Recovery Plan Module
Mainstem Columbia River Hydropower Projects

1.0 Purpose

This module summarizes the effects of Columbia River mainstem hydropower projects on all 13 Endangered Species Act (ESA)-listed anadromous salmonids in the Columbia basin, including the limiting factors and threats and expected actions (or strategy options) to address those threats. The area to be addressed by the module includes the accessible mainstem habitat in the upper Columbia (i.e., to the tailrace of Chief Joseph Dam) and lower Snake (to the tailrace of Brownlee Dam) rivers, respectively, downstream to the tailrace of Bonneville Dam.[1] This module will serve as the mainstem portion of all Columbia Basin ESA recovery plans (i.e., in support of plans for the Snake River, Upper Columbia, Mid Columbia, Lower Columbia, and Upper Willamette River species) until updates are appropriate in response to new information, such as direction from the Federal Columbia River Power System (FCRPS) and Upper Snake remands or other legal and technical proceedings.

1.1 How Salmon and Steelhead Use the Mainstem

All 13 ESA-listed species of salmon *(Oncorhynchus spp.)* and steelhead *(O. mykiss)* in the Columbia basin use the mainstem Columbia River for migration to and from freshwater natal areas to the Pacific Ocean, where they grow from juveniles to mature adults. Most of the listed species spawn and incubate in tributaries, but Snake River fall Chinook, some populations of Lower Columbia River fall Chinook, and Columbia River chum salmon spawn and incubate redds in the mainstem itself. Historically, the peak period for migration to the ocean has been spring and early summer, corresponding with snowmelt in the upper basin and high seasonal flows. However, juveniles from one species/population or another can be found in the system throughout the year.

Downstream travel has been shown to be active rather than passive; in addition to water velocity, the rate of travel is affected by date, the location where the fish begin their migration, fish size, and the extent of the parr-smolt transformation. Survival through the migration corridor declines with distance traveled, whether due to natural hazards (including predation), mortality due to passage at hydroelectric projects, or other factors associated with development (exotic predators, habitat conditions that make native predators more efficient, water quality, etc.).

Connor et al. (2005) described two juvenile life history types for Snake River fall Chinook salmon based on their emigration and rearing strategies. At the time of the ESA listing, it was assumed that all juveniles of this species were ocean-type fish, characterized by entering saltwater at age 0 and spending their first winter in the ocean. However, some of the smaller, later-migrating fall Chinook salmon from the Snake River basin delay seaward movement, wintering in Lower Granite Reservoir and resuming their

[1] A separate module (the Mainstem Columbia River Estuary Recovery Plan Module) provides the same types of information for the lower river below Bonneville, the estuary, and the near ocean plume..

seaward movement the following spring at age 1. According to Connor et al. (2005), although the condition of reservoir-type juveniles decreased over winter compared with ocean-type juveniles, the mean condition factor of the former always exceeded 1.0 in the single year of study.

After growth and maturation, whether in freshwater or the ocean, adult salmonids generally return to their natal spawning areas for reproduction. As described in ISG (1996), the timing of adult entry and movement in rivers and tributary streams, and even the size, shape, and strength of adult fish represent adaptations to the specific physical and biological challenges presented by the upstream route to a specific spawning area. For example, waterfalls and similar physical barriers may be passable only at a specific range of flows that typically occurs during one month of the year, and then only by fish that have the physical ability to jump over or otherwise ascend the barrier. For fall-spawning fish, warm water conditions in late summer often present thermal barriers to movement and their may be little suitable habitat for resting (Berman and Quinn 1991, cited in ISG 1996). Therefore, at the adult life stage, population-specific behavioral patterns, closely attuned to the available habitats, appear to be critical for survival and successful reproduction.

Preferred spawning habitat is determined by the incubation needs of embryos, i.e., high flow of oxygenated water through the interstitial spaces in the streambed (Quinn 2005). Salmon usually avoid both the slowest water (where fine sand and silt accumulate) and the fastest water. Salmon lay their eggs in nests called redds. In areas where winter freezing can destroy embryos, salmon often build redds at sites with upwelling groundwater, which is warmer than river water. In the Columbia basin, two of the listed species, SR fall Chinook and CR chum salmon, spawn both in tributaries and in the mainstem. In the vicinity of Ives Island (downstream of Bonneville Dam), chum spawn in shallow areas where it appears that river water is warmed by its transit through the gravel (Geist et al. 2002). At both Ives Island and in the Hanford Reach, fall Chinook salmon select upwelling sites in preference to non-upwelling sites (Geist 2000, Arntzen et al. 2005), but in other locations fall Chinook prefer to spawn in downwelling areas at the heads of riffles (Healey 1991). At both Ives Island and the Hanford Reach, fall Chinook salmon select redd sites containing the highest dissolved oxygen concentrations in the river and riverbed, which consistent with the requirements for incubating relatively large eggs (Healy 1991).

2.0 Habitat Limiting Factors and Threats Related to Mainstem Hydropower Projects and Operations

Hydropower development in the Columbia basin has impeded salmonid migrations, altered habitats, and increased predation on and competition faced by juvenile salmonids. The following descriptions are from NMFS (2004b) unless otherwise indicated.

2.1 Flow Alterations

Changes in flow patterns can affect salmon migration and survival through both direct and indirect effects. Juvenile and adult migration behavior and travel rates are related to river flow. Flow fluctuations may stimulate or delay juvenile emigration or adult migration, thereby affecting the timing of juvenile arrival in the estuary and ocean or adult arrival at the spawning grounds. Flow also affects the availability of habitat for mainstem spawning and rearing stocks. Rapid diurnal flow fluctuations can disrupt mainstem spawners, leave redds dewatered, or strand juveniles.

2.2 Water Quality

Flow regulation and reservoir construction have increased average water temperatures beyond optimums for salmon in the lower Columbia River. Large mainstem storage reservoirs have decreased maximum summer temperatures in the lower Snake and Columbia rivers, but have increased the period of time when temperatures are higher than optimal for salmonids. High water temperatures can cause migrating adult salmon to stop or delay their migrations. Warm temperatures can also increase the fishes' susceptibility to disease. Flow regulation and reservoir construction also have increased water clarity, which can affect salmon through food availability and susceptibility to disease and predation. Water can become supersaturated with atmospheric gases, primarily nitrogen, when water is spilled over high dams and this has resulted in substantial stress, which can lead to mortality. Gas supersaturation poses the greatest risk for the salmon stocks in the Lower Columbia Domain, which must pass Bonneville Dam or transit the portion of the mainstem immediately downstream of Bonneville.

2.3 Altered Ecosystems

Modification of riverine habitat into impoundments has resulted in changes in habitat availability, migration patterns, feeding ecology, predation, and competition. For example, the Bonneville Dam impoundment has inundated some spawning habitat in the lower reaches of the upper Columbia Gorge tributaries. Downstream migration is slower through impoundments; upstream migration is faster. Food webs are different in the impoundments than in natural rivers. Predation is a major source of mortality, although the same may have been true in the pre-development condition. Reservoir conditions (flow and temperature) may favor the growth of fish predators, including native northern pikeminnow and non-native walleye *(Stizostedion vitreum)* and smallmouth bass *(Micropterus dolomieui).*

2.4 Migration Barriers

2.4.1 Blocked Habitat

The construction of Grand Coulee Dam in 1939 blocked access to historical production areas for UCR spring Chinook salmon and steelhead (NRC 1996, Interior TRT 2003). Chief Joseph Dam, the re-regulating dam for Grand Coulee, is also impassable. The Sanpoil, Spokane, Colville, Kettle, Pend Oreille, and Kootenai rivers each may have supported one or more populations of Chinook and/or steelhead.

Before European contact, SR fall Chinook are believed to have occupied the mainstem Snake River up to Shoshone Falls (Gilbert and Evermann 1894, cited in Interior TRT 2003). In particular, the area downstream of Upper Salmon Falls, at RM 578, was identified by Evermann (1896) as the "... largest and most important salmon spawning ground of which we know in Snake River." After loss of these upstream reaches with construction of Swan Falls Dam in 1920, the reach between Marsing, Idaho, and Swan Falls Dam (RM 349 to 424) is believed to have been the primary spawning and rearing area for SR fall Chinook (Irving and Bjornn 1981; Haas 1965, cited in Interior TRT 2003). However, construction of the Hells Canyon Dam complex (1958–1967) cut off access to historical habitat upstream of river RM 248. Additional fall Chinook habitat was lost through inundation as a result of the construction of the lower mainstem Snake River dams (Groves and Chandler 1999).

2.4.2 Juvenile Dam Passage

Smolts typically migrate near mid-channel in the upper water column where water velocities are greatest. Fish are delayed at some mainstem hydroelectric projects because they stack up in dam forebays during daylight, reluctant to sound so they can either enter a turbine or find the intake to some of the juvenile bypass systems. Juveniles may experience substantially different mortality rates depending on whether passage occurs via turbines, a bypass system, or spill. Turbines are typically the most hazardous route.[2] Mortality results from abrupt pressure changes in the turbines and from mechanical injury. Thus, spillways and bypass systems are much safer routes. At many projects, current operations provide dedicated spill to facilitate dam passage by juveniles.

Surface bypass systems have generally proven highly effective at safely guiding juvenile fish downstream through non-turbine passage routes. An example of an effective and efficient juvenile bypass system is the one developed for the Wells Project in 1989. The hydrocombine configuration of the Wells Project, coupled with adaptations to the powerhouse and spillways, has resulted in a system that relies on the natural surface-oriented behavior of downstream migrating juvenile salmonids to guide them away from the turbines and pass them safely into the project tailrace. On average, the Wells bypass system collects and guides 92% of the spring-migrating juveniles away from the turbines and into safer routes of passage (Skalski et al. 1996).

A prototype removable spillway weir, or RSW, was installed at Lower Granite Dam on the lower Snake River in 2001 and at Ice Harbor Dam in 2005; a third is planned at Lower Monumental Dam in 2007. The RSW allows juvenile salmon and steelhead to pass the dam near the water surface under lower accelerations and lower pressures, providing a more efficient and less stressful dam passage route. The design of the RSW is different from existing spillways whose gates open 50 feet below the water surface at the face of the dam and pass juvenile fish under high pressure and high velocities. The RSW

[2] In conventional turbines, fish passing near the hub are subjected to turbulence, exposure to a cavitation zone, swirling flows, and sharp-edged gaps between the runner blades and the hub. Chelan PUD therefore recently replaced all of the units at Rocky Reach Dam with "reduced gap" turbines (i.e., smaller spaces between the turbine blades and the walls of the housing and at the hub).

creates a raised spillway crest, similar to a waterslide. Juvenile fish are safely passed over the weir more efficiently than with conventional spill while reducing migration delays at the dam. The RSW structure is designed to be "removable" by controlled descent to the bottom of the dam forebay, allowing the spillway to return to original flow capacity during major flood events.

Juvenile bypass systems that divert fish from turbine intakes are now in place at almost all the federal mainstem dams in the Columbia River system.[3] Most systems involve large submerged screens that project downward into the turbine intakes and deflect fish upward into a gatewell, where they pass through orifices into channels that run the length of the dam. The fish are then either routed back to the river below the dam or to the transport facilities at three of the four Snake River dams (Lower Granite, Little Goose, and Lower Monumental), and McNary Dam on the Columbia River. Juvenile fish destined for transport are routed from the bypass system to holding and loading facilities for loading into barges or trucks for transport. The transport barges and trucks carry the fish past the remaining projects for release below Bonneville Dam. River water circulates through the barges allowing the fish to imprint the chemicals and smells of the water during the trip downriver. The barges have a closed-circuit recirculation system which can shut off water intake in case of contamination in the river. They also have pumping systems which can help de-gas the water in areas where gas supersaturation is a problem.

Seasonal releases of water from the dams, called flow augmentation, can also aid salmon migration. Water stored in several FCRPS dams in the upper basin is used to augment flows when juveniles are moving through the system. Water stored during winter storms is released in the spring and summer months to improve flows (and in some cases, water temperatures) in the lower Snake and Columbia rivers.

The levels of juvenile survival expected for the near- (2004-2009), the mid- (2010-2013), and long-term (2014), per the updated proposed action in USACE et al. (2004), are discussed in Section 4. The future levels of survival are those NMFS estimates would occur as the FCRPS action agencies (USACE, USBR, and BPA) carried out the hydro operations and system configuration improvements they proposed in 2004.

2.4.3 Adult Dam Passage

Fish passage in the form of fish ladders is provided at the eight mainstem FCRPS projects in the lower Snake and lower Columbia rivers and the five mainstem FERC-licensed projects in the mid-Columbia reach. In general, adult passage facilities are highly effective. Nonetheless, salmon may have difficulty finding ladder entrances and fish also may fall back over the dam, either voluntarily (like steelhead that often "overshoot" their natal stream), or involuntarily, after exiting the fish ladder.

[3] Surface-flow bypass systems route most juvenile spring Chinook and steelhead away from the powerhouses at Bonneville Dam Second Powerhouse and Wanapum Dam. Rocky Reach is the only mid-Columbia PUD dam with guidance screens (in two of 11 units).

The levels of total adult survival[4] expected for the near- (2004-2009), mid- (2010-2013), and long-term (2014), per the updated proposed action in USACE et al. (2004), are discussed in Section 4. The future levels of survival are those NMFS estimated will occur as the FCRPS action agencies (USACE, USBR, and BPA) carry out the hydro operations and system configuration improvements they proposed in 2004.

3.0 Current Recovery Strategies and Actions

Current hydropower programs and operations are the result of completed or ongoing ESA section 7 consultations, ESA habitat conservation plans (HCPs) pursuant to section 10; FERC relicensing proceedings and other regulatory processes. In most cases, hydropower programs and operations are intended both to avoid jeopardy and to contribute to recovery. It is not possible at this time to draw a bright line distinction between the hydropower actions intended to meet ESA regulatory requirements and those intended purely for recovery. Thus, programs and their associated costs are reported that address both purposes rather than only for those intended for recovery per se.

3.1 Federally Owned and Operated Projects in the Columbia Basin

3.1.1 Federal Columbia River Power System

The Federal Columbia River Power System (FCRPS) consists of 14 projects, each comprising dams, powerhouses, and reservoirs, that are operated as a coordinated system for power production and flood control (while also effectuating other project purposes) on behalf of the Federal government under various Congressional authorities. These projects are: Dworshak, Lower Granite, Little Goose, Lower Monumental, and Ice Harbor dams, power plants, and reservoirs in the Snake River basin; Albeni Falls, Hungry Horse, Libby, Grand Coulee and Banks Lake (features of the Columbia Basin Project), and Chief Joseph dams, power plants, and reservoirs in the upper Columbia River basin; and McNary, John Day, The Dalles, and Bonneville dams, power plants, and reservoirs in the lower Columbia River basin.

The plan for operation of the FCRPS through 2014 is described in U.S. Army Corps of Engineers (USACE) et al. (2004), the *Final Updated Proposed Action (UPA) for the FCRPS Biological Opinion Remand* (2004 UPA). On May 26, 2005, the Federal District Court issued an opinion finding fault with the *NOAA Fisheries 2004 Federal Columbia River Power System* (FCRPS) *Biological Opinion* (2004 BiOp) (NMFS 2004b) in *National Wildlife Federation, et al., vs. National Marine Fisheries Service, et al.* On October 7, 2005, the court ordered a remand of NMFS (2004b). Pending any court ordered hydrosystem operations during the remand process, the FCRPS Action Agencies (i.e., USACE), U.S. Bureau of Reclamation (USBR), and Bonneville Power Administration (BPA) intend on following the actions identified in the 2004 UPA. The following is a general summary of those hydrosystem actions. These actions are intended

[4] NMFS is unable to separate hydro project related mortality of adult fish from other sources of mortality (e.g., natural mortality, the delayed effects of harvest actions, etc.). The estimates of adult mortality in Tables 2a-c therefore incorporate all of these factors.

to address the needs for survival and recovery of all 13 species of ESA-listed salmon and steelhead in the Columbia basin.

- **Continue adult fish passage operations.** The Action Agencies have already completed a number of reconfiguration projects at federal dams to improve fish passage. As a result, the dams have met or exceeded the adult fish survival performance standards set out in NMFS (2000a), and this performance will be maintained.
- **Improve juvenile fish passage.** Continue to implement specific capital improvements, giving priority for funding and implementation to dams with the lowest juvenile passage survival rates. Make new commitments to pursue removable spillway weirs (RSWs) or similar surface bypass devices, where feasible. These configuration modifications, combined with operational spill levels based on biological performance, will result in improved juvenile survival at federal dams compared with existing conditions for all species.
- **Modify fish transportation to improve juvenile survival.** Continue to collect and transport juvenile fish at Lower Granite, Little Goose, Lower Monumental and McNary dams. After installation of spillway weirs (see above), the Action Agencies will study spill vs. transport survival for summer migrating fish (planning date 2007/2008). Pending these studies, the best available scientific information will be used to manage the transportation program to improve the survival of the affected species.

The Corps estimates that it will cost $680-million over the ten-year period 2005-2014 to implement and monitor the configuration modifications described above (Merchant 2006a,b). This includes most of the research associated with monitoring the effectiveness of these facilities. About half of the total will be spent on surface bypass systems, such as removable spillway weirs and other surface-oriented juvenile passage facilities. In addition, Operation and Maintenance costs for fish facilities, the Juvenile Fish Transportation System, water quality, and the remainder of Corps sponsored research, are about $30 million per year.

- **Continue and enhance spill for juvenile fish passage.** Continue the basic spring and summer spill program from NMFS (2000a). As before, changes in spill levels at individual dams can be adjusted based on site-specific performance evaluations.
- **Continue reservoir operations and river flows to benefit migrating fish.** Continue to operate federal storage reservoirs to supplement streamflows and provide spill at mainstem dams to benefit juvenile fish migration consistent with current implementation of NMFS (2000a) as modified through implementation plans. The hydrosystem operation includes both discretionary and nondiscretionary actions.

At the time that NMFS published the 2004 Biological Opinion (November 2004), BPA analyzed the expected cost of its hydro system operations to meet the 2004 Biological Opinion's requirements. Those operations included spill for juvenile fish passage past the

mainstem dams and operating federal storage reservoirs to supplement streamflows at mainstem dams to enhance juvenile fish migration.

BPA's analysis then showed that the expected annual average cost of providing the 2004 Biological Opinion measures over 50 water conditions was almost $370 million. That estimate is out of date because it does not include additional energy production losses from the current additional juvenile passage spill ordered by the court as a part of the remand of the 2004 Biological Opinion nor updated electricity market prices. BPA has little to base a new cost analysis on at this time as the 2004 Biological Opinion remand process has not been completed but can simply state that it is expected there will be higher costs in the future (Schiewe 2006).

The spill for juvenile passage reduces power production because water is diverted away from the turbines and toward the spillway. Operating reservoirs to retain water through the winter that can then be used to supplement flows for juvenile spring migrants can also reduce annual power production: when stored water is released in the spring, it passes through the projects when they are spilling a percentage of their flow for juvenile passage. Thus, less power is produced than if the water had gone through those projects during winter, before the spill for juvenile fish passage began.

Lost power production results in reduced net power revenues for BPA either because less energy is produced and sold or because power was purchased outside the FCRPS to replace that which was not generated. There is often an additional loss in revenue due to the shift in timing of energy production from winter to spring. Energy produced during winter months is usually of greater value than that produced during the spring; the demand for power is higher during winter and at the same time, the supply is reduced.

3.1.2 U.S. Bureau of Reclamation Projects in the Upper Snake Basin above Brownlee Reservoir

The USBR's proposed actions in its November 2004 Biological Assessment covered operations at 12 projects in the upper Snake River basin: Baker, Boise, Burnt River, Little Wood River, Lucky Peak, Mann Creek, Michaud Flats, Minidoka, Owyhee, Palisades, Ririe, and Vale (collectively, the Upper Snake Project). The proposed actions encompassed USBR's future operations and routine maintenance, including storage and delivery of water, hydropower generation, and salmon flow augmentation. NMFS (2005) prepared a biological opinion on this proposal: the *Consultation for the Operation and Maintenance of 12 U.S. Bureau of Reclamation Projects in the Upper Snake River Basin above Brownlee Reservoir*.). On May 23, 2006, the Federal District Court (District Court) issued its opinion finding fault with the *NMFS' 2005 Biological Opinion* (2005 BiOp) (<NMFS 2005>) in *National Wildlife Federation, et al., vs. National Marine Fisheries Service, et al.* The Court has yet to issue a remand order in this case.

The USBR's action of providing salmon flow augmentation is intended to help address the needs for survival and recovery of all 13 species of ESA-listed salmon and steelhead in the Columbia basin. Although the physical project operations take place upstream of

the migration barrier at Idaho Power Company's Hells Canyon Complex, water released from the upper Snake River project reaches the lower Snake and Columbia rivers where it benefits juvenile salmon and steelhead migrants.

The USBR provides salmon flow augmentation by acquiring water through rental pools and leasing or acquiring natural flow rights. The Nez Perce Water Rights Settlement and the Idaho law that implemented the settlement provide that up to 487,000 acre-feet may be provided for flow augmentation. The USBR expects to spend about $59 million over the next ten years (McGarry 2006).

3.2 Federal Energy Regulatory Commission-licensed Projects

The Federal Energy Regulatory Commission (FERC) licenses five hydroelectric dams in the mid-Columbia reach (i.e., between Chief Joseph Dam and the confluence of the Snake and Columbia rivers): Wells (owned and operated by Douglas County Public Utility District (PUD)), Rocky Reach and Rock Island (Chelan County PUD), and Wanapum and Priest Rapids (Grant County PUD). FERC also licenses Idaho Power Company's (IPC) Hells Canyon Complex in the Snake River basin. Costs for these projects' operations and programs that contribute to recovery actions will be provided in the final recovery plans for the affected ESUs and Distinct Population Segments.

3.2.1 Hydropower Projects Owned and Operated by Chelan and Douglas PUDs

NMFS (2002) entered into three 50-year anadromous fish agreements and habitat conservation plans (HCPs), one for each of the three mainstem Columbia River hydroelectric projects owned by Chelan (Rocky Reach and Rock Island) and Douglas (Wells) County PUDs, pursuant to section 10 of the Endangered Species Act. The HCPs were developed to protect the five species of Columbia River steelhead and salmon (spring-run Chinook salmon; summer/fall-run Chinook salmon; sockeye salmon, steelhead, and coho salmon, two of which (Upper Columbia River spring-run Chinook salmon and steelhead) were listed as endangered at that time.[5] They satisfied the PUDs' regulatory obligations with respect to anadromous salmonid species under the Federal Power Act, Fish and Wildlife Coordination Act, Pacific Northwest Electric Power Planning and Conservation Act, the essential fish habitat provisions of the Magnuson-Stevens Fishery Conservation and Management Act, and Title 77 RCW, as well as the ESA. The agreements set a "no net impact" standard to protect salmon and steelhead at the Wells, Rocky Reach, and Rock Island projects, and provide some degree of certainty for the long-term operation of these projects.[6]

[5] NMFS (2006) revised its listing of UCR steelhead from "endangered" to "threatened" on January 5, 2006.
[6] The HCPs are intended to help prevent conditions that would lead to the need to list additional species of UCR salmon and steelhead in the future.

Each of the three HCPs established a standard of 91% combined adult and juvenile passage survival at each project (Wells, Rocky Reach, and Rock Island) (NMFS 2002).[7] The combined survival standard is comprised of 93% juvenile and 98% adult project passage survival for all anadromous salmonids. At the time the Incidental Take Permits were issued (August 20, 2003), NMFS estimated that the HCPs represented a 22 to 45% survival improvement potential over the survival levels observed under the historical operations of these three hydroelectric projects.

3.2.2 Hydropower Projects Owned and Operated by Grant County PUD

Grant County PUD's Interim Protection Plan, as modified in NMFS (2004a), sets survival standards for the Priest Rapids Project (Priest Rapids and Wanapum dams and reservoirs) that are identical to those described above for the HCPs. The following measures will be implemented to ensure that the standards will be met:

- Downstream passage measures, including spill through existing and top spill through future units; turbine operations and the installation of advanced turbines; total dissolved gas abatement; avian predator control; and a northern pikeminnow *(Ptychocheilus oregonensis)* removal program
- Continued operation and maintenance, and where needed, improvements to adult fishways at both Priest Rapids and Wanapum dams
- Design and construction of an off-ladder trap and fish-handling facilities at Priest Rapids Dam
- Sluiceway operations for steelhead fallbacks (kelts)

The FERC is in consultation with NMFS on the terms of a new, 50-year license for the Priest Rapids Project. With respect to its proposed action for mainstem facilities and operations, FERC has adopted the hydro actions in the Reasonable and Prudent Alternative in NMFS' Biological Opinion on Grant County PUD's Interim Protection Plan (NMFS 2004a) for listed salmon and steelhead, described above.

3.3 Idaho Power Company's Hells Canyon Project

The relicensing of the Hells Canyon Hydroelectric Project is the subject of ongoing administrative proceedings before FERC involving its owner, IPC; Federal, state, and tribal agencies; and other stakeholders. At present, IPC voluntarily operates the project to protect habitat used by fall Chinook salmon for spawning (i.e., by eliminating flow fluctuations), and incubation (i.e., by providing enough flow to prevent the dewatering of redds downstream of the project). As part of an interim settlement agreement in the license proceedings, IPC has agreed to release about 237 thousand acre-feet (kaf) of water during July and early August to improve downstream migration conditions for juvenile fall Chinook salmon (Tucker 2005).

[7] The HCPs allowed the PUDs to compensate for up to 9% project passage mortality through up to 7% hatchery production and up to 2% funding of tributary habitat enhancement projects. That is, the mitigation is intended to match the level of impact.

4.0 Survival Rates at Mainstem Lower Snake and Lower Columbia Hydro Projects

4.1 Survival Rates at Federal Projects

4.1.1 Juvenile Survival – Federal Projects

The point estimates and ranges for juvenile passage survival at the Federal projects in the lower Snake and lower Columbia rivers, shown in lines 3-13 in Tables 4.1a-c, are based on the 2004-2009, 2010-2013, and 2014 configurations and operations described in the 2004 UPA. NMFS used its Simulated Passage (SIMPAS) spreadsheet model to model survival over ten historical water conditions (the water years 1994-2003). The model apportioned the listed species to various passage routes (i.e., turbines, fish bypass system, sluiceway/surface bypass, spillway, and/or fish transportation) based on empirical data and input assumptions for fish passage parameters. The model then accounted for "successful fish passage" (survival) and "losses" (mortalities) through each of the alternative passage routes to estimate survival past each project. The model also accounted for the proportions of juvenile fish transported and left to migrate in-river. The model provides survival estimates at each project (dam plus pool) and throughout the FCRPS (from the head of Lower Granite Reservoir to the tailrace of Bonneville Dam).

The fish passage parameters used as inputs to SIMPAS when NMFS carried out this modeling exercise for the 2004 Biological Opinion included spill efficiency, fish guidance efficiency, spill/gas caps, turbine survival, spillway survival, sluiceway survival, bypass system survival, and diel passage patterns. The parameter values were quantified for each FCRPS dam and for SR steelhead, spring and fall Chinook salmon (which were considered indicator species for the spring and summer passage seasons, respectively). The parameter values selected for modeling represented the best available scientific information in 2004 and, in cases where empirical information was unavailable, outdated, or limited, represented NMFS' best professional judgment at that time. However, many of the modeled estimates shown in Tables 4.1a-c are now being updated in the collaborative process for the 2005-2006 FCRPS remand. NMFS' Northwest Fisheries Science Center has worked with a broad range of scientists from throughout the Northwest, to develop a new passage model (the Comprehensive Passage model, or COMPASS). The new model attempts to address several limitations of SIMPAS by predicting survival at a finer temporal scale; adding stochasticity (random variability); and improving the treatment of passage effects that are expressed after individuals have left the hydrosystem. NMFS therefore intends to amend this Mainstem Hydrosystem Module with updated survival estimates based on COMPASS modeling.

4.1.2 Adult Survival – Federal Projects

As described above for juvenile fish, the point estimates and ranges for adult passage survival at the Federal projects in the lower Snake and lower Columbia rivers, shown in lines 3-13 in Tables 4.2a-c, are based on the 2004-2009, 2010-2013, and 2014 configurations and operations described in the 2004 UPA. The sources for these

estimates, described in the footnotes to the tables, are primarily conversion rate calculations and radio-tag studies. The cumulative loss of adults migrating up the Columbia and Snake rivers can be calculated as the difference in adult counts between dams (after adjustments for legal harvest and tributary turnoff). Mortality can be related to passage through the dams and to other factors, such as illegal harvest, predation, gill-net interactions, and disease. Apparent adult loss between dams may also be due to factors other than mortality, such as counting errors, double-counting adults that fall back and re-ascend ladders, and straying and tributary turnoff. Therefore, a more reliable way to estimate adult passage loss is through the use of data from adult radio-tracking studies, which monitor the passage behavior of specific individual adults. Even with this method, however, many adult losses are not counted. For instance, there may not be any indication of a tagged adult's final fate except that it did not arrive at the next upstream dam. This unaccounted-for loss may be the result of mortality or straying and tributary turnoff, but it will not result from the counting errors inherent in the use of dam adult counts. The use of individually-coded adult radio-telemetry tags greatly increases the precision associated with studies of adult migration behavior at dams and survival through the mainstem corridor (NMFS 2000b).

While the final fate of many radio-tagged adults is uncertain, NMFS considers the unaccounted-for adult loss estimates calculated from these studies to be more representative of the mortality rate associated with passage through the FCRPS dams than an adult loss estimate based on the comparison of adult counts between dams (NMFS 1995). Therefore, data from radio-tagging studies, when available, were used to estimate the unaccounted-for adult loss rate and, as a corollary, the minimum survival rates of adults passing through the hydrosystem. These estimates are considered minimums, because some radio-tagged adults that were considered dam-passage-caused mortalities may have survived or suffered non-dam-caused fates. Minimum survival rates were derived by dividing the number of radio-tagged adults detected at an upstream dam by the number of adults tagged minus the number of fish accounted for in the study. Where multi-year study data are available for a particular species, the multiple-year results have been averaged.

4.1.3 Expectations for the Future – Federal Projects

For the near term, it is reasonable to expect that juvenile and adult survival rates through the FCRPS will be similar to the levels shown in Tables 4.1.a and 4.2.a (which correspond with the period 2004-2009). These operations are governed by the 2004 Biological Opinion, which the District Court left in place during the current remand, except that it may order specific provisions (e.g., spill for fish passage during 2005 and 2006) during a specific juvenile migration season. NMFS expects that these actions and their biological effects will change during the current remand, but exactly how they will change and how they will affect survival for each species and life stage is unclear. Given these uncertainties, if it is necessary for planning or analytical purposes to make

assumptions about mainstem hydrosystem impacts in the near-term, NMFS recommends that future impacts be considered similar to those shown in Tables 4.1.a and 4.2.a.[8]

4.2 Survival Rates at Mid-Columbia PUD Projects

4.2.1 Juvenile Survival – PUD Projects

The point estimates and ranges for juvenile passage survival at the PUD projects in the mid-Columbia River are shown in lines 1 and 2 in Tables 4.1a-c (i.e., UCR spring Chinook salmon and UCR steelhead). These estimates are based on PIT- and acoustic-tag studies, which are identified in the footnotes to the tables. The PUDs carried out these studies to evaluate the performance of their fish facilities and operations as required by their FERC licenses and by other agreements (see section 3.2.1). The three hydro projects covered by HCPs must meet a 93% juvenile average-per-project passage survival standard. If it is not achieved, a Coordinating Committee decides on "Additional Tools (actions, structures, facilities, or programs in addition to those proposed)" that can be used.

The juvenile project survival standard was met at Douglas PUD's Wells Project by the time their HCP was signed in 2002. The Coordinating Committee has since determined that it has been achieved for UCR spring Chinook salmon at Chelan PUD's Rock Island project (but not at Rocky Reach) as of 2004. Based on preliminary results of 2006 PIT- and acoustic-tag tests, the standard has been achieved for steelhead at both Rock Island and Rocky Reach. Grant County PUD, which did not develop an HCP but is required to meet the same standards under the terms of its existing FERC license, has met the juvenile project survival standard for UCR spring Chinook salmon (but not for UCR steelhead), at its Priest Rapids Project (Priest Rapids and Wanapum dams).

4.2.2 Adult Survival – PUD Projects

The point estimates and ranges for adult passage survival at the PUD projects in mid-Columbia River shown in Tables 4.2a-c (see lines 1 and 2) are based on an average per-project conversion rate of 0.987, raised to the number of projects that each species (or population) passes before turning off into a tributary or mainstem spawning areas (see table footnotes). Conversion rate calculations are described in section 4.1.2, above.

[8] A similar statement applies to the biological effects discussed in NMFS' 2005 BiOp for the USBR's Upper Snake Project.

Table 4.1a. Current (2004-2009) mainstem hydropower juvenile survival rates, point estimates of averages (Pt Est) and ranges (N/A = not available). The ranges are the lowest and highest average estimates in the studies identified in the footnotes.

Species	**Population**	**Juv Survival Mid-Columbia** Pt Est (Range)	**Avg Juv Survival Lower-Columbia** Pt Est (Range)	**Total Juv Survival** Pt Est (Range)[3]
1. UCR spring Chinook	Methow	0.728[1] (0.697 – 0.771)	0.673[2] (0.551 - 0.749)	0.490 (0.384 – 0.577)[3]
	Entiat	0.757[1] (0.739 – 0.774)	0.673[2] (0.551 - 0.749)	0.509 (0.407 – 0.580)[3]
	Wenatchee	0.823[1] (0.811 – 0.834)	0.673[2] (0.551 - 0.749)	0.554 (0.447 – 0.625)[3]
2. UCR steelhead	Methow	0.670[4] (0.621 – 0.732)	0.468[2] (0.162 - 0.616)	0.314 (0.101 – 0.451)[3]
	Entiat	0.696[4] (0.659 – 0.734)	0.468[2] (0.162 - 0.616)	0.326 (0.107 – 0.452)[3]
	Wenatchee	0.727[4] (0.708 – 0.747)	0.468[2] (0.162 - 0.616)	0.340 (0.115 – 0.461)[3]
		Juv In-river Survival Pt Est (Range)	**Juv System Survival (D=0.553)** Pt Est (Range)	Note: "System survival" accounts for both in-river migrants and transported fish; "D" is the differential delayed mortality of transported fish (after release below Bonneville Dam)
3. SR spr/sum Chinook	All pops.	0.502[2] (0.383 – 0.577)	0.515[2] (0.488 – 0.534)	
4. SR sockeye	Single pop.	0.502[5] (0.383 – 0.577)	0.515[5] (0.488 – 0.534)	
5. SR steelhead	All pops.	0.305[2] (0.045 – 0.429)	0.489[2] (0.750 – 0.899)	
		Juv In-river Survival Pt Est (Range)	**Juv System Survival (D=0.18)** Pt Est (Range)	**Juv System Survival (D=0.42)** Pt Est (Range)
6. SR fall Chinook	Single pop.	0.142[6] (0.084 – 0.249)	0.084[7] (0.040 – 0.108)	0.185[7] (0.088 – 0.238)
	Location Entering Mainstem	**Juv In-river Survival** Pt Est (Range)		
7. MCR steelhead	MCN Res	0.468[2] (0.162 – 0.616)		
	JDA Res	0.555[2] (0.261 – 0.725)		
	JDA Dam	0.696[2] (0.396 – 0.880)		
	TDA Res	0.725[2] (0.411 – 0.914)		
	BON Res	0.838[2] (0.611 – 0.954)		
8. LCR Chinook Yearling smolts	BON Res	0.900[2] (0.855 – 0.935)		

Subyearling smolts	BON Res	0.860[2] (0.767 – 0.972)		
9. LCR steelhead	BON Res	0.838[2] (0.611 – 0.954)		
10. LCR coho	BON Res	N/A[8]		
11. UWR Chinook		N/A[9]		
12. UWR steelhead		N/A[9]		
13. CR chum	BON Res	N/A[8]		

[1] **Rock Island:** 4-yr avg of 2002-2005 PIT+acoustic-tag studies [Peven 2006]); **Rocky Reach:** 2-yr average of PIT+acoustic-tag studies in 2004 and 2005 [Peven 2006]; **Wells:** 3-yr avg of 1998-2000 PIT-tag studies (use chin+stlhd data) [Table 3-5 in NMFS 2002]; **Wanapum+Priest Rapids:** 2003 PIT-tag study [Table 3-5 in NMFS 2004a].

[2] Estimates from NMFS (2004b), Table 6.5; average survival is based on effect of 2004-2009 configuration and operations modeled over ten historical water years (1994-2003); range shows lowest and highest estimates derived from the ten model runs.

[3] Ranges for Total Juvenile Survival of UCR spring Chinook and steelhead use low and high values for mid-Columbia reach and low and high values for lower-Columbia reach, respectively. Where a range of estimates is not available for the mid-Columbia reach, the point estimate is multiplied by the low and high values for the lower- Columbia reach.

[4] **Rock Island:** 3-yr average of 2004-2006 acoustic tag studies (2006 data are preliminary) [Peven 2006]; **Rocky Reach:** 3-yr average of 2004-2006 acoustic tag studies (2006 data are preliminary) [Peven 2006]; **Wells:** assume 3-yr avg of 1998-2000 PIT-tag studies (use chin+stlhd data) [Table 3-5 in NMFS 2002]); **Wanapum+Priest Rapids:** assume same as 2000 PIT-tag result [Table A-2 in NMFS 2004a].

[5] Estimates from NMFS (2004b), Table 6.5, were extrapolated from per project survival of SR spr/sum Chinook through the four lower Columbia River projects; average survival is based on effect of 2004-2009 configuration and operations modeled over ten historical water years (1994-2003).

[6] In-river estimates from NMFS (2004b), Table 6.5 - applies to subyearlings, assumes L. Col flow/survival relationship; average survival is based on effect of 2004-2009 configuration and operations modeled over ten historical water years (1994-2003); range shows lowest and highest estimates derived from the ten model runs.

[7] System survival estimates from spreadsheet \SIMPAS D Sensitivity.xls, which supported the analysis in Attachment 5 of Appendix D in NMFS (2004b); average survival is based on effect of 2004-2009 configuration and operations modeled over ten historical water years (1994-2003).

[8] NMFS does not know of any passage survival studies using juvenile coho or chum salmon at Bonneville Dam

[9] UWR Chinook salmon and steelhead do not pass Bonneville Dam

Table 4.1b. Mainstem hydropower juvenile survival rates for the period 2010-2013, point estimates of averages (Pt Est) and ranges (N/A = not available). The ranges are the lowest and highest average estimates in the studies identified in the footnotes.

Species	**Population**	**Juv Survival Mid-Columbia** Pt Est (Range)	**Avg Juv Survival Lower-Columbia** Pt Est (Range)	**Total Juv Survival** Pt Est (Range) [3]
1. UCR spring Chinook	Methow	0.736[1] (0.711 – 0.773)	0.719[2] (0.595 – 0.798)	0.549 (0.423 – 0.616) [3]
	Entiat	0.765[1] (0.754 – 0.775)	0.719[2] (0.595 – 0.798)	0.550 (0.449 – 0.618) [3]
	Wenatchee	0.823[1] (0.811 – 0.834	0.719[2] (0.595 – 0.798)	0.592 (0.583 – 0.665) [3]
2. UCR steelhead	Methow	0.750[4] (0.695 – 0.819)	0.499[2] (0.175 – 0.655)	0.374 (0.139 – 0.536) [3]
	Entiat	0.780[4] (0.737 – 0.821)	0.499[2] (0.175 – 0.655)	0.389 (0.129 – 0.538) [3]
	Wenatchee	0.814[4] (0.792 – 0.836)	0.499[2] (0.175 – 0.655)	0.406 (0.139 – 0.548) [3]
		Juv In-river Survival Pt Est (Range)	**Juv System Survival (D=0.553)** Pt Est (Range)	Note: "System survival" accounts for both in-river migrants and transported fish; "D" is the differential delayed mortality of transported fish (after release below Bonneville Dam)
3. SR spr/sum Chinook	All pops.	0.541[2] (0.415 – 0.626)	0.523[2] (0.500 – 0.546)	
4. SR sockeye	Single pop.	0.541[5] (0.415 – 0.626)	0.523[5] (0.500 – 0.546)	
5. SR steelhead	All pops.	0.329[2] (0.049 – 0.462)	0.495[2] (0.414 – 0.535)	
		Juv In-river Survival Pt Est (Range)	**Juv System Survival (D=0.18)** Pt Est (Range)	**Juv System Survival (D=0.42)** Pt Est (Range)
6. SR fall Chinook	Single pop.	0.153[6] (0.090 – 0.236)	0.085[7] (0.041 – 0.109)	0.186[7] (0.089 – 0.239)
	Location Entering Mainstem	**Juv In-river Survival** Pt Est (Range)		
7. MCR steelhead	MCN Res	0.499[2] (0.175 – 0.655)		
	JDA Res	0.574[2] (0.269 – 0.748)		
	JDA Dam	0.720[2] (0.409 – 0.909)		
	TDA Res	0.738[2] (0.419 – 0.931)		
	BON Res	0.841[2] (0.612 – 0.957)		
8. LCR Chinook Yearling smolts	BON Res	0.901[2] (0.856 – 0.935)		

Subyearling smolts	BON Res	0.861[2] (0.768 – 0.973)		
9. LCR steelhead	BON Res	0.841[2] (0.612 – 0.957)		
10. LCR Coho	BON Res	N/A[8]		
11. UWR Chinook		N/A[9]		
12. UWR steelhead		N/A[9]		
13. CR chum		N/A[8]		

[1] **Rock Island:** 4-yr avg of 2002-2005 PIT+acoustic-tag studies [Peven 2006]); **Rocky Reach:** assume juv. surv. std in HCP [NMFS 2002] is met -- i.e., 0.930 per project; **Wells:** 3-yr avg of 1998-2000 PIT-tag studies (use chin+stlhd data) [Table 3-5 in NMFS 2002]; **Wanapum+Priest Rapids:** (assume juv. surv. std in NMFS 2004a [i.e., 0.930 per project] is met).

[2] Estimates from NMFS (2004b), Table 6.6; average survival is based on effect of 2004-2009 configuration and operations modeled over ten historical water years (1994-2003); range shows lowest and highest estimates derived from the ten model runs.

[3] Ranges for Total Juvenile Survival of UCR spring Chinook and steelhead use low and high values for mid-Columbia reach and low and high values for lower-Columbia reach, respectively. Where a range of estimates is not available for the mid-Columbia reach, the point estimate is multiplied by the low and high values for the lower- Columbia reach.

[4] **Rock Island, Rocky Reach, and Wells:** assume same as 2004; **Wanapum+Priest Rapids:** assume that juv. surv. std in HCP [NMFS 2002] is met (i.e., 0.930 per project).

[5] Estimates from NMFS (2004b), Table 6.6, were extrapolated from per project survival of SR spr/sum Chinook through the four lower Columbia River projects; average survival (and ranges) are based on effect of 2010-2013 configuration and operations modeled over ten historical water years (1994-2003).

[6] In-river estimates from NMFS (2004b), Table 6.6 - applies to subyearlings, assumes L. Col flow/survival relationship; average survival is based on effect of 2010-2013 configuration and operations modeled over ten historical water years (1994-2003); range shows lowest and highest estimates derived from the ten model runs.

[7] System survival estimates from spreadsheet \SIMPAS D Sensitivity.xls, which supported the analysis in Attachment 5 of Appendix D of NMFS (2004b); average survival is based on effect of 2010-2013 configuration and operations modeled over ten historical water years (1994-2003).

[8] NMFS does not know of any passage survival studies using juvenile coho or chum salmon at Bonneville Dam

[9] UWR Chinook salmon and steelhead do not pass Bonneville Dam

Table 4.1c. Mainstem hydropower juvenile survival rates for 2014, point estimates of averages (Pt Est) and ranges (N/A = not available). The ranges are the lowest and highest average estimates in the studies identified in the footnotes.

Species	**Population**	**Juv Survival Mid-Columbia** Pt Est (Range)	**Avg Juv Survival Lower-Columbia** Pt Est (Range)	**Total Juv Survival** Pt Est (Range)[3]
1. UCR spring Chinook	Methow Entiat Wenatchee	0.736[1] (0.697 – 0.771) 0.765[1] (0.739 – 0.774) 0.823[1] (0.811 – 0.834)	0.735[2] (0.605 – 0.827) 0.735[2] (0.605 – 0.827) 0.735[2] (0.605 – 0.827)	0.541 (0.422 – 0.638)[3] 0.562 (0.480 – 0.640)[3] 0.605 (0.489 – 0.690)[3]
2. UCR steelhead	Methow Entiat Wenatchee	0.750[4] (0.621 – 0.732) 0.780[4] (0.659 – 0.734) 0.814[4] (0.708 – 0.747)	0.506[2] (0.605 – 0.827) 0.506[2] (0.605 – 0.827) 0.506[2] (0.605 – 0.827)	0.380 (0.376 – 0.605)[3] 0.395 (0.400 – 0.607)[3] 0.412 (0.428 – 0.618)[3]
		Juv In-river Survival Pt Est (Range)	**Juv System Survival (D=0.553)** Pt Est (Range)	Note: "System survival" accounts for both in-river migrants and transported fish; "D" is the differential delayed mortality of transported fish (after release below Bonneville Dam)
3. SR spr/sum Chinook	All pops.	0.563[2] (0.426 – 0.674)	0.531[2] (0.510 – 0.556)	
4. SR sockeye	Single pop.	0.563[5] (0.426 – 0.674)	0.531[5] (0.510 – 0.556)	
5. SR steelhead	All pops.	0.336[2] (0.050 – 0.472)	0.495[2] (0.415 – 0.536)	
		Juv In-river Survival Pt Est (Range)	**Juv System Survival (D=0.18)** Pt Est (Range)	**Juv System Survival (D=0.42)** Pt Est (Range)
6. SR fall Chinook	Single pop.	0.161[6] (0.095 – 0.249)	0.086[7] (0.041 – 0.109)	0.187[7] (0.089 – 0.240)
	Location Entering Mainstem	**Juv In-river Survival** Pt Est (Range)		
7. MCR steelhead	MCN Res JDA Res JDA Dam TDA Res BON Res	0.506[2] (0.176 – 0.664) 0.582[2] (0.271 – 0.758) 0.729[2] (0.412 – 0.920) 0.747[2] (0.421 – 0.942) 0.846[2] (0.613 – 0.963)		
8. LCR Chinook Yearling smolts	BON Res	0.906[2]		

Subyearling smolts	BON Res	(0.857 – 0.943) 0.861[2] (0.678 – 0.973)		
9. LCR steelhead	BON Res	0.846[2] (0.613 – 0.963)		
10. LCR coho	BON Res	N/A[9]		
11. UWR Chinook		N/A[9]		
12. UWR steelhead		N/A[8]		
13. CR chum				

[1] **Rock Island:** 4-yr avg of 2002-2005 PIT+acoustic-tag studies [Peven 2006]); **Rocky Reach:** assume juv. surv. std in HCP [NMFS 2002] is met (0.930 per project); **Wells:** 3-yr avg of 1998-2000 PIT-tag studies (use chin+stlhd data) [Table 3-5 in NMFS 2002]; **Wanapum+Priest Rapids:** (assume juv. surv. std in NMFS 2004a [i.e., 0.930 per project] is met).

[2] Estimates from NMFS (2004b), Table 6.7; average survival is based on effect of 2014 configuration and operations modeled over ten historical water years (1994-2003); range shows lowest and highest estimates derived from the ten model runs.

[3] Ranges for Total Juvenile Survival of UCR spring Chinook and steelhead use low and high values for mid-Columbia reach and low and high values for lower-Columbia reach, respectively. Where a range of estimates is not available for the mid-Columbia reach, the point estimate is multiplied by the low and high values for the lower- Columbia reach.

[4] **Rock Island, Rocky Reach, and Wells:** assume same as 2004; **Wanapum+Priest Rapids:** assume same as 2010 (i.e., 0.930 per project).

[5] Estimates from NMFS (2004b), Table 6.7, were extrapolated from per project survival of SR spr/sum Chinook through the four lower Columbia River projects; average survival (and ranges) are based on effect of 2014 configuration and operations modeled over ten historical water years (1994-2003).

[6] In-river estimates from NMFS (2004b), Table 6.7 - applies to subyearlings, assumes L. Col flow/survival relationship; average survival is based on effect of 2014 configuration and operations modeled over ten historical water years (1994-2003); range shows lowest and highest estimates derived from the ten model runs.

[7] System survival estimates from spreadsheet \SIMPAS D Sensitivity.xls, which supported the analysis in Attachment 5 of Appendix D of NMFS (2004b); average survival is based on effect of 2004-2009 configuration and operations modeled over ten historical water years (1994-2003).

[8] NMFS does not know of any passage survival studies using juvenile coho or chum salmon at Bonneville Dam

[9] UWR Chinook salmon and steelhead do not pass Bonneville Dam

Table 4.2a. Current (2004-2009) mainstem hydropower adult survival rates, point estimates of averages (Pt Est) and ranges (N/A = not available). The ranges are the lowest and highest average estimates in the studies identified in the footnotes.

Species	**Population**	**Adult Mid-Col. Survival** Pt Est (Range)	**Avg Adult FCRPS Survival** Pt Est (Range)	**Total Adult Survival** Pt Est (Range) [3]
1. UCR spring Chinook	Methow	0.970[1] (N/A)	0.920[2] (0.911 – 0.935)	0.892 (0.884 – 0.907)[3]
	Entiat	0.976[1] (N/A)	0.920[2] (0.911 – 0.935)	0.897 (0.889 – 0.912)[3]
	Wenatchee	0.982[1] (N/A)	0.920[2] (0.911 – 0.935)	0.904 (0.895 – 0.918)[3]
2. UCR steelhead	Methow	0.941[4] (N/A)	0.941[2] (0.922 – 0.961)	0.885 (0.868 – 0.904)[3]
	Entiat	0.953[4] (N/A)	0.941[2] (0.922 – 0.961)	0.897 (0.879 – 0.0.916)[3]
	Wenatchee	0.964[4] (N/A)	0.941[2] (0.922 – 0.961)	0.907 (0.889 – 0.926)[3]
		Adult FCRPS Survival Pt Est (Range)		
3. SR spr/sum Chinook	All pops.	0.846[2] (0.750 – 0.936)		
4. SR sockeye	Single pop.	0.831[5] (0.750 – 0.936)		
5. SR steelhead	All pops.	0.833[2] (0.750 – 0.899)		
		Adult Survival Pt Est (Range)		
6. SR fall Chinook	Single pop.	0.847[2] (0.800 – 0.923)		
	Location Leaving Mainstem	**Adult Survival** Pt Est (Range)		
7. MCR steelhead	MCN Res	0.911[2] (N/A)		
	JDA Res	0.933[2] (N/A)		
	JDA Dam	0.933[2] (N/A)		
	TDA Res	0.954[2] (N/A)		
	BON Res	0.977[2] (N/A)		
8. LCR Chinook Spring-run	BON Res	0.965[6] (N/A)		
Fall-run	BON Res	0.980[7]		

		(N/A)		
9. LCR steelhead	BON Res	0.974[8] (N/A)		
10. LCR coho	BON Res	0.980[9] (N/A)		
11. UWR Chinook		N/A[10]		
12. UWR steelhead		N/A[10]		
13. CR chum		N/A		

[1] Based on an average per-project conversion rate of 0.994 raised to # projects (Graves 2005).
[2] Estimates from NMFS (2004b), Table 6.5; average survival is based on effect of 2004-2009 configuration and operations modeled over ten historical water years (1994-2003); range shows lowest and highest estimates derived from the ten model runs.
[3] Ranges for Total Adult Survival of UCR spring Chinook and steelhead use average value for mid-Columbia reach and low and high values for lower-Columbia reach, respectively.
[4] Based on an average per-project conversion rate of 0.988 raised to # projects (Graves 2005).
[5] Estimates from NMFS (2004b), Table 6.5, were extrapolated from per project survival of unlisted UCR sockeye through the four lower Columbia River projects; average survival (and ranges) are based on effect of 2004-2009 configuration and operations modeled over ten historical water years (1994-2003).
[6] Estimated adult survival rates for LCR spring-run Chinook salmon are based on Bjornn et al. (2000).
[7] Estimated adult survival rates for LCR fall-run Chinook salmon are based on per-project survival rate of SR fall Chinook salmon.
[8] Estimated adult survival rates for LCR steelhead are based on Keefer et al. (2004).
[9] Estimated adult survival rates for LCR coho salmon are based on per-project survival rate of SR fall Chinook salmon.
[10] UWR Chinook salmon and steelhead do not pass Bonneville Dam.

Table 4.2b. Mainstem hydropower adult survival rates for the period 2010-2013, point estimates of averages (Pt Est) and ranges (N/A = not available). The ranges are the lowest and highest average estimates in the studies identified in the footnotes.

Species	**Population**	**Adult Mid-Col. Survival** Pt Est (Range)	**Avg Adult FCRPS Survival** Pt Est (Range)	**Total Adult Survival** Pt Est (Range) [3]
1. UCR spring Chinook	Methow	0.970[1] (N/A)	0.920[2] (0.911 – 0.935)	0.892 (0.884 – 0.907)[3]
	Entiat	0.976[1] (N/A)	0.920[2] (0.911 – 0.935)	0.898 (0.889 – 0.918)[3]
	Wenatchee	0.982[1] (N/A)	0.920[2] (0.911 – 0.935)	0.904 (0.895 – 0.918)[3]
2. UCR steelhead	Methow	0.941[4] (N/A)	0.941[2] (0.922 – 0.961)	0.885 (0.868 – 0.904)[3]
	Entiat	0.953[4] (N/A)	0.941[2] (0.922 – 0.961)	0.897 (0.879 – 0916)[3]
	Wenatchee	0.964[4] (N/A)	0.941[2] (0.922 – 0.961)	0.907 (0.889 – 0.926)[3]
		Adult FCRPS Survival Pt Est (Range)		
3. SR spr/sum Chinook	All pops.	0.846[2] (0.750 – 0.936)		
4. SR sockeye	Single pop.	0.831[5] (0.750 – 0.936)		
5. SR steelhead	All pops.	0.833[2] (0.730 – 0.899)		
		Adult FCRPS Survival Pt Est (Range)		
6. SR fall Chinook	Single pop.	0.847[2] (0.800 – 0.923)		
	Location Leaving Mainstem	**Adult Survival** Pt Est (Range)		
7. MCR steelhead	MCN Res	0.911[2] (N/A)		
	JDA Res	0.933[2] (N/A)		
	JDA Dam	0.933[2] (N/A)		
	TDA Res	0.954[2] (N/A)		
	BON Res	0.977[2] (N/A)		
8. LCR Chinook Spring-run	BON Res	0.965[6] (N/A)		

Fall-run	BON Res	0.980[7] (N/A)		
9. LCR steelhead	BON Res	0.974[8] (N/A)		
10. LCR coho	BON Res	0.980[9] (N/A)		
11. UWR Chinook		N/A[10]		
12. UWR steelhead		N/A[10]		
13. CR chum		N/A		

[1] Based on an average per-project conversion rate of 0.994 raised to # projects (Graves 2005).
[2] Estimates from NMFS (2004b), Table 6.6; average survival is based on effect of 2004-2009 configuration and operations modeled over ten historical water years (1994-2003); range shows lowest and highest estimates derived from the ten model runs.
[3] Ranges for Total Adult Survival of UCR spring Chinook and steelhead use average value for mid-Columbia reach and low and high values for lower-Columbia reach, respectively.
[4] Based on an average per-project conversion rate of 0.988 raised to # projects (Graves 2005).
[5] Estimates from NMFS (2004b), Table 6.6, were extrapolated from per project survival of unlisted UCR sockeye through the four lower Columbia River projects; average survival (and ranges) are based on effect of 2010-2013 configuration and operations modeled over ten historical water years (1994-2003).
[6] Estimated adult survival rates for LCR spring-run Chinook salmon are based on Bjornn et al. (2000).
[7] Estimated adult survival rates for LCR fall-run Chinook salmon are based on per-project survival rate of SR fall Chinook salmon.
[8] Estimated adult survival rates for LCR steelhead are based on Keefer et al. (2004).
[9] Estimated adult survival rates for LCR coho salmon are based on per-project survival rate of SR fall Chinook salmon.
[10] UWR Chinook salmon and steelhead do not pass Bonneville Dam.

Table 4.2c. Mainstem hydropower adult survival rates for 2014, point estimates of averages (Pt Est) and ranges (N/A = not available). The ranges are the lowest and highest average estimates in the studies identified in the footnotes.

Species	**Population**	**Adult Mid-Col. Survival** Pt Est (Range)	**Avg Adult FCRPS Survival** Pt Est (Range)	**Total Adult Survival** Pt Est (Range)[3]
1. UCR spring Chinook	Methow	0.970[1] (N/A)	0.920[2] (0.911 – 0.935)	0.892 (0.884 – 0.907)[3]
	Entiat	0.976[1] (N/A)	0.920[2] (0.911 – 0.935)	0.900 (0.899 – 0.913)[3]
	Wenatchee	0.982[1] (N/A)	0.920[2] (0.911 – 0.935)	0.904 (0.895 – 0.944)[3]
2. UCR steelhead	Methow	0.941[4] (N/A)	0.941[2] (0.922 – 0.961)	0.885 (0.868 – 0.904)[3]
	Entiat	0.953[4] (N/A)	0.941[2] (0.922 – 0.961)	0.897 (0.879 – 0.916)[3]
	Wenatchee	0.964[4] (N/A)	0.941[2] (0.922 – 0.961)	0.907 (0.889 – 0.926)[3]
		Adult FCRPS Survival Pt Est (Range)		
3. SR spr/sum Chinook	All pops.	0.846[2] (0.750 – 0.936)		
4. SR sockeye	Single pop.	0.831[5] (0.750 – 0.936)		
5. SR steelhead	All pops.	0.833[2] (0.750 – 0.899)		
		Adult Survival Pt Est (Range)		
6. SR fall Chinook	Single pop.	0.847[2] (0.800 – 0.813)		
	Location Leaving Mainstem	**Adult Survival** Pt Est (Range)		
7. MCR steelhead	MCN Res	0.911[2] (N/A)		
	JDA Res	0.933[2] (N/A)		
	JDA Dam	0.933[2] (N/A)		
	TDA Res	0.954[2] (N/A)		
	BON Res	0.977[2] (N/A)		
8. LCR Chinook Spring-run	BON Res	0.965[6] (N/A)		
Fall-run	BON Res	0.980[7]		

		(N/A)		
9. LCR steelhead	BON Res	0.974[8] (N/A)		
10. LCR coho	BON Res	0.980[9] (N/A)		
11. UWR Chinook		N/A[10]		
12. UWR steelhead		N/A[10]		
13. CR chum		N/A		

[1] Based on an average per-project conversion rate of 0.994 raised to # projects (Graves 2005).
[2] Estimates from NMFS (2004b), Table 6.7; average survival is based on effect of 2014 configuration and operations modeled over ten historical water years (1994-2003); range shows lowest and highest estimates derived from the ten model runs.
[3] Ranges for Total Adult Survival of UCR spring Chinook and steelhead use average value for mid-Columbia reach and low and high values for lower-Columbia reach, respectively.
[4] Based on an average per-project conversion rate of 0.988 raised to # projects (Graves 2005).
[4] Estimates from NMFS (2004b), Table 6.7, were extrapolated from per project survival of unlisted UCR sockeye through the four lower Columbia River projects; average survival (and ranges) are based on effect of 2014 configuration and operations modeled over ten historical water years (1994-2003).
[6] Estimated adult survival rates for LCR spring-run Chinook salmon are based on Bjornn et al. (2000).
[7] Estimated adult survival rates for LCR fall-run Chinook salmon are based on per-project survival rate of SR fall Chinook salmon.
[8] Estimated adult survival rates for LCR steelhead are based on Keefer et al. (2004).
[9] Estimated adult survival rates for LCR coho salmon are based on per-project survival rate of SR fall Chinook salmon.
[10] UWR Chinook salmon and steelhead do not pass Bonneville Dam.

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