of the water column (tidal prism, nearshore circulation, stratification, etc.) in the vicinity of the jetty are more difficult to mitigate. However, the possibility exists to use engineered logjams (ELJs) or other secured (untreated) woody debris to provide the same function as a riprap or walled structure. These types of structures have been used successfully as groins on riverine shorelines, even in locations where critical infrastructure is meant to be protected (Herrera 2004). To prevent the isolation of channel waters, these structures can be built to be semi-permeable to allow for water with differing salinity to pass through, thus minimizing the impacts on nearshore circulation. Such structures can also be built so that fish can pass through them.

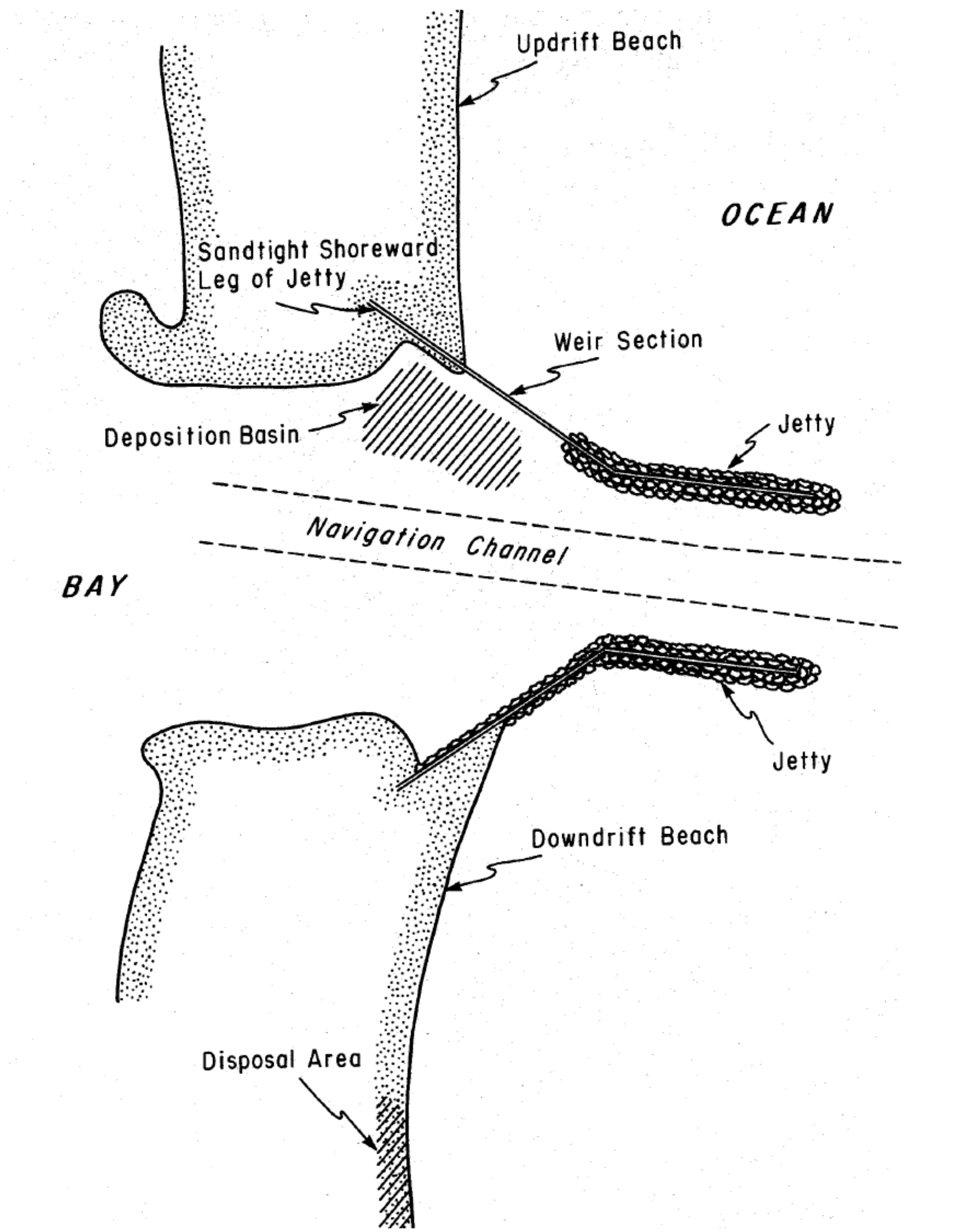

Figure 11-1. Schematic of sediment by-pass system (Seabergh and Kraus 2003).

11.2.2.2 Breakwaters

Thirty years of research on breakwaters and artificial reefs has led to a rich data set that has identified pitfalls in offshore, shore-parallel, hard-substrate deployment.

- Where possible, use temporary, removable shore-protection measures, such as moored floats (Thompson et al. 2002).
- If a permanent breakwater is necessary, locate the breakwater(s) to best connect the activity site to other areas of hard-rock habitat in order to reduce the probability of an invasive species infestation (Thompson et al. 2002).
- Use clean earthen materials where possible (i.e., no materials that would leech metals or other exotic organic compounds [e.g., creosote-treated wood]) (Thompson et al. 2002).
- Avoid the use of vertical walls (Bulleri and Chapman 2004). Where possible, mimic the slope of predevelopment shoreline, which in most cases in Puget Sound is between 6:1 and 10:1 (Finlayson 2006).
- Submerge the breakwaters where possible (i.e., in areas of small tides and large waves, the outer coast) (Thompson et al. 2002).
- Where possible, use removable, temporary floating breakwaters in place of permanent, continuous breakwater walls (Thompson et al. 2002).
- Avoid simple geometric designs. A complex landscape has been shown to be more productive for wide variety of fishes than simple geometries (Moschella et al. 2005; West et al. 1994).
- Provide a rough, complex surface on which a variety of organisms can colonize. Gullies and small caves can be especially fruitful (Moschella et al. 2005), particularly if they are large enough to allow sand to accumulate (Fabi et al. 2006).

11.2.2.3 Groins and Bank Barbs

On marine shorelines, the impacts of groins or groin-like structures can be minimized by following these guidelines:

- Minimize the structure's cross-section in the shore-parallel direction.
- Minimize groin wetted length.
- Use earthen materials or untreated wood where possible.
- Avoid the use of structural members that would interrupt groundwater exchange between the sea and the shore.

- Avoid the use of vertical walls (Bulleri and Chapman 2004).

- Allow wrack to accumulate in and around the structure.

- Reduce the protrusion of the structure into the flow as much as possible.

On riverine shorelines, modifications to stabilize banks should mimic natural geomorphic and riparian conditions to the extent possible to limit incidental take. Along riverine shorelines, this would include the placement of engineered logjams (see Figure 11-2), the reconnection of floodplains, and the restoration of riparian forests (Collins et al. 2003). In general, groins and bank barbs provide greater habitat diversity than simple rock revetments (Hjort et al. 1983; Li et al. 1984), and thus are preferred over the construction of rock revetments. Because rivers are dynamic systems, localized bank stabilization efforts can shift the ongoing channel response to an adjacent river segment (Leopold et al. 1964). Bank hardening projects should therefore consider such impacts and take appropriate measures to mitigate these effects.

Figure 11-2. Example of bank protection before (left) and after (right) removal of the rock revetment and installation of engineered logjams in the Mashel River near Eatonville, Washington.

To repair an existing groin, a licensed engineering geologist with experience evaluating projects should determine if removing the structure will cause more damage to the shoreline than letting it remain, or if significant impacts will occur to life or property if the groin is removed. Erosion occurring along adjacent beaches as a result of pre-existing geomorphic conditions near the property should not be considered a significant impact. In addition:

- The replacement structure should be designed to allow uninhibited passage of alongshore sediment movement.

- The footprint along the shoreline should be minimized to the greatest extent possible.

11.2.3 Overwater Structures

11.2.3.1 Shading

Nightingale and Simenstad (2001b), Carrasquero (2001), and Thom et al. (1995, in Haas et al. 2002) provide impact minimization measures for the design, construction, and revetment of a variety of overwater structures. WDFW might want to consider following the guidance provided by these authors, such as:

- Increasing the height of overwater structures to allow light transmission under the structures.
- Decreasing structure width to decrease the shade footprint.
- Aligning the structure in a north-south orientation to allow the arc of the sun to cross perpendicular to the structure, which reduces the duration of light limitation each day.
- Using the smallest number of pilings possible, allowing more light beneath the structure.
- Using grated surfaces or including openings in the deck surface to pass light, as opposed to prisms. Gayaldo and Nelson (2006) found that grating (with 37 to 58 percent open space) transmits 10 times more light under piers than do acrylic prisms. In addition, light that passes through open grating penetrates the water evenly under the pier, whereas light transmitted though prisms concentrates beams of light that do not always reach the water surface. The U.S. Army Corps of Engineers Regional General Permit for residential overwater structures in inland marine waters within Washington State (USACE 2005) requires ramps to be grated, and floats are required to have grating account for a minimum of 30 percent of the surface area; the grating must have 60 percent open area and be oriented to maximize light penetration (USACE 2005). Additionally the Regional General Permit for residential overwater structures in inland marine waters prohibits pier widths greater than 6 feet, float widths greater than 8 feet and lengths greater than 20 feet, and the construction of new or the modification of existing fingers, "ells," and T structures onto floats (USACE 2005).

Southard et al. (2006) provides additional recommendations on minimization measures specific to shading impacts on juvenile salmonids.

- To minimize the shade-related impacts to migrating juvenile salmonids created by ferry terminals, overwater structures should be designed and constructed to allow incidental light to penetrate as far under as possible, while still providing the necessary capacity and safety considerations necessary to support their intended function. The physical design (e.g., dock height and width, dock orientation, construction design materials, piling type and number) will influence whether the shadow cast on the nearshore covers a sufficient area and level of darkness to constitute an impediment. Construction of closely spaced terminal structures should be avoided to minimize the potential cumulative impacts of multiple overwater structures on juvenile salmonid migration (Nightingale and Simenstad 2001b).

- Experiment with technologies and designs that can soften the light-dark edge to minimize potential temporary inhibition of movement.

- The incorporation of light-enhancing technologies in the design of overwater structures is likely to maintain light levels under overwater structures greater than what is required by juvenile salmonids for feeding and schooling (i.e., estimated at between 0.0001 and 1 foot-candles, depending on age and species). To encourage daytime movement under terminals and other overwater structures, it would be beneficial to decrease the dark-edge effect as much as possible. Providing even a small amount of light in a regular pattern under a dock may encourage fish to swim underneath. Natural lighting for fish could also be enhanced if the underside of the dock were reflective.

- Continued research is needed to improve our understanding of the relationship between overwater structures and the behavior of migrating juvenile salmonids. Acoustic tagging-tracking technology should be further used to address the data gaps in our knowledge.

- Fish feeding behavior during temporary delays of movement should be investigated. If prey resources and refuge habitat are adequate, fish may benefit from holding in an area adjacent to a terminal.

Kahler et al. (2000) recommends the following measures to mitigate or avoid the undesirable impacts of overwater structures on salmonids in lakes:

- No net increase in overwater coverage should occur in the Lake Washington system — permits for new construction should be contingent on permits for replacement structures. Only replacement structures that demonstrate a reduction in overwater coverage should be permitted. The amount of overwater coverage eliminated from the replacement pier could be held in a “surface area mitigation bank,” which new piers would have to draw from. Gradually lower the total net coverage over local lakes.

- All piers, both new and replacement structures, should be restricted to a 3.5-foot-wide cantilever bridge that spans the nearshore area to a narrow moorage structure of the minimum size necessary to moor the applicant’s boat.

- Cantilever bridge structures should be grated and as high off the water as practicable, and moorage structures should be no less than 24 inches above OHWL. Floating structures should have maximum light penetration and be removed annually after boating season.

- Prisms and grating should be studied to determine their efficacy at providing sufficient ambient light for macrophyte production under piers. The best products should be utilized in all new or replacement overwater structures to minimize losses of primary productivity.

11.2.3.2 Aquatic Vegetation

Where conditions are suitable for eelgrass growth, impacts of overwater structures should be avoided or minimized by use of the following measures:

- Avoid impacts by locating structures away from eelgrass beds whenever possible.
- Minimize the area of impact by using the best available installation methods.
- Minimize shading by using the lowest possible number of pilings.
- Space pilings to minimize shade to areas suitable for eelgrass.
- Minimize dimensions of the structure to reduce shade.
- Incorporate design elements such as grated decks or deck openings to reduce shade.
- Whenever possible, orient structures to reduce the shade in habitat that is otherwise appropriate for eelgrass growth (e.g., structures oriented east-west cast a shadow on a single area for a longer period of the day than do structures oriented north-south).
- Locate the structure as high above the water as practical to reduce shade.
- Encourage shared-use docks to minimize cumulative impacts.
- Remove floats during off season and store at an upland location.
- Avoid vessel impacts to eelgrass by maximizing the vertical and horizontal distance between vessel propellers and eelgrass to the extent practicable, maintaining a minimum clearance of 1 foot below the propeller.

Adopting these measures would likely result in avoidance and minimization of eelgrass and macroalgae impacts to the greatest extent practicable. However, it is likely that some projects would still require compensatory mitigation to completely offset temporal loss of eelgrass function and site-specific and cumulative impacts on eelgrass.

11.2.3.3 Substrate Modifications

In the nearshore environment, where overwater structures alter the benthic environment via shellhash deposition and establishment of invertebrate communities on pilings, use of fewer and more widely spaced pilings will help to reduce sea star and crab bioturbation of the benthos (Thom et al. 1995, in Haas et al. 2002).

Prohibiting overwater structures from grounding out during low tide events will avoid potential impacts such as affecting aquatic organisms by directly crushing the organisms or changing the character of the substrate. The U.S. Army Corps of Engineers prohibits the grounding of floats on tidal substrates at any time in their Regional General Permit No. 6 (USACE 2005).

11.2.4 Marinas and Terminals

General methods to minimize and mitigate the impacts from construction apply to marinas and terminals. In addition, site selection , facility design strategies, and operations best management practices can be used to avoid, minimize, and mitigate negative impacts of marinas and terminals on habitats and HCP species.

11.2.4.1 Facility Planning

11.2.4.1.1 Site Selection Strategies

- Site marinas/terminals away from areas with littoral and aquatic freshwater vegetation, where practicable.

- Locate marinas/terminal in areas that are naturally deep enough to avoid resuspension of sediments associated with prop wash.

- Locate new shipping terminals and marinas: (1) in existing developed areas where nearshore areas have already been dredged, or (2) in areas where the natural bathymetry of the shoreline steeply drops off close to shore.

- Locate marinas/terminal in areas with low or impaired biological integrity.

11.2.4.1.2 Facility Design and Operation Strategies

All Environments (Marine, Riverine, and Lacustrine)

- If possible, all marina activities should include some component of on-site habitat enhancement. Types of enhancement include prototype (soft) shoreline stabilization techniques, planting, and beach nourishment. The mix of these activities should be consistent with the preactivity conditions.

- In the design of the marina itself, a number of alterations to traditional designs can minimize the impacts associated with hydraulic and geomorphic modifications. For instance, submerged breakwaters and weir jetties should be used in place of structures that are exposed. However, both submerged and emergent breakwaters have hydraulic and geomorphic impacts on adjacent areas. Weir jetties are particularly effective at reducing the littoral disruptions associated with marina activities, especially when accompanied by a strategy of beach nourishment and sediment routing (Seabergh and Kraus 2003).

- Construction of marina/terminal facilities often involves project activities such as channel modifications, bank hardening, groins and bank barbs, and other such projects. If hydraulic and geomorphic modification cannot be avoided, identify the area affected by the impacts. For example, the area of alteration includes areas affected by embedding, scour, or deposition. For projects of this size, hydraulic modeling of potential impacts using well-established sediment transport models should be required (Miller et al. 2001).

- Minimize width of the structure over the water.

- When applicable and feasible, require construction of longer marina/terminal decks that keep vessels in deeper water to avoid/minimize propeller wash effects on sensitive habitat areas such as eelgrass beds.
- Residential/recreational floats should be sited in deeper water to reduce the potential impacts associated with propeller wash.
- Use the smallest number of pilings necessary to carry the load.
- Design pile-supported structures with maximum open space between pilings to allow waves, currents, and sediment to pass beneath.
- Allow light transmission wherever possible along the shallowest areas of migratory corridors and over any areas near or adjacent to submerged aquatic vegetation.
- Locate the structure as high as practical to increase light transmission.
- Use light-reflecting materials on underside of docks, whenever feasible.
- Consider solar-powered artificial lighting under the dock, if light transmission is not possible. However, compared to full sunlight, grating transmits 10 times more light under a pier than, for example, acrylic prisms (Gayaldo and Nelson 2006); hence, the use of grating is always a better option than prisms.
- Construct marinas/terminals so that most of the overwater coverage is beyond the photic zone.
- Increase the distance between the dock and the water to allow greater light penetration.
- Place the potential shade-casting structures perpendicular to the arc of the sun (i.e., north–south placement) to maximize transmission of light under the structure.
- Install grating with maximum open spacing and ensure that the open space is kept uncovered or unshadowed by other pier features or gear.
- Orient grating to maximize transmission of light under the structure.
- Promote community-use docks to minimize the proliferation of single-family residential docks along shorelines.
- Site slips for smaller boats in shallow water, with slips for larger boats placed in deeper water.

- Facilities should be sited, if possible, so that dredging is not required.

- Require the use of rub strips on treated wood piles or timbers that are abraded by vessels (fender piles) or docks (guide piles) to reduce physical breakup of the piles.

- Use low-intensity artificial nighttime lighting and shield the lighting to prevent artificial light transmission to the ambient nighttime underwater light environment.

- Encourage the use of upland boat storage areas and the use of slings.

- Require that stormwater runoff be 100 percent contained.

- Encourage designs that create shallow-sloped pocket beach areas instead of continuous vertical bulkheads or riprap.

- Avoid the use of continuous sheet (impermeable) piles and encourage the use of permeable geomaterials (e.g., geotubes) (Oh and Shin 2006).

- Where possible, mantle the waterward side of the pile with natural materials (i.e., sediment consistent with the environment).

- Where possible, use removable, floating breakwaters in place of permanent, continuous breakwater walls.

Additional Considerations in Marine Environments

- Minimize the amount of pier area that directly contacts the shoreline to allow light penetration to the nearshore intertidal and shallow subtidal areas.

- Locate breakwaters to best connect to other areas of hard-rock habitat.

- Use submerged breakwaters in place of exposed breakwaters where appropriate (i.e., in areas of small tides and large waves, on the outer coast).

Additional Considerations in Lacustrine Environments

Considering that many reservoirs are located in a distinctly different climate than those in marine settings, there are some BMPs that are specific to these projects.

- Rock cribs, similar to jetties, were found to provide structural complexity for smaller fish in Lake Tahoe, California (Beauchamp et al. 1994), but this advantage may be outweighed by the interception of spawning materials from deposition in littoral zones and increased deposition of fine materials on rocky substrate. Coves, especially with inundated herbaceous vegetation, were found to yield the largest numbers of young fish in four Mississippi reservoirs (Meals and Miranda 1991).

11.2.4.1.3 Navigational Channel and Berthing/Maintenance Dredging

General recommendations to avoid and minimize the impacts of dredging are provided in the Dredging: Marine Issues white paper (Nightingale and Simenstad 2001a) and include:

- Use multiseason pre- and postdredge project biological surveys to assess animal community impacts;
- Incorporate cumulative effects analysis into all dredging project plans;
- Use landscape-scale planning concepts to plan for beneficial use projects most suitable to the area's landscape ecology and biotic community and food web relationships;
- Identify turbidity and noise thresholds to assess fish injury risks; and
- Analyse and synthesize what is known about the spatial and temporal distribution of fish and shellfish spawning, migration behaviors, and juvenile rearing to evaluate environmental windows for dredging on a site-specific basis.

The following recommendations are intended to reduce the effects of dredging on HCP species.

- For new marine, riverine, and lacustrine projects and significant expansions beyond general maintenance dredging, thoroughly assess the large-scale, cumulative impacts of the resulting changes in bathymetry, habitat loss, and change to estuarine/nearshore marine ecosystem dynamics (e.g., salinity intrusion).
- Require hopper dredges, scows, and barges or any other equipment used to transport dredged materials to the disposal or transfer sites to completely contain the dredged material.
- For long-term projects where continuous dredging and on-loading to barges occurs, require periodic movement of the barge to reduce unnecessary shading.
- Modify in-water work windows to take into consideration what is known about site-specific spatial and temporal distribution of fish and shellfish eggs, larvae, and juveniles.
- Evaluate the application of in-water work windows on a site-specific basis based upon the location and features of the site, such as sediment composition, plant and animal assemblages, and timing of seasonal and migration patterns.
- Use presampling bathymetric surveys, records from previous dredging events, and best professional judgment to estimate the volume of sediments likely to be dredged; base sampling and testing requirements on this estimated volume.
- Avoid projects and expansions that convert intertidal to subtidal habitat. If such conversion is unavoidable, employ comprehensive, large-scale risk assessment to identify the cumulative effects of site-specific changes on ecosystem dynamics.

- Select dredging equipment types according to project-specific conditions, such as sediment characteristics.

- Base turbidity threshold testing for dredging operations upon background site turbidity.

- In areas where dredging is proximal to sensitive habitats (or in projects where sediments both suitable and unsuitable for unconfined open water disposal will be dredged adjacent to each other), use a computerized electronic sensor system to monitor dredging operations. Such tools can assist in operational documentation and regulatory compliance by providing record accessibility and clarity. It also offers advantages for planning, estimating, and managing dredging activities.

- Increase the use of multiseason preproject surveys of benthos to compare with post project surveys to understand dredging impacts.

- Where applicable and involving uncontaminated sediments, consider beneficial use of dredged materials that can contribute to habitat restoration, rehabilitation, and enhancement, particularly for projects that incorporate a landscape ecology approach.

- Avoid beneficial use projects that impose unnatural habitats and features on estuarine, marine, and riverine landscapes.

- Dredging should be conducted to a depth not greater than a navigation channel depth at the seaward end. If necessary, authorize dredging to depths greater than the navigation channel at the seaward end only in berthing areas and turning basins for commercial shipping purposes.

- Use hydrodynamic models to predict system-wide changes in salinity, turbidity, and other physicochemical regimes for project assessment planning that avoids or minimizes impacts on aquatic habitat.

11.2.4.1.4 Vessel Activities

- Manage vessel operations to minimize the adverse effects of prop wash.

- Take precautions to avoid impacts from accidental spills of fuel and contaminants and post guidelines and protocols for handling spills for all personnel to view.

- Provide spill response training.

- Establish guidelines and protocols to avoid introduction of invasive species.

- If aquatic vegetation is present at or adjacent to a pier or wharf facility, establish guidelines and protocols outlining where vessel traffic should occur when entering or leaving the site.

11.2.5 Habitat Modifications

Habitat modification projects are designed to protect, create, and/or restore habitat. Unfortunately, not every project is successful and some projects result in habitat degradation due to poor design or site constraints. This section presents suggested measures which should be followed during the construction and design phase to increase the chance of success of the projects.

11.2.5.1 Beaver Dam Removal/Modifications

The habitat and species impacts of beaver dam removals can be decreased through a number of measures.

- Gradual drawdown of the beaver impoundment is important because it reduces the mobilization of sediments within the impoundment and provides motile organisms more time to evacuate the pond. This “notching” technique is frequently used in small dam removals (Doyle et al. 2003; Stanley et al. 2002).
- Other strategies to manage beaver include the application of flow devices which control the pond level so that flooding conditions are alleviated (Beaver Solutions 2007). This management strategy is ideal because the positive environmental benefit of the beaver pond is not lost while flooding issues are resolved simultaneously.
- Other strategies include the use of enlarged culverts. Beaver often use culverts as dam sites but research has shown that the application of enlarged culverts discourages dam building near the roadway (Jensen et al. 2001). It has been estimated that over the life of the enlarged culvert, the costs of installation will be less than those associated with beaver management activities (Jensen et al. 2001).

11.2.5.2 Large Woody Debris Placement/Movement/Removal

Historical forest clearing, river snagging, and splash damming has greatly reduced the quantity of woody debris in rivers and streams of the Pacific Northwest (Collins et al. 2002; Montgomery et al. 2003). Snagging records from the region suggest that wood loading in large Pacific Northwest rivers was 100 times greater than present-day wood loading and contained larger trees (Collins et al. 2002). Restoration efforts that increase wood loading must also consider the size and placement of wood pieces that will provide the stability necessary for habitat protection and function.

Logjams consisting of small pieces of wood are less stable than those jams anchored by large, key members (Braudrick and Grant 2000). Maclennan (2005) noted that overloading of loose wood in two Puget Sound estuaries resulted in reduced diversity and abundance of aquatic vegetation. Studies such as these suggest that stabilizing wood or adding wood that will not mobilize during flood events should be the goal of most LWD additions. If structural stability is a major goal of LWD additions, it is vital to either place large pieces of wood that will not move during the design flood event or provide stability using other means, such as piles. Observations from the undisturbed Queets watershed show that the size of key members capable of forming stable, natural logjams varies with channel depth and width (Abbe and Montgomery 2003).

Other factors increasing stability include the ability of logjams to accrete additional wood delivered by floods and the root cohesion and added roughness provided by vegetation growing on accumulations of woody debris.

The structural failure of wood placed in aquatic environments can impose construction impacts on HCP species. The adverse ecological impacts on HCP species caused by the structural instability and failure of instream woody debris can be minimized or avoided by ensuring that wood placed in rivers is properly engineered according to accepted engineering guidelines. Such guidelines are currently under development by the Washington chapter of the American Council of Engineering Companies (ACEC). Project success depends on a thorough understanding of the site-specific geomorphic constraints, quantifiable habitat goals, and the development of performance-based criteria that account for the anticipated hydrodynamic forces and the desired factor of safety for stability (Miller and Skidmore 2003; Slate et al. 2007). In addition, WDFW has published a series of guidelines through the department's Aquatic Habitat Guidelines Program. These guidelines are available from WDFW and include the Stream Habitat Restoration Guidelines document (Saldi-Caromile 2004), which provides guidance for habitat assessment, the development of restoration goals, and implementation of habitat restoration techniques.

Constructing stable logjams may involve harvesting large conifer trees from the few remaining patches of old-growth forest in the region. Habitat-protection measures can include the use of wood from blow-down or the wholesale purchase of trees from commercial harvest projects. Alternative sources of wood, such as salvaging trees from reservoirs, should also be considered to provide habitat benefits that will outweigh the impacts associated with project construction. As mentioned above, the use of piles in engineered log structures can eliminate the need for large, key-member logs that would otherwise be required for stability.

11.2.5.3 Spawning Substrate Augmentation

With the realization that early gravel augmentation projects were failing due to a lack of consideration regarding stream hydraulics and site geomorphology (Kondolf et al. 1996), practitioners began adopting new techniques and management strategies. It is recommended that every gravel augmentation project be based upon information gathered from detailed monitoring of site conditions and a geomorphic analysis of the reach, including estimates of sediment transport rates. Given the stochastic nature of riverine systems, even with detailed hydrologic and geomorphic information, the outcome of the project may be uncertain. Consequently, an adaptive management approach is recommended whereby the project is designed as an experiment. Bunte (2004) recommends the following adaptive management steps when conducting a gravel augmentation project:

1) *Pre-project Analysis*: In this step information is collected to formulate a conceptual model that explains how the stream should ideally function with an active gravel bed. For sustainable geomorphological and biological functionality, a channel shape must be attained in which:

- The 1.5-year recurrence interval flow fills the channel to its morphological bankfull stage
- Gravel is partially mobile every 1-2 years

- The flow regime is seasonally variable
- The timing of high and low flows corresponds with the needs of the salmon population.

2) *Measuring and modeling*: In this step data are collected and used to model the reach to predict gravel mobility and channel form under different restoration and stream discharge scenarios. The information derived here is used to inform the next step.

3) *Monitoring, evaluation, adjustment*: In this post-project step the site is monitored and evaluated to quantify channel response to the gravel augmentation. This step is vital and frequently not included in most restoration efforts due to a lack of funding. It is in this step that information regarding where the project may have gone wrong and how it might be remedied is collected. Without this step the project may fail and no lessons will have been learned. The ramifications of gravel augmentations are poorly understood (CALFED 2005), and it is only through projects which include monitoring programs that the science of gravel augmentation will progress.

11.2.5.4 In-Channel/Off-Channel Habitat Creation/Modifications

As with gravel augmentation, the prediction of the outcome of the majority of in-channel restoration work has some associated uncertainty. To reduce the risk associated with this uncertain outcome, a strategy must be in place to address the potential failure of the project. Project failure has been a common occurrence in past in-channel restoration efforts (Babcock 1986; Frissell and Nawa 1992) and every measure should be taken to prevent the failure of future projects. Suren and McMurtrie (2005) suggest that in-channel restoration efforts should focus on watersheds which have a natural hydrograph and minimal sediment loading. They argue that external drivers will dictate reach scale dynamics and that without a watershed based approach reach-scale restoration will be useless. In a separate study, Frissell and Nawa (1992) monitored 161 instream structures and found that 60 percent of the structures had the opposite of the intended effect on the stream. They attributed the high failure rate to the fact that structures were placed in both high velocity and sediment laden reaches. Other studies have found instream structures placed in Pacific Northwest streams to be more durable, with only a 20 percent failure rate after 5-year recurrence interval flood events (Roper et al. 1998). Regardless, most research indicates that instream structures are more likely to fail in large rivers (Roper et al. 1998), high energy environments (Frissell and Nawa 1992), and when sediment loading is elevated (Frissell and Nawa 1992; Suren and McMurtrie 2005).

These studies suggest a harsh reality which is that in-channel restoration is least likely to succeed in those reaches that need it the most. Streams with flashy hydrographs caused by watershed deforestation or urban development, streams with high sediment loads from anthropogenic disturbance in the watershed, these are the degraded systems that restoration practitioners focus on. These are also the systems where most restoration practitioners fail to achieve their goals. The recommendation which results from these studies is to focus in-channel rehabilitation efforts on those channels that have a natural hydrograph and average sediment loading. In more heavily impacted systems, a top-down approach whereby hydrology is addressed on the watershed scale may be more appropriate and effective (Roni et al. 2002).

Off-channel habitat modification has a higher success rate that in-channel work because the site does not receive the same flood induced shear stresses. The primary avenues of failure for off-channel habitat modification are infilling or isolation from the main channel, and improper hydrologic design. If off-channel habitat is too intimately connected with the channel, then the goal of increased habitat diversity will not be achieved. If the off-channel site is too disconnected from the channel, then entrapment may become an issue. This suggests that the most vital aspect of an off-channel habitat modification is the amount and duration of flows which flush the off-channel habitat. A recent study by Henning et al. (2006) indicated that floodplain habitat (i.e., enhanced wetlands) with flow control structures that provided an outlet for fish emigration and a longer hydroperiod for rearing, produced significantly higher age-1 coho abundance than unenhanced wetlands. Studies such as this suggest that off-channel restoration efforts should focus on the connectivity of the habitat with the main channel when designing the project.

11.2.5.5 Riparian Planting/Restoration/Enhancement

Some have argued that the maintenance of a healthy riparian system should be paramount in channel rehabilitation and should take precedence over in-channel work (Opperman and Merenlender 2004). Riparian restoration is indeed a powerful tool, but the project must be properly conducted in order for ecosystem benefits to be realized. As with most restoration efforts that do not attempt to remedy the processes driving ecosystem degradation, riparian planting will be best applied in watersheds that are either minimally or moderately impacted. If riparian planting is to be performed in highly degraded watersheds, the work needs to be conducted within the context of larger watershed restoration efforts. Riparian rehabilitation efforts which create a narrow corridor of improved habitat downstream of a degraded watershed may not improve stream conditions (Teels et al. 2006). In a study of forest fragments in agricultural areas of the South Island, New Zealand, Harding et al. (2006) found that forest fragments of 5-7 ha, located in the lower reaches of the study catchment did not mitigate the negative effects of upstream agriculture on stream functioning. They concluded that in order for a riparian buffer to be maximally effective the buffer should extend to all channels in the distributary network, even small first order tributaries.

A number of researchers have conducted literature reviews of the many riparian restoration research projects which have been performed since the practice became widespread in the 1970s (Hickey and Doran 2004). These synthesis papers have a number of recommendations regarding buffer width:

- Buffers should be between 33 and 165 ft (10 and 50 m) wide for effective nitrogen filtration (Mayer et al. 2005).

- Buffers should be greater than 98 ft (30 m) in width for effective nitrogen and phosphorus filtration (Hickey and Doran 2004).

- Forested buffer width should extend to the edge of the floodplain to reduce the impact of upslope silviculture practices on stream microclimate (Anderson et al. 2007).

- Buffer widths of 98 ft (30 m) or greater are required to protect the ecological integrity of the stream (Broadmeadow and Nisbet 2004).

The standard practice today is to create or maintain buffer widths that are approximately 3.2–33 ft (1–10 m) in width (Hickey and Doran 2004). The available research indicates that this range is too narrow to protect ecosystem functioning and that widths in excess of 98 ft (30 m) are preferable.

11.2.5.6 Wetland Creation/Restoration/Enhancement

Research has indicated that floodplain wetlands are most productive when hydraulic residence time on the floodplain is on the order of 2 to 10 days (Ahearn and Dahlgren 2005; Hein et al. 2004). Additionally, studies have indicated that when residence time on floodplains is below this threshold the floodplain becomes a net sink for algal biomass instead of a net source (Ahearn and Dahlgren 2005; Tockner et al. 1999). This suggests that small floodplain restorations may not increase food resources within the waterway and that restoration efforts should focus on large floodplains (or small floodplains which receive relatively low volumes of water). There is a delicate balance in the hydroperiod of restored wetlands; too much connectivity between the wetland and the main channel and the productivity of the wetland decreases; too little and the export of food resources to the channel is decreased while the probability of fish stranding on the floodplain increases. In a study located in the lower Chehalis River, Henning et al. (2006) collected juvenile Pacific salmon data in both natural wetlands and in wetlands that were enhanced with weirs designed to promote connectivity. They found that enhanced wetlands had significantly higher age-1 abundance than unenhanced wetlands that were a similar distance from the main-stem river. This study suggests that measures which promote connectivity between riparian wetlands and adjacent water bodies will benefit native fish species.

Several studies have examined the effectiveness of salt marsh restoration practices (French and Stoddart 1992; Williams and Orr 2002; Hood 2004; Konisky et al. 2006; Simenstad et al. 2006). These works lead to the following recommendations:

- Ensure that the marsh has not subsided below the elevation required for emergent marsh vegetation and, if so, provide sediment source such that this elevation will be reached shortly after the project has been constructed (Williams and Orr 2002).

- Consider the geomorphology of both the seaward and landward tide-channel network when designing the dimensions of tide channels (Hood 2004).

- Consider the project within the broader geomorphic context (Simenstad et al. 2006).

- Where possible, remove all dike structure so as not to compromise or constrict the tide channel network (Hood 2004).

11.2.5.7 Beach Nourishment/Contouring

Several decades of beach nourishment on the east coast and in Europe provide a track record of nourishment activities where nearshore organisms have been established (Speybroeck et al. 2006). Studies from these locales will be particularly germane to projects on the outer coast of

Washington, and in similar high-energy, sandy environments. Based upon an exhaustive survey of this work, (Speybroeck et al. 2006) makes the following recommendations:

- Choose nourishment grain size commensurate to the wave energy environment. Where possible, an estimate of storm wave height should be made to make this determination.
- Avoid short-term compaction by plowing immediately after construction (applicable only to sandy nourishment projects).
- Execute the nourishment in a period of low beach use by fish, birds, and other motile organisms.
- Break large nourishment projects into a number of smaller projects and stagger them such that nourishment in one reach feeds adjacent reaches (USFWS 2002).
- Select the nourishment technique consistent with the natural mode of sediment delivery (e.g., longshore transport on the outer coast and in the Strait of Juan de Fuca; bluff landslides in Puget Sound).

Other work, some of which has been performed in settings more typical of western Washington, similar to that of Puget Sound, has put forward other recommendations:

- Completely remove former bulkhead materials where possible (Gerstel and Brown 2006).
- Avoid using dredged materials from nearby marine elevations above wave base (Demir et al. 2004).
- When large projects are undertaken, reduce the size of individual renourishment placements by subdividing the site and alternately nourishing different portions of the project site (Munoz-Perez et al. 2001).
- Avoid nourishing areas immediately adjacent to eelgrass beds. If nourishment is carried out near eelgrass, ensure that sedimentation rates in the affected meadows do not exceed the rate found by Mills and Fonseca (2003) to cause significant mortality (i.e., >25% of the average stem length).

11.2.5.8 Reef Creation

Thirty years of artificial reef research have led to a rich data set that has identified pitfalls in offshore hard-substrate deployment (Thompson et al. 2002). The following suggestions are taken directly from this work:

- Locate the reef to best connect the activity site to other areas of hard-rock habitat to reduce the probability of an invasive species infestation (Thompson et al. 2002).

- Use clean earthen materials where possible (i.e., no materials that would leech metals or other exotic organic compounds, e.g., creosote-treated wood).
- Avoid the use of vertical walls (Bulleri and Chapman 2004).
- Place reefs completely below wave and tidal influence to minimize hydrogeomorphic disturbance to adjacent shorelines.
- Avoid simple geometric designs. A complex landscape has been shown to be more productive for a wide variety of fishes than simple geometries (Moschella et al. 2005; West et al. 1994).
- Provide a rough, complex surface on which a variety of organisms can colonize. Gullies and small caves can be especially fruitful (Moschella et al. 2005), particularly if they are large enough to allow sand to accumulate (Fabi et al. 2006).
- Use stable materials only. Materials that decay or that can become mobile during storms can endanger the communities that inhabit the reef and ultimately reduce fish numbers (USA-Today 2007).
- Protect reef areas from fishing (Guidetti et al. 2005).

11.2.5.9 Eelgrass and other Aquatic Vegetation Enhancement

Eelgrass planting has been traditionally considered a difficult enterprise (Thom 1990). However, recent work has demonstrated that it is possible to restore eelgrass populations if an adaptive management strategy is undertaken from the beginning of the restorative work (Thom et al. 2005). Further, Thom et al. (2005) described the elements necessary for a successful eelgrass restoration program:

- Clear goal statement—drives what is done
- Conceptual model—organizes understanding
- Monitoring—provides information for management decisions
- Evaluation framework—provides a mechanism to evaluate information openly and objectively
- Adjustment strategy—ensures clear plans and mechanisms to implement actions when adjustment is necessary
- Dissemination of information—lets others learn regionally and nationally.

In terms of the planting method, there are several eelgrass planting techniques (Pickerell et al. 2005). The most common approach is simply to manually plant adult shoots in the restoration area (Fonseca et al. 1998). Mechanized approaches have been attempted with mixed results (Pickerell et al. 2005). As any direct method of planting initiates some disturbance of the seabed (ultimately causing resuspension of sediment that is potentially harmful to nearby existing plants), several methods have sought to more closely simulate natural reproduction. In particular, Pickerell et al. (2005) put forth a technique to use buoys to broadcast seed across a particular area. This was demonstrated to be effective in encouraging the colonization of eelgrass without the impacts associated with intrusive planting, although it has not yet been proven effective in Washington State waters.

11.2.6 Channel Modifications

11.2.6.1 Dredging

A number of techniques have been developed that may be used to mitigate the effects of dredging on sensitive ecosystems (Smits 1998). However, many of these require a trade-off with regard to dredging efficiency and impacts on organisms. For example, in hydraulic dredging, the dredging rate can be adapted by increasing the amount of water pumped up relative to the amount of sediment that is dredged, which can help to reduce the extent of turbidity plumes, although the possibility of entrainment increases (Erftemeijer and Lewis 2006). Other examples of environmentally sensitive dredging equipment have been cited by Erftemeijer and Lewis (2006):

- Encapsulated bucket lines for bucket chain dredgers
- Closed clamshells for grab dredgers
- Auger dredgers
- Disc cutters
- Scoop dredgers and sweep dredgers.

In muddy environments that are underlain by sand, suction of material from below without exposing dredged material to the water column is also possible with new technology (RBW 2007). In this case, if implemented correctly, the effects to fish and invertebrates associated with entrainment and water-column turbidity could be virtually eliminated.

Measures to mitigate the destruction of aquatic resources found by Erftemeijer and Lewis (2006) include:

- confined land-disposal,
- turbidity modeling (plume prediction),
- turbidity thresholds,
- limits to allowable reduction in aquatic species productivity,
- minimizing the duration of dredging,
- seasonal restrictions to avoid fish use and aquatic flowering periods,
- limiting over-dredge quantities,
- use of silt screens,

- prohibiting dredging near eelgrass areas,
- stopping dredging when turbidity thresholds are exceeded, and
- adoption of legislation banning the use of certain (clamshell) dredging methods.

Contractual requirements have also been used to constrain the impacts on aquatic wildlife associated with dredging (Erftemeijer and Lewis 2006). In the bridge project to connect Denmark to Sweden, two major tools were introduced to ensure that dredging-induced turbidity was kept below the limits necessary to fulfill the environmental objectives and criteria of the project:

> (1) the contractor was held responsible through his contract for keeping the spill below specified limits varying in time and space, taking into consideration environmentally sensitive periods and areas;
>
> (2) a monitoring program was implemented to identify dispersal of significant turbidity occurrences, and documenting key variables related to the most sensitive benthic communities.

Dredging was stopped temporarily during peak tidal currents on twenty occasions to keep within these environmental restrictions (Thorkilsen and Dynesen 2001). These measures helped to ensure that there were no significant impacts from dredging and construction of this major infrastructure project.

Although a common practice in Washington State, the installation of physical barriers such as silt screens has not always proved as successful in practice (USACE 2005). Enclosure of dredging equipment with a silt screen is restricted mainly to use with stationary dredgers using pipeline discharge methods, and is always accompanied by some degree of leakage underneath. Protection of an environmentally sensitive area with silt screens may in some cases be viable, but only if the physical conditions of the site (especially waves and currents) allow their effective use (USACE 2005). As a result, a rigorous monitoring program is recommended to accompany any barrier method, such as silt screens.

Dredged spoils disposal presents another challenge to protect aquatic species. USACE (1983) classifies disposal into three categories: open water, confined (either in upland areas or at sea), and habitat development (usually beach nourishment in Washington State). Open ocean disposal of clean materials have been shown to have little effect on benthic invertebrate populations when strict procedures regarding release have been followed (Simonini et al. 2005). Typically, confined land disposal is more preferable when sediments are contaminated (USACE 1983). However, care should be used when disposing of sediments on land. Runoff from confined disposal sites have been shown to be a source of pollution (Peijnenburg et al. 2005). Beach nourishment of dredged materials presents its own challenges and is discussed at length in the Habitat Modifications white paper (Herrera 2007b).

11.2.6.2 Gravel Mining and Scalping

The ecological impacts and effects on HCP species of instream and pit mining can be significantly reduced or eliminated if future management of gravel mining emphasizes incentives to use alternative sources of construction aggregate such as glacial outwash deposits, reservoir deltas, quarries, and recycled concrete rubble.

If gravel mining is to occur in a riverine environment, several steps can be taken to minimize impacts on HCP species. To reduce the impacts of gravel mining on substrate conditions, Collins and Dunne (1989) recommended limiting instream gravel extraction rates to the ambient rate at which sediment is replenished by natural bedload transport processes. Additionally, quantitative site assessments should be performed to measure and document habitat changes and habitat use and preferences of salmonids before and after bar scalping activities, using both scalped and control sites.

Norman et al. (1998) offer several recommendations for planning and siting floodplain gravel mines. Wherever possible, large gravel mines should be located in uplands away from the river valley bottom. A poor second choice is to locate mining on terraces high above the active (100-year) floodplain. In Washington, upland glacial deposits offer ample rock supplies. Mining these deposits eliminates the potential for stream capture or river avulsion. Furthermore, pits in these locations have a good potential for successful long-term reclamation.

11.2.6.3 Sediment Capping

There are numerous ways in which to conduct a sediment capping project, and each technique is associated with different impacts. Some projects, like the Boston Harbor Capping Project (see Lyons et al. 2006), may require the construction of a confined aquatic disposal (CAD) cell to contain dredged material and a sediment cap. Construction of a CAD cell is associated with numerous impacts such as noise caused by pile driving, and contaminants leaching from treated wood products. Other projects may require the deposition of only a small in-situ cap. The impacts associated with these projects will be relatively small. However, independent of project size, practitioners should follow a number of common best management practices:

1. Practitioners should use clean capping material preferably dredged from areas where dredging was going to occur independent of the need for capping sediment. For instance, the sediment for the Eagle Harbor Sediment Cap was obtained from the Snohomish River Navigation Project (Palermo et al. 1998).

2. To ensure sufficient cap thickness, practitioners should account for bioturbation depth, erosion potential (USACE 1991c), and leaching potential. A minimum depth of 3 to 4 feet is recommended (USACE 1991a).

3. To avoid displacement of contaminated sediment, capping material should be of an equal or lesser density than the contaminated sediment that is to be covered (USACE 1991a).

4. Although such systems are expensive, practitioners should use an active barrier system (ABS), such as activated carbon (Murphy et al. 2006), zeolite (Jacobs and Forstner 1999), calcium carbonate (Hart et al. 2003), coke (McDonough et al. 2007), or a low hydraulic conductivity layer (Hull et al. 1999).

These recommendations can apply to any cap placement method; however, some methods have a greater impact than others. To reduce suspended solids concentrations and contaminated sediment displacement during construction, pump-down capping techniques should be used over point-dump techniques (USACE 1991b). Although more expensive, pump-down techniques allow for more control of where capping material is deposited while simultaneously reducing ambient suspended solids and contaminated material entrainment.

Capping is frequently associated with dredging, either to obtain the cap material (e.g., Eagle Harbor, Washington) or in projects where dredging spoils are capped (e.g., Boston Harbor, Massachusetts).

11.2.6.4 Channel Creation and Alignment

The adverse ecological impacts and effects on HCP species caused by channel creation and alignment activities can be diminished using techniques that are based on an understanding of site-specific geomorphic and ecological processes. For example, the engineered placement of wood, planting of riparian vegetation, avoidance of erosion-prone areas, and levee setback all illustrate techniques that can be incorporated into bank stabilization projects to promote desirable ecological outcomes. WDFW has published a series of guidelines through the department's Aquatic Habitat Guidelines Program. These guidelines are available from WDFW and include the Integrated Streambank Protection Guidelines document (WDFW 2003), which provides guidance for assessing and selecting bank protection techniques, and the Stream Habitat Restoration Guidelines document (Saldi-Caromile 2004), which has an entire chapter devoted to of channel modification techniques.

The structural failure of wood placed in aquatic environments as mitigation for channel creation and alignment activities can impose construction impacts on HCP species. The adverse ecological impacts on HCP species caused by the structural instability and failure of instream woody debris can be minimized or avoided by ensuring that wood placed in rivers is properly engineered according to accepted engineering guidelines. Such guidelines are currently under development by the Washington chapter of the American Council of Engineering Companies (ACEC). Project success depends on a thorough understanding of the site-specific geomorphic constraints, quantifiable habitat goals, and the development of performance-based criteria that account for the anticipated hydrodynamic forces and the desired factor of safety for stability (Miller and Skidmore 2003; Slate et al. 2007).

USEPA (2007) recommends distributing small-scale practices throughout the landscape.

For activities that require dewatering, impacts can be minimized by performing work during low-flow or dry conditions and by pumping sediment-laden water from the work area to an infiltration treatment site. Disturbed areas within the channel should be stabilized with a layer of sediment corresponding to the ambient bed to prevent an influx of fine sediment once water is reintroduced to the site. Science-based protocols for fish removal and exclusion activities should be adopted to track and report the number and species of fish captured, injured, or killed. Projects should also require slow dewatering and passive fish removal from the dewatered area before initiating active fish-removal protocols. During passive fish removal, seining is recommended before using electrofishing, which carries a greater risk of mortality (NMFS 2006).

11.2.7 Water Crossings

11.2.7.1 Hydraulic and Geomorphic Modifications

11.2.7.1.1 Channel Hydraulics

HPAs typically require that structures such as bridges and culverts have capacity to convey flood flows and debris. Additional measures that can minimize impacts include finding an alternative to building the structure; siting the structure as far as possible outside of the active channel; minimizing the structure's footprint; and generally designing the structure to have the least possible effect on channel hydraulics (Bates 2003). Guidance for appropriate design of engineered channels is readily available; the Corps channel rehabilitation manual (Watson et al. 1999) provides a widely used example, and another useful source is the Corps manual *Hydraulic Design of Stream Restoration Projects* (Copeland et al. 2001). WDFW's culvert manual (Bates 2003) also provides excellent design guidance for culvert placement. Procedures for hydraulic design of culverts in steep (greater than 3 percent gradient) channels are detailed by Papanicolaou and Maxwell (2000).

Standard procedures for channel isolation and in-water work appear to be largely effective at minimizing channel hydraulic effects associated with work within the OHWL. However, some specialized additional measures may be appropriate for minimizing the risk of frac-outs from high pressure directional drilling (HPDD) water crossings. Examples of itemized measures intended to minimize the risk of frac-outs and expediently respond to their consequences are provided by Fisheries and Oceans Canada (2006) and California Coastal Commission (2000). WDFW may consider adopting these measures as rule (appropriately, within WAC 220-110-100(3)), periodically reviewing and revising them in consultation with the federal agencies and requiring them for all HPDD projects that need an HPA. In addition to minimizing adverse channel hydraulic impacts, the recommended measures also address substrate modifications and water quality impacts associated with HPDD operations. Compliance with such measures should ensure that incidental take due to frac-outs has been minimized to the greatest practicable extent, thereby meeting the ESA criterion.

Risk of damage from "catastrophic" events such as debris flows, dam-break floods, and rare conventional floods can be minimized by increasing the design standard (e.g., to 500-year flood capacity), using fords rather than culverts at sites where fish passage is not an issue, or siting piers/abutments so as to span the channel migration zone (see Bolton and Shelberg 2001 for discussion of channel migration zones).

11.2.7.1.2 Littoral Drift

Impacts to littoral drift can be avoided or minimized by avoiding or reducing those features that interfere with littoral transport processes through the following measures:

- Bury conduits so that they do not extend above the sediment surface (MOEE 1995) (currently required under WAC 220-110-100(2)).

- Design pile-supported structures with sufficient open space between pilings to allow waves, currents, and sediment to pass beneath (MOEE 1995).

- Avoid certain impacts from floating water crossings placed perpendicular to shorelines, which dampen wave action and prohibit natural shoreline erosional processes, by minimizing the dimensions of these types of structures.

The effects of these measures are site-specific, and thorough study of the littoral drift cell and potential habitat affected should be conducted on projects that could affect the system's littoral currents and wave action.

11.2.7.1.3 Substrate Modifications

The identified impacts of marine substrate modification (as distinct from substrate changes that occur in response to channel or shoreline hydraulic changes) are generally beneficial. The reviewed studies do not recommend specific habitat protection, conservation, mitigation, and management strategies. However, if the federal agencies express concern about the possible cumulative effects of marine substrate modifications on potentially covered species, it would be appropriate to track such effects in the course of overall HPA program monitoring. In this way, new data could be accumulated to help guide adaptive management of the program.

Substrate modification in freshwater environments generally consists of placing fill or culverts into aquatic habitat or adjacent riparian/floodplain habitat. Means of reducing the impact of such actions include:

- Minimizing fill placement by siting bridge abutments far enough apart to span the channel or using bottomless culverts that span the channel.

- Minimizing use of approach fills or including flood relief culverts in approach fills.

- Siting bridges or culverts, where possible, at locations where the channel is naturally confined.

- Oversizing culverts to ensure that they will pass LWD and large bedload particles.

11.2.7.2 Water Quality

No specific measures for water quality impacts from water crossing structures were identified.

11.2.7.3 Aquatic Vegetation

11.2.7.3.1 Eelgrass and Macroalgae

Where conditions are suitable for eelgrass growth, impacts of water crossing structures should be avoided or minimized by use of the following measures:

- Avoid impacts by locating structures away from eelgrass beds whenever possible.

- Minimize the area of impact by using the best available installation methods.

- Minimize shading of bridges over eelgrass and macroalgae by using the lowest possible number of pilings.

- Space pilings to minimize shade to areas suitable for eelgrass.
- Minimize dimensions of bridges to reduce shade.
- Incorporate design elements into bridges to reduce shade where feasible.
- Whenever possible, orient bridges to reduce the shade in habitat that is otherwise appropriate for eelgrass growth (e.g., structures oriented east-west cast a shadow on a single area for a longer period of the day than do structures oriented north-south).
- Locate the bridge deck as high above the water as practical to reduce shade.
- Avoid vessel impacts to eelgrass during water crossing construction by maximizing the vertical and horizontal distance between vessel propellers and eelgrass to the extent practicable.

Adopting these measures would likely result in avoidance and minimization of eelgrass and macroalgae impacts to the greatest extent practicable. However, it is likely that some projects would still require compensatory mitigation to completely offset temporal loss of eelgrass function and site-specific and cumulative impacts on eelgrass.

The reviewed literature did not identify minimization or mitigation techniques to address impacts to macroalgae.

11.2.7.4 Freshwater Aquatic Vegetation

No specific measures for freshwater aquatic vegetation impacts from water crossing structures were identified.

11.2.7.5 Riparian and Shoreline Vegetation

No specific measures for riparian vegetation impacts from water crossing structures were identified.

11.2.7.6 Artificial Lighting

For bridges, artificial lighting may not be avoidable; therefore, compensatory mitigation may be required to fully account for potential adverse impacts associated with artificial lighting.

11.2.7.7 Shading

Nightingale and Simenstad (2001b) and Carrasquero (2001) provide impact minimization measures for the design, construction, and revetment of a variety of overwater structures. Many of these measures appear to be applicable to water crossings, especially bridges. The guidance provided by these authors includes:

- Increasing the height of overwater structures (in this case, bridges) to allow light transmission under the structures.

- Decreasing structure width to decrease the shade footprint.
- Using the smallest number of pilings possible, allowing more light to penetrate beneath the structure.

It may also be helpful to construct bridges with a grated deck that allows some light transmission.

11.2.8 Fish Passage Structures

Best professional judgment of the design standards that are commonly used in the Pacific Northwest and elsewhere include the Draft Fish Passage Standards developed by NOAA Fisheries (NMFS 2001), draft revisions to these standards currently in development, WDFW culvert design guidelines (Bates et al. 2003), and WDFW fishway design guidelines (Bates 1997).

11.2.8.1 Design Criteria

Regardless of the structure type, it is apparent from available research that "one-size-fits-all" guidance for the design of fish passage structures will not yield adequate results where the passage of multiple HCP species at multiple life-history stages is a concern. Structure design and specific structural parameters should take into account these biological requirements to ensure long-term success. In this context, fish passage structures that attempt to mimic natural hydraulic and geomorphic complexity are likely to provide the most effective results. Current WDFW guidance emphasizes this approach.

Specific circumstances, such as the retrofitting of existing culverts or the development of fishways, may require engineered solutions based on the swimming abilities of target fish species. Where passage requirements for species of interest are uncertain, factors of safety should be incorporated to the extent practicable. Structure design must also accommodate the hydraulic and geomorphic context of the system in which it is being installed. This will increase the likelihood of successful operation over time, and ideally decrease the need for maintenance.

Consider the following parameters when developing design criteria for retrofitted culverts and fishways for juvenile salmonid passage:

- Design for the smallest size of fish anticipated to migrate through the structure.
- Create complex, interconnected low-flow velocity zones within the structure. Incorporation of roughness features (e.g., corrugation, gravel and cobble embedded within concrete, baffles) appears to aid in this objective by creating turbulence that induces low-velocity conditions in the boundary layer.

11.2.8.2 Culverts

In circumstances where culverts are required, structures that are designed appropriately for the hydraulic and geomorphic context of the project site can provide a high degree of fish passage and habitat protection. Accordingly, current design guidance directs project proponents in identifying the most appropriate type of structure for their specific circumstances.

Culvert design guidance has continually evolved in recent years as the result of ongoing research on fish passage requirements, as well as a growing understanding of the broader effects of culverts on the aquatic environment. WDFW guidance to date has emphasized the use of three design methods:

- the no-slope and stream-simulation options, which emphasize the placement and/or natural accumulation of bed material within the culvert to promote a hydraulically complex environment; and
- the hydraulic design option, which emphasizes the use of hydraulic calculations to design a structure based on the swimming performance of target species.

The stream-simulation option is currently the recommended approach to culvert design. The no-slope option is similar in concept, except that this method is limited to lower gradient environments with shorter culvert requirements. These geomorphically oriented designs attempt to accommodate natural fluvial processes to the greatest extent possible, thereby providing passage for a full range of aquatic species.

When properly designed for the hydraulic and geomorphic conditions present in the watershed, these geomorphic designs can provide a high degree of fish passage function with limited effects on ecosystem connectivity. However, any design that fails to incorporate the full range of current and future geomorphic conditions in the watershed may cause unintended effects on habitat conditions, or may ultimately fail to provide fish passage if channel conditions change. For example, a culvert design that fails to recognize the likelihood of migrating headcuts either reaching or being liberated by the structure may not allow the channel to adjust as required. Conversely, a culvert may be designed appropriately for current conditions, but the design may fail to recognize development trends in the watershed that could change local hydrologic and geomorphic conditions.

This speaks to the need for guidance for a predesign hydraulic and geomorphic assessment of current and likely future watershed conditions. This guidance should emphasize assessment of current conditions in the watershed (specifically with regards to channel evolution), and the hydraulic and geomorphic trajectory of the system. The latter should consider likely future land use patterns and their likely effect on hydrologic and geomorphic conditions. This guidance should also cover methods for addressing existing headcut conditions and channel incision, using grade control measures or other forms of habitat and/or channel modification as needed.

Culvert design guidance has evolved in recent years given acknowledgement of the complexities and uncertainties inherent when using the hydraulic design method to provide passage for a broad range of species. This method has become less favored over time because of its demonstrated failure to adequately provide juvenile fish passage, as well as other concerns. This weakness is due in part to limitations and uncertainties in the calculations used, failure to consider the design life of the project in the context of natural variability in channel conditions, and inappropriate criteria used to direct design guidance in the Hydraulic Code. With regard to the former, the hydraulic calculations employed in this method are limited from the standpoint that they may not fully capture the complexity of turbulence and boundary layer velocities within culverts that can aid or hinder fish passage.

Despite these limitations, the hydraulic design option is still employed in specific circumstances where retrofitting of a barrier culvert is required (e.g., when removal or replacement is impractical in the immediate future). In such cases, the use of rigorous hydraulic engineering methods is a desirable approach where fish passage must be considered. However, it must be stressed that the design approach be informed by the best available science on the swimming performance, behavior, and migratory requirements of all species and all life-history stages likely to be affected by the structure in question. As this information is developed, culvert design guidance should be updated accordingly. It is recommended that biological criteria not be included in the Hydraulic Code, however, because the code is updated too infrequently to reflect the most recent science.

Two examples illustrate the weaknesses inherent in the hydraulic design method. First, available data described throughout this white paper indicate that culverts and other fish passage structures need to accommodate the passage of fish species and life-history stages with a broad range of swimming abilities and behavioral requirements. Most research applicable to the retrofitting of culverts has focused on salmonids. However, protection of salmonids may not adequately protect the full range of HCP species. For many other HCPS species, data on swimming performance are too limited to be useful in guiding design, or do not exist at all.

Second, WAC 220-110-070 sets the design discharge criterion as the flow rate that is exceeded no more than 10 percent of the time during the months of active adult and juvenile migration (Bates et al. 2003; Powers and Saunders 2002). If the culvert velocities are less than or equal to the allowable velocity at the high passage design discharge, the WAC criterion is met. If not, the culvert is considered a barrier. However, barrier determinations made by the physical and hydraulic measurements described in the WAC, may not accurately represent the influence a culvert has on the movement of HCP species that are less well understood. Consequently, it is recommended that information be collected on the behavior of nonsalmonid fish species to document the actual effect of culverts on fish movement.

The Washington State Department of Transportation leads a cooperative program to study juvenile salmonid passage through culverts by systematically conducting statistically designed experiments in a full-scale culvert system at the Culvert Test Bed (CTB) at the WDFW Skookumchuck Hatchery near Tenino, Washington (Pearson et al. 2005, 2006). The CTB program is a unique opportunity to provide scientifically sound information that can be used to develop better designs for retrofitted structures (Pearson et al. 2005, 2006). However, WDFW staff have questioned the effectiveness of this program. If this program continues, research should focus on providing relevant understanding of the relationship between hydraulics and behavioral and physiological limitations necessary to develop sound design criteria. In this context, expansion of the program to evaluate the passage requirements of other HCP species may be valuable. As the need for retrofitted culverts declines over time (i.e., barrier culverts are removed or replaced, rather than retrofitted), the program can be retired.

Although not supported by direct citation from scientific literature, general recommendations regarding trash racks and livestock fences associated with culverts are provided in NMFS (2001). According to NMFS (2001), trash racks and livestock fences should not be used near the culvert inlets as accumulated debris may severely restrict fish passage and cause potential injuries to fish. Where fencing cannot be avoided, it should be removed during adult salmon upstream migration periods. Timely clearing of debris is also important, even if flow is getting around the fencing. Cattle fences that rise with increasing flow are highly recommended.

11.2.8.3 Fish Ladders/Fishways

Fishways are generally not recommended but may be useful in some applications, such as where excessive drops occur at a culvert outlet (NMFS 2001).

In general, given that fishways are commonly associated with dams, to the extent possible, owners should pursue notching or complete dam removal. The most biologically sound solution to fish passage related impacts from dams is to allow for free and unimpeded upstream and downstream migration at all times of the year.

Based on data and findings from the ongoing monitoring of constructed projects, FishXing (2007) offers the following recommendations with respect to fishway construction:

- Where applicable, design internal weirs with gradual side-slopes. Weirs with gradual side-slopes create a thin sheet of plunging water along the edges. The hydraulics of this thin sheet of water in the receiving pool creates good leaping conditions for smaller fish. Also, place a bevel on the downstream edge of V-notch weirs to create the best conditions for leaping by smaller fish. Placing the bevel on the upstream side may also improve debris passage.

- In a fishway, if the volume of each step-pool is relatively small, it may create excessive turbulence at relatively low flows. Assessing turbulence during the design process involves identifying the highest flow for passage through the step-pools and then sizing the pools to dissipate the energy associated with that flow. Turbulence in step-pools is assessed using the Energy Dissipation Factor (EDF). If the EDF is excessive at the high-passage design flow, either the pool volume should be increased, the drop height reduced, or the proportion of streamflow that bypasses the pools should be increased.

11.2.8.4 Roughened Channels

The effects of roughened channel construction are similar to those imposed by channel creation and realignment. Therefore, the habitat protection, conservation, mitigation, and management strategies discussed for channel creation apply also to roughened channel construction.

Based on constructed project monitoring data, FishXing (2007) provides the following recommendations for roughened channels associated with culverts:

- Construction of a roughened channel requires skilled equipment operators and on-site construction guidance from persons familiar with this type of design. Expert construction oversight is needed to avoid the construction of wider and shallower-than-designed roughened channels. These deviations from the design have the potential to create insufficient depth at lower fish migration time flows, possibly hindering fish passage.

- When rock must be used, the use of larger-than-specified rock to construct the bank of a roughened channel results in large voids within the bank rock. This will allow water flow behind the rocks, thus scouring the native bank material. The potential for this issue is greater when donated or “recycled” rock is used to construct the bank of a roughened channel, as it may not meet design specifications. If the problem occurs, it can be addressed with the use of smaller material added in the void areas to prevent water from flowing behind the rocks and scouring the native material.

- In roughened channel projects that extend through/past a culvert, using a continuous slope through the culvert rather than a short, oversteepened section would improve fish passage conditions.

- When designing roughened channel, consider the geomorphic and hydraulic impacts beyond the project area to avoid or minimize the potential for unintended impacts.

- Use an interdisciplinary team of engineers, hydrologists, fisheries biologists, and geomorphologists to identify and address potential problems beyond the project area during the preliminary design phase.

- Poor culvert alignment can increase the risk of debris plugging, scour adjacent banks, and reduce capacity. When extending or installing a culvert, consider the impacts on alignment between the culvert inlet and approaching channel.

- The natural streambed below a lined or hardened channel is typically susceptible to scour and downcutting. Therefore, it is advisable to include a transition area that dissipates energy and reduces velocity before flow enters the natural channel. Addressing this in the initial design phase may avoid the need for subsequent replacement or retrofits.

- Limiting the project length to the right-of-way can make it extremely difficult to satisfy fish passage objectives while maintaining a stable channel. To achieve the project's objectives, consider extending the project reach beyond the right-of-way. This will require coordination with adjacent property owners as well as stakeholders early in the project design.

11.2.8.5 Weirs

Using weirs to provide hydraulic controls in the channel upstream and/or downstream of a culvert can create a continuous low flow path through the culvert and stream reach intended to facilitate fish passage (NMFS 2001). These weirs should be designed to provide instream habitat complexity. To achieve this secondary objective, as well as to greatly improve their hydraulic performance, grade control weirs should be designed as complex structures, rather than simple or single-log structures. Simple or single-log structures are easily undermined and have often been observed in the field posing a barrier to fish after a few months of operation.

Where permanent weirs are desired to manage fish passage, these structures should be designed to limit hydraulic and geomorphic modifications to the greatest extent possible. Specifically, permeability to the downstream transport of water, LWD, sediment, organic material, and fish movement is desirable to limit broader ecological effects.

11.2.8.6 Trap and Haul

The principal biological benefits for a trap-and-haul system typically include connecting populations, increasing genetic exchange, and increasing access to habitat for multiple lifestages and species. These benefits can also be achieved with fishways. Given that trap-and-haul systems are typically less expensive than fishways, the former may be more appealing for some applications. However, although initially less expensive than a fishway, a trap-and-haul system has the disadvantage of higher annual maintenance to ensure that the mechanical equipment and systems work properly during the entire fish passage season (Ferguson et al. 2002). Due to these higher maintenance requirements, trap-and-haul systems are likely to cause more environmental disturbance than fishways, thus increasing their chance to affect HCP species (e.g., through water quality impacts).

Trap-and-haul programs present additional disadvantages that render them less desirable than volitional passage. Fish capture and handling are sources of potential injury and stress that can lead to immediate, delayed, or indirect mortality. In some cases logistical considerations may require release of transported fish at locations that significantly alter their migratory corridor. This in turn may lead to undesirable effects on survival, fitness, and/or spawning productivity. When imposed over several generations, these combined stressors have the potential to impose selection pressures that may result in undesirable evolutionary consequences.

Trap-and-haul programs are labor intensive, which translates to ongoing management costs. While failure to regularly maintain fish passage structures is likely to lead to a gradual degradation in function, trap-and-haul programs are entirely dependent on annual funding to function. In this light, structures that provide volitional passage are clearly preferable.

Given these inherent limitations, consideration should be given to the preferential construction of fishways over trap-and-haul systems where practicable to reduce the potential for undesirable effects on HCP species and their habitats.

11.2.9 Fish Screens

Several strategies exist for improving how fish screens are used in Washington State. These strategies fall into the following categories:

- Management strategies
- Strategies for improving fish screen design and structure

11.2.9.1 Management Strategies

11.2.9.1.1 Improved Training and Research

Designing an effective fish screen requires an integrated understanding of the engineering demands of the structure, site-specific performance requirements, and understanding of the biological needs of the species the screen is intended to protect. This combined knowledge is necessary to develop both an effective screen design, and to provide operational parameters for the water withdrawal or diversion when sensitive species are present that cannot be effectively protected.

WDFW currently provides training, design, and installation assistance for screening projects. WDFW-sponsored research conducted at the Yakima Screen Shop facility has produced many of the screen concepts and design criteria in current use in the region. There is some level of ongoing coordination among state and federal agencies in the Pacific Northwest on research and practical application of screening technologies. However, funding cuts in recent years have limited research and collaboration, leading to the abandonment of efforts targeted at developing and building effective screening technologies. The screen assistance and the screen research programs should be strengthened and coordinated with efforts at the federal level and in other states in the region.

Web-based case studies that evaluate the effectiveness of integrated design and operational parameters would be particularly useful.

11.2.9.1.2 Improved Rules and Guidance

The most current WDFW guidance on fish screen design is in incomplete draft form and has not been revised since 2001 (WDFW 2001a). This guidance document should be updated and improved based on the latest technical information and made available to managers and the public. A notable weakness in this and other fish screen guidance documents is the widespread use of inconsistent terminology, resulting in standards that are confusing and at times contradictory. The revised guidance document should be coordinated for consistency with NOAA guidelines, using a parallel format and consistent terminology to allow for easy cross-referencing among documents. Where state standards necessarily depart from federal guidance, the differences should be clearly highlighted and the rationale for the departure explained. The design guidance should also incorporate a set of typical design drawings for common screen designs and a range of flows, as well as provide contact information for manufacturers and vendors. The guidance should be supported by up-to-date web-based technical assistance, including current case studies that are regularly updated.

Currently, fish screens are typically designed conservatively around scenarios to provide protection of the smallest and weakest swimming salmonid life stages, the most extreme temperature conditions (which affect swimming performance), and the highest flow rates, conditions that are rarely observed in practice. Using the swimming performance and requirements of the smallest and weakest-swimming species and/or life-history stages likely to be exposed to the screen is presumed to provide broad protection for the full range of species and life-history stages likely to be exposed to the screen. This is a useful uniform recommendation that should be employed in all screen designs. However, screen facilities designed to such standards might impose a greater burden on the operator due to their operational limits and maintenance requirements, or engineering demands that are infeasible in certain cases. In such cases, operators have an incentive to contribute to research.

Even when properly engineered for site conditions, a fish screen may not be able to protect all HCP species/life stages. For example, planktonic larvae may be unavoidably entrained through even the most protective screen system. To provide additional protection where performance limitations cannot be overcome through design, WDFW may want to investigate expansion of authority under the Hydraulic Code to impose operational limits on water withdrawals, allowing water withdrawal restrictions to be included as part of the approval process under the HPA program for fish screens.

These restrictions would be enforced in circumstances where screens cannot provide adequate protection when sensitive life-history stages of various species are present. Water users in high-priority habitats (i.e., habitats where HCP species may be acutely vulnerable) should be required to develop an operational plan that is certified by state and federal agencies. Moreover, research should be dedicated to developing effective screen technologies for settings where flow restrictions are not practicable.

11.2.9.1.3 Improved Performance and Compliance Monitoring

More consistent monitoring and enforcement will greatly benefit the advancement of fish screen science, and help to ensure that existing screens are as protective of HCP species as possible.

Performance monitoring is a necessary tool to determine whether existing screens are functioning as intended and how effective they are at avoiding or limiting entrainment and impingement of sensitive species and/or life stages. For nearly two decades, the Bonneville Power Administration (BPA) has funded ongoing monitoring of fish screen systems on several of the larger irrigation diversions on Columbia River tributaries, including the Yakima, Walla Walla, Umatilla, and other river systems (Carter et al. 2003; Knapp 1992; McMichael and Chamness 2001; Vucelick and McMichael 2003; Vucelick et al. 2004). WDFW has received funding from BPA and NMFS through intergovernmental memoranda of agreement to conduct screen inspection and maintenance on screen systems throughout the Columbia River basin, and to a lesser extent in western Washington. WDFW currently operates a statewide screen maintenance and inspection program, partially subsidized by federal funds, that provides maintenance guidance and monitors maintenance compliance and screen performance.

Improved compliance monitoring is a necessary strategy to enhance protection of HCP species. Even when the best possible screen design and operational criteria are developed, some fish screens will not be operated or maintained as necessary to provide the level of protection desired. Noncompliance with permitting requirements is certain to be an issue of concern regardless of any advances in screen design and operational implementation. Full funding and expansion of the WDFW program would provide a useful and necessary means for training fish screen specialists, and provide case studies for demonstrating successful design and operational procedures. This type of program should consider the following objectives:

- Pre- and postconstruction review of fish screen designs and as-builts for all high-priority screen projects to confirm that the structure was built as intended.

- Incorporation of operational certification into the approval process under the HPA program, with a set recertification schedule based on inspection performance.

- Routine monitoring of fish screens (e.g., every other year, every 3 years) to evaluate compliance with maintenance and operational requirements for recertification purposes.

- Coordination with performance monitoring to provide a mechanism for addressing underperforming structures.

A comprehensive compliance program should include a mandatory but practical pathway for owners of noncompliant screens to address structural and operational issues as quickly as possible. Compliance incentives should first provide funding and technical assistance (building on existing state-level programs) to help owners meet recertification requirements, followed by enforcement and legal action as necessary.

11.2.9.1.4 Fish Screen Operations

In cases where the protection provided by fish screens is fundamentally limited, knowledge of when sensitive species and/or life-history stages are present can be used to manage the timing of water withdrawals. For example, intake systems that will unavoidably entrain fish larvae at high mortality rates could be shut down when larvae are most likely to be present. These management practices would require an expansion of WDFW's authority to regulate water withdrawals, which is currently limited.

Noise, Visual, and Physical Disturbance

Underwater noise, visual, and physical disturbance are, to a certain extent, unavoidable with screen systems that employ mechanical debris-clearing systems. Mechanical systems should be sound insulated and located above water to the extent practicable to limit continuous underwater noise that could contribute to auditory masking effects or avoidance behavior (except in circumstances where noise is being used as a behavioral deterrent). Air jet or hydraulic debris-clearing systems for in-channel screens should be calibrated to limit impulsive sound below established disturbance thresholds where practicable (e.g., 150 dB_{RMS} for salmonids). Proper siting of in-channel screens should limit behavioral avoidance of suitable habitats or other undesirable effects.

Entrainment and Impingement

Require design criteria to consider the full range of HCP species that are likely to encounter the fish screen. Screen mesh size, mesh material, and approach velocity are critical factors in determining entrainment and impingement risk. Current scientific understanding of the swimming performance and risk of entrainment or impingement-related effects is less than uniform across the range of HCP species. Current design criteria may not consider the full range of HCP species likely to occur and therefore may not be as protective as possible.

Introduction of Toxic Substances

Fish screens have the potential to introduce toxic substances to the aquatic environment through two primary pathways:

(1) accidental spills of fuel, oil, lubricants, or other pollutants during construction and maintenance; and

(2) screen equipment failure resulting in the release of toxic lubricants.

Construction, maintenance, and operational-related impacts can be avoided by requiring the project proponent or contractor to have an established spill prevention and spill containment plan in place, through proper equipment maintenance, and through the use of nontoxic, food grade hydraulic fluids and lubricants. Although these actions are commonly taken, making such actions mandatory could further reduce impacts.

11.2.9.2 Strategies for Improving Fish Screens

11.2.9.2.1 In-Channel Screens

In-channel screens vary widely in design configuration, ranging from simple screens on small, private water supply systems to large and complex structures on industrial water intake systems. Given this variety, the strategies identified lean toward recommendations specific to designs for certain applications or of a certain scale. Strategies identified include the following:

- **Infiltration galleries:** Develop guidance criteria for the siting, design, and operation of infiltration gallery screens. Alternatively, adopt NMFS criteria found in NMFS Anadromous Salmonid Passage Facility Design, Section 13 Infiltration Galleries (Experimental Technology (February 2008).

- **Fishway screening requirements:** Screen auxiliary intake systems for fishways and fish ladders, to prevent exposure of smaller sensitive fish to entrainment-related injury.

- **Siting of large intake systems:** Site intake systems at locations and depths where planktonic life-history stages of HCP species are less likely to occur. This highlights the value of incorporating biological expertise into the design of fish screens and related flow control structures.

11.2.9.2.2 Off-Channel Screens

Off-channels screens also encompass a range of designs appropriate for different conditions; therefore, design strategies are relatively specific to given design types.

- **General flow control for off-channel screens:** Screens should be designed to accommodate the hydrologic context of the system in question. Use automated headgate systems programmed to respond to changes in flow conditions. Overtopping by high flows or due to debris accumulation is the most common cause of screen failure and elevated entrainment risk. Other changes in flow conditions can change diverted flow rates, screen submergence, bypass flows, and other parameters in ways that adversely affect screen performance.

- **Flow control for inclined plate screens:** The screen design should provide for a minimum depth of water over the entire screen face. This depth should be based on expectations of the size and type of debris, size, and condition of fish (or other HCP species) requiring passage, and the potential variation in flow that could reduce the depth to below the desired minimum. To achieve these conditions, a substantial amount of bypass flow is typically required and flow conditions must be carefully monitored. Downward sloping screens require at least several feet of head loss to operate effectively. These constraints typically limit this type of screen to riverine applications. Because of the restrictive control of flow necessary for downward-sloping fixed plate screens to provide fish and debris clearance, this design is not recommended except where constant and precise flow control can be provided.

- **Hydraulic and geomorphic considerations:** Off-channel screen designs that incorporate bypass channels impose distinct hydraulic and geomorphic effects, because the bypass channel flow is removed from the main channel and is unavailable until it is discharged at some point downstream. These effects can be minimized by limiting the length of the bypass, discharging the return flow as short a distance downstream as practicable. This design criterion must be balanced against the need to provide sufficient head loss to maintain bypass flow velocities necessary to clear debris, and to discharge entrained fish at a safe location (e.g., areas unsuitable for loitering by lie-in-wait predators).

  These competing design requirements may lead to relatively long bypass channels. If the length of the affected reach is significant (e.g., greater than five times the average reach width) and the flow required to operate the bypass channel is a significant portion of the streamflow in the channel downstream of the diversion, then undesirable changes in channel morphology may occur due to factors such as vegetation encroachment.

- **Avoiding ecosystem fragmentation effects:**

  - Screens employing bypass channels must provide sufficient sweeping velocities to draw downstream migrant and dispersing fish into the bypass system, avoiding delay.

  - Site bypass systems to minimize the length of the bypassed reach. Site outlets to minimize predation on organisms exiting the system.

  - Do not locate bypass outlets in side channels or other channel features where the discharge could create attraction flows that delay upstream movement of migratory species.

  - Consider the potential cumulative effects of migration delays imposed by multiple screen systems when permitting the screen as well as the related flow control structure or channel modification.

11.2.10 Flow Control Structures

11.2.10.1 Construction and Maintenance Activities

In a recent document on procedures to minimize nonpoint source pollution from hydromodification projects, the USEPA (2007) proposed measures to minimize construction problems from sediment increases and chemical pollution. The management practices are specific to the location of the project, the local climate, and source of potential pollution.

Erosion and sediment control procedures are used to prevent sediment from entering surface waters during the construction or maintenance of flow control structures. Proper erosion and sediment control practices should be used to protect surface water quality because of the high potential for the loss of sediment directly to surface waters during these types of projects. Erosion control can be maximized by minimizing the area and time of land disturbance and by stabilizing disturbed soils to prevent erosion in a timely matter. USEPA (2007) has suggested using sediment and erosion control practices borrowed from other applications, such as urban development and construction activities. Potential erosion control activities include application of the following methods and practices:

- Bank shaping and planting
- Bulkheads and seawalls
- Check dams
- Coconut fiber roll
- Erosion control blankets
- Locate potential land disturbing activities away from critical areas
- Mulching
- Preserve on-site vegetation
- Retaining walls
- Revegetation
- Riparian improvements
- Sediment fences
- Sodding
- Vegetated filter strips
- Wind erosions controls.

Minimization of runoff will reduce potential impacts on water quality during construction activities. Practices for controlling chemicals and pollutants include the following (USEPA 2007):

- Check dams
- Constructing runoff intercepts
- Equipment runoff control
- Fuel and maintenance staging areas
- Locate potential land-disturbing activities away from critical areas
- Pesticide and fertilizer management
- Pollutant runoff control
- Preserve on-site vegetation
- Sediment traps
- Vegetated filter strips.

In the construction of new flow control structures, avoidance or minimization of impacts can be accomplished through site selection and facility design. For construction and maintenance activities, management strategies can be implemented to minimize underwater noise, dewatering and fish handling, and construction/maintenance dredging impacts.

11.2.10.2 Dams

Dams severely alter natural rivers systems in many ways including physically blocking the movement of migrating species, altering the natural flow regime, and reducing suitable habitats. Mitigation of these impacts can be divided into three general groups:

(1) actions to improve fish passage,

(2) actions to restore natural flow regime, and

(3) actions to reduce water quality impacts.

In addition, certain actions can be taken during the construction phase of dam projects. The special case of dam removal will often serve to reverse or greatly minimize impacts from dam projects in the long term.

11.2.10.2.1 Fish Passage

To minimize migratory impacts from dams, adequate fish passage structures are required that allow a majority of fish to reach upstream and downstream habitats. For example, Webber et al. (2007) concluded that the design of dams and fish barriers should have fast and slow portions to increase migration over these structures. In laboratory studies, the authors demonstrated that white sturgeon attempt to pass barriers with short bursts, followed by a resting period. Therefore, design of fish barriers (e.g., weirs, dams, step-pools) should have fast sections 2.76–8.27 ft/sec (0.84–2.52 m/sec), followed by slower sections 1.64–2.23 ft/sec (0.5–0.68 m/sec) for recovery (Webber et al. 2007). Information on optimal swimming velocities, height restrictions, diurnal migration patterns, and behavior at passage facilities for HCP species are necessary to optimize fish passage in the presence of dams.

11.2.10.2.2 Flow Regime

Numerous studies have concluded that in order to maintain the ecological integrity of riverine environments in the presence of dams, some return to a natural flow regime is needed (Bednarek 2001). A return to the natural flow regime maintains habitat complexity and connectivity, limits impacts from altered sediment transport and substrate composition, and improves species diversity. These are sometimes referred to as environmental flows (Chester and Norris 2006). In the Grand Canyon, attempts to remediate sediment movement by prescribed flooding or higher (elevation) releases of water through dams have taken place. Collier et al. (1997) documented that incised beaches and sand bars downstream of Glen Canyon dam were somewhat restored during these “flood” events. However, beaches and sandbars still suffered from a reduction in sediment supply.

Biodiversity is best protected where dam operation emulates a natural system. Food webs require variable flow regime and floodplain inundation (Power et al. 1996). Environmental flows used in Australia showed that macroinvertebrate communities were similar to those of unregulated flows in the region (Chester and Norris 2006). In addition, flow releases that simulate variable flows have been observed to improve the diversity of warmwater fish assemblages (Travnichek et al. 1995). On the Tallapoosa River (Alabama), the relative abundance of species classified as fluvial specialists increased from below 40 to more than 80 percent after initiating a more variable flow regime.

11.2.10.2.3 Water Quality

The primary impacts from dams on water quality include altered temperatures and altered dissolved oxygen concentrations. These modifications can be minimized if water releases from the reservoir can occur at multiple depths (Bednarek 2001). This mitigation practice will vary depending on the local conditions, as well as on what species are present; therefore, this practice should be analyzed on a case-by-case basis. In some cases, multiple-depth flow releases will solve these water quality problems; in other cases, they will not (Bednarek 2001).

11.2.10.2.4 Dam Removal

Dam removal is the best way to reestablish thermal regimes and natural sediment transport, restore habitat complexity, and minimize water quality changes. Dam removals are becoming more common as facilities are applying to renew licenses because, in some cases, dam removal is a more economical or safer option (Bednarek 2001). Dam removal, in general, restores natural sediment transport in the system by increasing habitat diversity in the former impoundments (Bednarek 2001) and replenishing coastal systems where beach erosion has proliferated (DOI 1995). Recently, eulachon have been observed in the Elwha River (Washington), and dam removal will likely increase the availability of sand and gravel sizes required for these fish to spawn (Shaffer et al. 2007). Dam removal allows organisms to migrate freely, reduces delays in migration, and reduces mortality caused by fish passage structures (Travnichek et al. 1993).

One significant environmental concern from dam removal projects is the release of stored sediment from the former impoundment. Stored sediments may cause increases in downstream sediment transport and turbidity; however, these increases will be a short-term impact while the river transitions back to a free-flowing system. Factors influencing the duration of impact from sediment releases from a dam removal include: (1) the length of time dam was present, (2) velocity and gradient of river, and (3) removal techniques (Bednarek 2001). The frequency of storms after removal is also important. The downstream effects from sediment releases can be on the order of days (Winter 1990) to many years. In some cases, sediment release will be equivalent to a periodic storm event (Winter 1990). Along with increases in turbidity, there is the potential for contamination arising from pollutants that are adsorbed onto sediment particulates. Pollutant contamination can be reduced by conducting a preremoval evaluation of sediments or dredging, and by conducting a slow drawdown of the reservoir prior to dam removal (Bednarek 2001).

11.2.10.3 Weirs

Weirs are similar to dams but are generally smaller in scale. As a result, mitigation activities associated with weirs are identical to those described for dams.

11.2.10.4 Dikes and Levees

Breaching of dikes and levees has been used to reconnect channel and floodplain habitats, with several documented benefits. After breaching levees on the Consumes River (California), floodplain geomorphology became more complex, with changes in topography, woody debris recruitment, and vegetation (Florsheim and Mount 2002). In addition, restored connectivity has been shown to enhance nutrient cycling by reducing nitrate loading downstream (Sheibley et al. 2006). Finally, levee breaches can influence algal dynamics and overall water quality of the restored floodplain (Ahearn et al. 2006).

Erosion and failure of levees may be reduced through planting vegetation. Conversely, vegetation removal is often encouraged on levees to provide access for inspection, fight flooding, reduce rodent burrowing, and to prevent root-induced water removal (Bolton and Shellberg 2001). However, this study also noted that grass and vegetation actually stabilize these structures, similar to vegetated stream banks. In addition, grass coverage on levees will cause a more even wetting and drying of the structures through transpiration, which will lessen cracking and failure from uneven drying after flood events. Taller vegetation may shade levees and reduce the cracking of earthen levees from extreme heat.

Where possible, dike and levee projects should be designed to retain as many natural hydraulic and geomorphic features as possible. This can be achieved by increasing the distance between the levees to allow channels to naturally meander, incorporating meanders into the channelization project, minimizing the reach length where levees are constructed, or creating artificial side channels (Bolton and Shellberg 2001). The creation of artificial side channels simulates a low-flow channel; when flooding occurs, water spills out into the "floodplain" and creates side channel and side pool habitats. Levee projects can be conducted so that in-channel (e.g., pools, riffles) features are preserved (Bolton and Shellberg 2001). This can easily be achieved by not dredging the channel after the levee or dike is constructed. As with all of these mitigation strategies, their feasibility depends on several site-specific factors, including the purpose of the project, the size of the project area, cost, and safety.

11.2.10.5 Outfalls

Hydraulic and geomorphic modifications associated with outfalls can be eliminated with a design that minimizes alterations to the physical environment surrounding the outlet. A few recommendations are:

- Locate all outfall infrastructure below-grade in areas where sediment transport is significant.
- Place submerged outfall outlets below the closure depth or light penetration depth, whichever is greater.
- Where possible, avoid discharges that are significantly different in density, temperature, salinity, and turbidity from the receiving water.
- Minimize the flow velocities of the discharged fluid. If the flow rates are expected to significantly alter the circulation or geomorphology in the vicinity of the outlet, perform hydrodynamic modeling to assess and limit the area of impact.
- To avoid scour associated with large discharge velocities, site the outfall outlet in an area of pre-existing immobile substrate, where possible.
- Screen the outlet to prevent fish entrainment into the outfall piping.
- Site exposed outfalls so they do not protrude or disrupt sediment transport. Where possible, placement of the outlet should be approved by a licensed geologist.

Where hydraulic and geomorphic modifications are unavoidable, mitigation of such effects is necessary. This could include routing the sediment around the geomorphic disruption.

Monitoring plans associated with submerged outfalls should include ongoing inspections of the outlet infrastructure for the presence of invasive species.

One of the most significant impacts from outfall projects is the alteration of water quality in receiving waters. These impacts can be minimized by:

- Ensuring that the contaminant load in the effluent has been reduced to the greatest extent possible (Williams and Thom 2001).
- Locating outfalls in marine areas where dilution and flushing are maximized (Williams and Thom 2001).
- In riverine environments, establishing a mixing zone will lower the effects downstream.
- Because sediments are associated with many types of pollutants (Murakami and Takeishi 1977), reducing the amount of sediment in the outfall discharge is desirable.

11.2.10.6 Intakes and Diversions

The primary hydraulic and geomorphic alterations associated with intakes and diversions are related to the piping infrastructure for these systems. The most common issue related to intakes and diversions is the entrainment of fish and invertebrates. This impact is mitigated by using fish screens.

Alteration of the amount of water removed and the timing of water removals can minimize impacts related to these structures. For example, a study of downstream drifting shrimp larvae showed that a large percentage of the larvae can be entrained in water intakes, with a mortality of 42 percent and almost 100 percent removed from water column during low flows (Benstead et al. 1999). However, the authors showed that most drift took place at night. When the intake was turned off for 5 hours at night, mortality was reduced to 11–20 percent (Benstead et al. 1999). This study demonstrates that knowing the migration and behavior patterns of HCP species will allow managers to minimize the impacts from flow control structures such as water intakes and diversions. In addition, Miller et al. (2007) discuss that to minimize impacts from diversions on macroinvertebrate communities, diversions should preserve environmental conditions as much as possible.

11.2.10.7 Tide Gates

Tide gates can significantly alter the migration of aquatic organisms and change the natural flow regime. The less time a tide gate is closed, the less likely the impacts on HCP species will be. The type of tide gate and the materials used for its construction can influence how long the gate remains open during the day. Tide gate design is summarized in Giannico and Souder (2005), and improvements for fish passage are described in Charland (1998).

- Tide boxes with side-hinged gates result in lower velocities required to open the gate compared to top-hinged gates because less force is needed to open them.
- Gates constructed of lighter aluminum need less water to open than heavier steel or cast iron gates of comparable size (Giannico and Souder 2005).
- Side-hinged gates open slower such that they also reduce bubbling, turbulence, and scour (Giannico and Souder 2005).

- If information is known about the local behavior and migration patterns of HCP fish or other species, tide boxes may be manually opened to maximize passage during migration and other high-use periods.