APPENDIX D
BIOLOGICAL EFFECTS ANALYSIS AND SIMPAS MODEL DOCUMENTATION

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TABLES

D.1 BACKGROUND

Since late 1999, National Marine Fisheries Service (NMFS) has been engaged in Endangered Species Act (ESA) Section 7 consultation with the Federal Action Agencies (U.S. Corps of Engineers [Corps], Bureau of Reclamation [BOR], and Bonneville Power Administration [BPA]) to develop a biological opinion on the effects of the Action Agencies' proposed action and future operation and configuration of the Federal Columbia River Power System (FCRPS) projects. In January 2000, to facilitate completion of the Section 7 consultation process, the Federal agencies formed five action teams. The Biological Effects Team was charged with estimating effects of current operations and potential future configurations and operations on the survival of listed juvenile outmigrants. This information was used by NMFS to analyze the listed species' biological requirements in the action area (Section 6.1.1), as well as at the species level (Section 6.1.2). The team included Federal biologists and engineers representing NMFS, the Corps, and BPA. NMFS Hydro Program staff picked up where the Biological Effects Team analysis left off to complete the biological effects analysis described in this appendix.

For juvenile fish using the mainstem Columbia and Snake rivers as a migration corridor, the primary evaluation method is simulation modeling of the proposed action on the action area biological requirements. The Biological Effects Team agreed to use NMFS' Simulated Passage (SIMPAS) model to evaluate the biological benefits of juvenile salmonid passage measures. The spreadsheet model, developed by staff in the Hydro Program of NMFS' Northwest Region, is a fish passage accounting model that apportions the run 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 accounts for "successful fish passage" (survival) and "losses" (mortalities) through each of the alternative passage routes to estimate survival past each project. The model also accounts for the proportions of juvenile fish transported and left to migrate inriver. The model also provides survival estimates at each project (dam plus pool) and throughout the system (from the head of Lower Granite Reservoir to the tailrace of Bonneville Dam).

The Biological Effects Team reviewed and analyzed fish passage assumptions used by NMFS in earlier fish passage modeling exercises, those developed in the Plan for Analyzing and Testing Hypotheses (PATH) process, and the most recent empirical data to determine fish passage parameters for input into the SIMPAS model. The team also used the latest compilation of fish passage information contained in the four white papers recently prepared by the Northwest Fisheries Science Center (NWFSC):

- "Passage of Juvenile and Adult Salmonids Past Columbia and Snake River Dams" (NMFS 2000c)

- "Predation on Salmonids Relative to the Federal Columbia River Power System" (NMFS 2000d)
- "Salmonid Travel Time and Survival Related to Flow in the Columbia River Basin" (NMFS 2000e)
- "Summary of Research Related to Transportation of Juvenile Anadromous Salmonids Around Snake and Columbia River Dams" (NMFS 2000f)

Examples of the fish passage parameters reviewed by the Biological Effects Team include 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 both spring and fall chinook salmon (considered indicator species for the spring and summer passage seasons, respectively). The parameter values selected for modeling represent the best available scientific information, and, in cases where empirical information was unavailable, outdated, or limited, represent the team's best professional judgment.

As a result of this collaborative analytical effort, on March 20, 2000, the Biological Effects Team prepared a draft Biological Effects Team report and sent it out for review to the 13 Tribes and other regional fisheries comanagers. The draft report documented preliminary results of SIMPAS model runs incorporating current passage conditions. The assumptions and estimated dam passage survival rates used in this analysis were updated on the basis of comments on that draft and on drafts of this biological opinion.

There are limitations in modeling juvenile fish survival based solely on empirical data gathered during a single year. Fish passage conditions differ from year to year, environmentally as well as operationally and structurally. Flow, temperature, runoff timing, fish condition, spill level, and extended- versus standard-length screens in turbine intakes are some of the factors that can change. To address these limitations, the NMFS Hydro Program staff used all the most recent empirical passive integrated transponder (PIT)-tag reach survival information collected from 1994 through 1999 to model a range of fish passage and environmental conditions for yearling and subyearling chinook and steelhead. Because water conditions ranged from low flow (in 1994) to high flow (1997) during this period, this approach demonstrated the modeled variation in juvenile passage survival that results from different environmental (and the resulting operational) conditions.

The Biological Effects Team also recognized that survival estimates for relatively long river reaches are less subject to error than those for shorter reaches. PIT-tag data were used to estimate survival probabilities between successive dams (i.e., detection sites). The estimate for the overall reach was calculated as the product of the estimates for each of the shorter reaches.

The statistical model resulted in consecutive estimates that are inversely correlated: an underestimate in one reach tends to be followed by an overestimate in the next (or vice versa). Even though this property indicates that the product of two (or more) estimates should be more precise than the individual estimates, the use of project-by-project survival estimates does not result in substantially decreased accuracy.

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D.2 DEVELOPMENT AND HISTORY OF SIMPAS SPREADSHEET MODEL

The SIMPAS (simulated passage) spreadsheet model was first developed by NMFS' Hydro Program staff to evaluate potential actions for the 1995 FCRPS Biological Opinion. Since then, it has been used regularly as an exploratory tool to evaluate the structural or operational measures for their potential to reduce the mortality of juvenile salmon and steelhead at these projects. In 1999, the Federal Caucus' Hydro Workgroup and the Multispecies Framework's Ecological Working Group used a variant of this model (SIMPAS2) to evaluate hydrosystem alternatives that were not modeled by PATH. The Hydro Workgroup used this model as a tool for generating point estimates of likely survival improvements for several new alternatives. Most recently, to more fully evaluate potential actions for the 2000 FCRPS Biological Opinion, NMFS updated the original SIMPAS model to accommodate additional passage routes (for example, raised spillway crest and surface bypass routes).

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D.3 METHODOLOGY

The SIMPAS model starts with a group of fish (1.00) and applies an estimated pool survival to these fish prior to their reaching a project. The model then assigns the surviving fish to various routes of passage at the project, applies an estimated survival rate for the respective routes of passage, removes the estimated proportion of fish that are transported from a given project (if it is a collector project), and then recombines the surviving fish in the tailrace of the project. This process is repeated for each additional project. Fish guidance and survival estimates are typically averages of empirically measured rates through various routes of dam passage (or derived from average fish passage efficiency estimates) or various reservoir pools. When empirically based estimates are not available, passage parameter estimates are obtained from studies at other similar projects or from best professional judgement.[1]

For each species, model input includes:

- Seasonal average flows and spill levels
- Average spill, sluiceway, and guidance efficiency estimates
- Average survival rates through various passage routes and reservoirs

For each species, model output estimates include:

- Proportion of fish transported and left inriver
- Project-specific and system survival estimates
- Fish passage efficiency at each project
- Mortality due to passage through turbines

[1] A report prepared by the Biological Effects Team (March 16, 2000) also documents the parameter estimates used in the initial SIMPAS modeling work for the 2000 FCRPS Biological Opinion.

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D.4 CAVEATS TO SIMPAS MODELING RESULTS

The SIMPAS model is a useful analytical tool to enable screening of alternative fish passage options, however, there are a number of important caveats to the appropriate use of SIMPAS modeling results. These include:

- The juvenile survival rates shown in Tables D-7 through D-23 are based on juvenile passage studies only and cannot be used to infer the likelihood of adult returns.
- The juvenile survival rates shown, as well as the input passage parameters, are point estimates, i.e., confidence intervals are not calculated or implied.
- The model does not contain a time-step function, so both inputs and outputs are scaled to seasonal averages.
- The model does not account for the potential effects of various fish passage options on forebay passage in terms of reducing delay, residence time, or predation.
- Best professional judgment was used to develop some of the passage parameters, e.g., in some cases, fish passage data gathered at one dam during a single passage season were applied to several other similar hydrosystem projects.

In addition, the reach survival data available for calibration of the SIMPAS analysis and for estimating reservoir effects is limited to NMFS PIT-tag data collected between 1994 and 1999. The analysis used these empirical data to calibrate, or “ground truth,” the model results. These years represent a range in flow and environmental conditions. In several years, reach survival data were extrapolated from some of the upper projects in the Snake River (on a per-mile basis) to the entire system (see discussion in the Pool Survival section below). The reach survival estimates are point estimates roughly classified by the volume of runoff during the year in which the data were collected. These survival estimates do not represent the kind of multi-year analysis that ideally would be used to estimate the range of reach survival rates expected under a 50-year record of flow conditions. They do, however, provide a general sense of the between-year variation observed in the last 6 years.

Although there may be uncertainty about the accuracy of the resulting pool and dam survival estimates, the Biological Effects Team and NMFS found that the model output for 1994 through 1999 was reasonable and produced reach survival estimates similar to the empirical estimates. Once the model was calibrated to data for the current operation, the Biological Effects Team and NMFS considered that they had a reasonable base case from which to make comparisons of additional model studies of potential future juvenile fish passage actions over a range of water conditions represented by water years 1994 to 1999 (see Table 9.7-1 for SIMPAS model results of intensive Reasonable and Prudent Alternative [RPA] hydro actions).

Other models attempting to characterize these same effects have relied on flow/survival or travel time/predation relationships applied to a simulated monthly flow condition. Each approach has its own limitations. On balance, however, NMFS determined that this relatively simple and straightforward approach made the best use of the most recent empirical survival information and was adequate for the purposes of this analysis. The framework for this analysis is now also consistent with the monitoring and evaluation program described in Section 9.6.5; therefore, as additional information is collected, it can be incorporated directly into future versions of this analysis.

D.4.1 Example of SIMPAS Model Calculations

This simple example, using a single hypothetical project, is provided to illustrate how the model works. The example provides the necessary input parameter estimates, demonstrates the types of calculations made by the SIMPAS model, and provides the model output based on these calculations.

D.4.1.1 SIMPAS Input Parameters

Flow:

- Total project flow = 100 thousand cubic feet per second (kcfs)
- Total project spill = 40 kcfs (24 hours per day)

Project configuration:

- Only three passage routes are available to fish: spillway, fish bypass system, and turbines
- Spill effectiveness (i.e., ratio of fish per unit volume of water through the spillway) = 1.25
- Fish guidance efficiency of turbine intake screens = 50%

Survival estimates:

- Pool survival = 96 %
- Spillway survival = 98 %
- Bypass system survival = 96 %
- Turbine survival = 90 %

D.4.1.2 SIMPAS Calculations and Output

Step 1: Determine proportion of fish arriving at project

Proportion surviving pool and arriving at the project (0.960) = starting proportion (1.000) x pool survival (0.960)

Step 2: Calculate proportion of fish passing via spillway, bypass system, and turbines

Proportion of fish passing via spillway (0.480) = proportion of fish arriving at project (0.960) x proportion of water spilled (0.400) x spill effectiveness (1.250)

Proportion of fish passing via fish bypass system (0.240) = proportion of fish remaining (0.960 - 0.480 = 0.480) x fish guidance efficiency of the turbine screens (0.500)

Proportion of fish passing via turbines (0.240) = proportion of fish remaining (0.960 - 0.480 - 0.240 = 0.240)

Step 3: Calculate the proportion of fish surviving the spillway, bypass system, and turbines

Proportion of fish surviving the spillway (0.470) = proportion of fish passing via spillway (0.480) x survival rate through spillway (0.980)

Proportion of fish surviving the fish bypass system (0.230) = proportion of fish passing via the bypass system (0.240) x survival through the bypass system (0.960)

Proportion of fish surviving the turbines (0.216) = proportion of fish passing via the turbines (0.240) x survival through the turbines (0.900)

Step 4: Calculate the proportion of fish surviving to the project tailrace (assuming project does not collect fish from the fish bypass system for transport)

Proportion of starting population surviving to project tailrace (0.916) = proportion surviving spillway (0.470) + proportion surviving fish bypass system (0.230) + proportion surviving turbines (0.216)

Step 5: Calculate Output Parameters

Proportion of fish surviving the reservoir and project = 0.916 proportion surviving to tailrace (0.916) ÷ starting proportion (1.000)

Proportion of fish surviving the project only = 0.954 proportion surviving to tailrace (0.916) ÷ proportion arriving at the project (0.960)

Proportion of fish avoiding turbine passage (fish passage efficiency) = 0.750 (proportion of fish passing via spillway [0.480] + proportion of fish passing via fish bypass system [0.240]) ÷ proportion of fish arriving at the project (0.960)

Proportion of fish killed by turbines at this project = 0.024 proportion of fish passing via turbines (0.240) - proportion of fish surviving turbines (0.216)

D.4.1.3 SIMPAS Model Parameters

Tables D-1 through D-6 identify the SIMPAS model input parameters used by the Biological Effects Team and NMFS for yearling chinook, subyearling chinook, and steelhead for both the existing conditions and the conditions expected under full implementation of the RPA.

D.4.1.3.1 Pool Survival. Pool survival estimates were developed for yearling chinook (spring migrants), subyearling fall chinook (summer migrants), and steelhead (spring migrants) at each of the eight FCRPS mainstem projects for use in the SIMPAS model. The methods used to derive the pool survival estimates from empirical PIT-tag measurements collected over a range of water conditions from 1994 to 1999 are described below. The methods used to estimate pool survivals for all three species are discussed in the following sections, beginning with 1994, a low-flow year.

Empirical reach survival data used for determining pool survival estimates were derived from the following sources: Muir et al. in press *(*chinook and steelhead 1994 to 1998, Lower Granite tailrace to McNary tailrace); Smith et al. 2000b (chinook and steelhead 1999, head of Lower Granite pool to Bonneville tailrace); Smith et al. 1998 (chinook, 1994 to 1996, and steelhead, 1995 to 1996, head of Lower Granite pool to Lower Granite tailrace); Hockersmith et al. 1999 (steelhead, 1997, head of Lower Granite to Lower Granite tailrace); Smith et al. 2000a (chinook, 1998, head of Lower Granite to Lower Granite tailrace and McNary tailrace to John Day tailrace, and steelhead, 1998, head of Lower Granite to Lower Granite tailrace and McNary tailrace to Bonneville tailrace); and Williams et al. in press (steelhead, 1997, McNary tailrace to John Day tailrace).

Yearling Chinook Salmon, 1994 to 1999

Yearling Chinook Salmon, 1994. Estimates of pool survival in 1994, a low-flow year,[2] were based on empirical (PIT-tag) reach survival data for mixed stock (hatchery and wild) yearling chinook (Table D-7).

[2] 1994 April through August modified runoff volume at Lower Granite Dam was 12.15 million acre-feet (maf), or 53% of the 71-year (1929 through 1999) average. The Columbia River runoff volume at The Dalles Dam over the same period was 67.2 maf, or 73% of average.

Table D-1. Estimated dam passage parameter values for juvenile SR spring/summer chinook salmon. These values were used in the SIMPAS modeling of the effects of current FCRPS operations on the action area biological requirements of yearling migrants. Passage parameters shown in this table for SR spring/summer chinook salmon are assumed to represent those of all yearling chinook salmon migrants.

					Survival		SBC or		
Project	Spill Efficiency	Spill Cap	FGE	Turbine	Spillway	Bypass	Sluice Eff.	SBC or Sluice S	Diel Pass
LWG	Eqn.[7]	60 kcfs	75%[3]	93%[1]	98%[2]	98%[1]	n/a	n/a	68%[9]
LGS	Eqn.[7]	45 kcfs	78%[3]	92%[1]	100%[1]	99%[1]	n/a	n/a	68%[7]
LMN	Eqn.[7]	40 kcfs	49%[3]	92%[16]	97%[16]	95%[1]	n/a	n/a	83%[10]
IHR	Eqn.[8]	105 kcfs night, 45 kcfs day	54%[7]	90%[2]	98%[2]	98%[2]	n/a	n/a	50%[11]
MCN	1:1[2]	135 kcfs (120-150 range)	83%[3]	90%[2]	98%[2]	98%[2]	n/a	n/a	50%[7]
JDA	1:1[2]	85 kcfs or 60% (70-100 range)	73%[12]	90%[2]	98%[2]	98%[2]	n/a	n/a	80%[1]
TDA	1.2:1[4]	230 kcfs or 64%	3%[14]	90%[2]	90%[5]	n/a	12%[4]	96%[6]	50%[2]
BON I			39%[12]	90%[1,2]		90%[7,15]	22%[13]	98%[7]	
	1:1[2]	135 kcfs (120-150 range)			98%[2]				50%[2]
BON II			48%[12]	90%[1,2]		98%[2]	n/a	n/a	

Sources:
[1] NMFS (2000c).
[2] Marmorek et al. (1998).
[3] NMFS (1998).
[4] Ploskey et al. (1999) (reported as a percent of project passage).
[5] E. Dawley (1998, 2000a,b), average of all 64% spill tests, 1997 to 1999.
[6] Dawley et al. (1998)
[7] Best professional judgment.
[8] Eppard et al (2000).
[9] BioSonics' powerhouse hydro acoustic estimate (Kuehl 1986).
[10] Mean of 1988 and 1989 hydro acoustic estimates (McFaden 1988).
[11] 1986 hydro acoustic estimate (Sullivan et al. 1986).
[12] NMFS (2000a).
[13] NMFS (2000b).
[14] Estimated with 6-inch orifice passage (ends up in sluiceway).
[15] Estimate no better than turbine survival. No data, known problem area.
[16] Based on calibration using 1999 Little Goose tailwater to Lower Monumental tailwater reach survival estimate.

Table D-2. Estimates of passage parameters for juvenile SR fall chinook salmon: current passage conditions at FCRPS hydro projects. These values were used in SIMPAS modeling of effects of current FCRPS operations on action area biological requirements. Passage parameters shown for SR fall chinook salmon are assumed to represent those of all subyearling chinook migrants.

Project	Spill Efficiency	Spill Cap	FGE	Turbine S	Spillway S	Bypass S	Sluice Eff.	Sluice S	Diel Pass
LWG	Eqn.[2]	N/A	53%[1]	90%[3]	98%[3]	98%[2]	n/a	n/a	68%[2]
LGS	Eqn.[2]	N/A	53%[2]	90%[3]	98%[3]	98%[2]	n/a	n/a	68%[2]
LMN	Eqn.[2]	N/A	49%[2]	90%[3]	98%[3]	98%[2]	n/a	n/a	83%[2]
IHR	Eqn.[2]	45 kcfs day 100% - 9 kcfs night	54%[2]	90%[3]	98%[3]	98%[2]	n/a	n/a	50%[2]
MCN	1:1[3]	200 minus 155 kcfs Ph capacity	62%[1]	90%[3]	98%[3]	97%[9]	n/a	n/a	50%[2]
JDA	1:1[3]	85 kcfs or 60% (70-100 range)	32%[10]	90%[3]	98%[3]	98%[2]	n/a	n/a	80%[1]
TDA	1.2:1[8]	230 kcfs or 64%	3%[12]	90%[3]	88%[7]	n/a	10%[6]	89%[13]	50%[3]
BON I[14]		75 kcfs day[15]	9%[10]	90%[3]		82%[4]	6%[11]	95%[2]	
	1:1[2]	135 kcfs night			98%[5]				50%[3]
BON II		(120-150 kcfs range)	28%[10]	94%[4]		98%[2]	n/a	n/a	

Sources:
[1] NMFS (2000c).
[2] Based on observations and best professional judgment.
[3] Marmorek et al. (1998).
[4] Ledgerwood et al. (1990), with adjustments for tailrace mortality and predator removal since 1990.
[5] Holmes (1952) and Ledgerwood et al. (1990).
[6] Ploskey et al. (1999).
[7] Dawley (1998, 2000a,b) reports, mean of 1997 to 1999 data.
[8] 1.2:1 @64% spill (Allen et al. 1999).
[9] NMFS unpublished data (Muir 1999).
[10] NMFS 2/ /00 memo to Hydro files.
[11] NMFS 2/ /00 memo to Hydro files.
[12] Estimated with 6-inch orifice passage (ends up in sluiceway).
[13] Dawley et al. (1998).
[14] Assu e BON Ph 1 priority in summer.
[15] min. PH flow of 30 kcfs.
[16] Based on Corps (Years) Transport Reports for LGR, LGS, LMN, MCN for 1994 and 1996 (low and high flow years).
[17] Low, medium, high flows.

Table D-3. Estimates of the values of dam passage parameters for juvenile steelhead. These values were used in the SIMPAS modeling of the effects of current FCRPS operations on the action area biological requirements. Passage parameters shown in this table for SR steelhead are assumed to represent those of all steelhead yearling migrants.

Project	Spill Efficiency	Spill Cap	FGE	Survival Turbine	Survival Spillway	Survival Bypass	SBC or Sluice Eff.	SBC or Sluice S	Diel Pass
LWG	Eqn.[5]	60 kcfs	81%[3]	93%[5]	98%[2]	98%[1]	n/a	n/a	76%[1]
LGS	Eqn.[5]	45 kcfs	81%[3]	92%[1]	100%[1,5]	95%[1]	n/a	n/a	76%[5]
LMN	Eqn.[5]	40 kcfs	82%[1]	93%[5]	97%[1]	93%[1]	n/a	n/a	83%[6]
IHR	Eqn.[5]	105 kcfs night, 45 kcfs day	93%[1]	90%[5]	98%[5]	98%[5]	n/a	n/a	50%[5,7]
MCN	1:1[5]	135 kcfs (120-150 range)	89%[1]	90%[5]	98%[5]	98%[5]	n/a	n/a	50%[5]
JDA	Eqn[10]	85 kcfs or 60% (70-100 range)	85%[1]	90%[5]	98%[5]	98%[5]	n/a	n/a	83%[1]
TDA	1.2:1[5,11]	230 kcfs or 64%	3%[5]	90%[5]	90%[5]	n/a	12%[4]	96%[5,6]	50%[5]
BON I			41%[1]	90%[5]		90%[5,9]	22%[5]	98%[7]	
	1:1[5]	135 kcfs (120-150 range)			98%[5]				50%[5]
BON II			48%[8,1]	90%[1,5]		98%[5]	n/a	n/a	

Sources:
1 NMFS (2000c,a).
2 Marmorek et al. (1998).
3 NMFS (1998).
4 Ploskey et al. (1999) (reported as a % of project passage).
5 Best professional judgment.
6 Mean of 1988 and 1989 hydro acoustic estimates (McFaden 1988, Ransom and Sullivan 1989).
7 1986 hydro acoustic estimate (Sullivan et al. 1986).
8 NMFS (2000b).
9 Estimate no better than turbine survival. No data, known problem area.
10 Hansel et al. (1999).
11 BioSonics (1999).

Table D-4. Estimates of passage parameters for juvenile SR spring/summer chinook salmon. These values were used in SIMPAS modeling of the effects of RPA actions and FCRPS operations on action area biological requirements. Passage parameters shown in this table for SR spring/summer chinook salmon are assumed to represent those of all yearling chinook salmon migrants.

					Survival						
	Proj.	**Spill Eff.**	**Spill Cap**	**FGE**	**Turbine**	**Spillway**	**Bypass**	**SBC or Sluice Eff.**	**SBC or Sluice S**	**Diel Pass**	**Qualitative Comments**
Gas Fast Track	LWG	Eqn.[6]	80 kcfs	75%[3]	93%[1]	98%[2]	98%[1]	n/a	n/a		TDG abate. during forced spill
			12-hr spill							68%[8]	
Improved Spill			24-hr spill							68%	Reduced forebay delay/predation/stress
SBS w/BGS, spill		Eqn.[6,13]		75%[3]						50%	
SBS Ph w/SWI+BGS				75%[3]		98%[6]		29%[18]	98%	50%	Could increase fish guidance efficiency
SBS Ph w/SWI-BGS				75%[3]				17%[18]			
JBS Improve.		Eqn.[6]					99%				Reduced stress, direct loading
Gas Fast Track	LGS	Eqn.[6]	70 kcfs	78%[3]	92%[1]	100%[1]	99%[1]	n/a	n/a		TDG abate. during forced spill
			12-hr spill							68%[11]	
Improved Spill			24-hr spill							68%	Reduced foreb. delay/pred/stress
SBS w/BGS, spill		Eqn.[6,13]		78%[3]						50%	
SBS PH w/SWI+BGS				78%[3]		98%[6]		29%[18]	98%	50%	Could increase FGE
SBS Ph w/SWI-BGS				78%[3]				17%[18]			
Gas Fast Track	LMN	Eqn. [6]	70 kcfs	49%[3]	92%[14]	98%[6]	95%[1]	n/a	n/a	83%[9]	TDG abate. during forced spill
			12-hr spill							83%[9]	
Improved spill			24-hr spill							50%	Reduced foreb. delay/pred/stress
SBS w/BGS, spill		Eqn.[6,13]								50%	
SBS Ph w/SWI+BGS						98%[11]		29%[18]	98%		Could increase FGE
SBS Ph w/SWI-BGS								17%[18]			
JBS Improve.				78%[6]			98%				
JBS outfall relocation							99%				

Table D-4 Continued. Estimates of passage parameters for juvenile SR spring/summer chinook salmon. These values were used in SIMPAS modeling of the effects of RPA actions and FCRPS operations on action area biological requirements. Passage parameters shown in this table for SR spring/summer chinook salmon are assumed to represent those of all yearling chinook salmon.

	Proj.	Spill Eff.	Spill Cap	FGE	Survival Turbine	Survival Spillway	Survival Bypass	SBC or Sluice Eff.	SBC or Sluice S	Diel Pass	Qualitative Comments
24-hr spill	IHR	Eqn.[7]	105 kcfs	54%[6]	90%[2,6]	98%[2,6]	98%[2,6]	n/a	n/a	50%[10]	TDG increased
24-hr spill	IHR		45 kcfs/day	54%[6]	90%[2,6]	98%[2,6]	98%[2,6]	n/a	n/a	50%[10]	TDG reduced
Gas Fast Track	MCN	1:1[2]	135 kcfs	83%[3]	90%[2]	98%[2]	98%[2]	n/a	n/a	50%[6]	
12-hr spill			160 kcfs							50%	
24-hr spill			160 kcfs.							50%	TDG increas., reduc. delay/stress
JBS Improve.							99%				Reduced stress, direct loading
Surf. Bypass						98%	98%				
Gas Fast Track	JDA	1:1 1/	180 kcfs	73%[11]	90%[2]	98%[2]	98%[2]	n/a	n/a	50%	
Ext.-length screens				82%[16]							FGE based on prototype testing
Raised S. crest		Eqn.[6,13]								50%	
I/T sluice relo.	TDA	1.2:1[4,6] @64%	230 kcfs	n/a	90%[1]	90%[5]	n/a		98%[6]	50%[3]	Reduced Stress
Surface bypass								22%[4]			Sluice eff =12% + 10% improve.
Gas Fast Track			30-45% to 230 kcfs			98%[6]					3% Gatewell Orifice Passage
Surface bypass		1.7:1[4,6] @40%								50%	
JBS Improve.	Bon I			72%[15]			98%[2,6]	22%[12]	98%[6]		
MGRs	Bon I				92%[17]						
Surface bypass	Bon I			80%			98%[6]			50%	
Gas Fast Track		1:1[2]	175 kcfs			98%[2]				50%[2]	135 kcfs 24-hrs interim operation
JBS Improve.	Bon II			60%[6]	90%[1,2]		98%[2]	n/a	n/a		
Corner Coll.	Bon II							60%[6]	98%[6]		

Sources:
1 NMFS (2000c).
2 Marmorek et al. (1998).
3 NMFS (1998).
4 Ploskey et al. (1999) (percent of total project passage).
5 Dawley (1998, 2000a,b).
6 Best professional judgment.
7 Eppard et al. (2000).
8 BioSonics 1985 powerhouse hydro acoustic estimate (Kuehl 1986).
9 Mean of 1988 and 1989 hydro acoustic estimates (McFaden 1988, Ransom and Sullivan 1989).
10 1986 hydro acoustic estimate (Sullivan et al. 1986).
11 NMFS (2000a).
12 NMFS (2000b).
13 Variable spill efficiency: 5@10%, 3@20%, 2@40%, 1.5@50%, 1@60% spill.
14 Based on calibration using 1999 Little Goose tailwater to Lower Monumental tailwater reach survival estimate.
15 Monk et al. (1999).
16 Brege et al. (1997).
17 Based on potential improvement due to minimum gap runners (MGRs).
18 Adams and Rondorf (1999).

Table D-5. Estimates of passage parameters used for juvenile SR fall chinook salmon. These values were used in SIMPAS modeling of the effects of RPA actions and FCRPS operations on action area biological requirements. Passage parameters shown in this table for SR fall chinook salmon are assumed to represent those of all subyearling chinook migrants.

	Proj.	Spill Eff.	Spill Cap	FGE	Survival Turbine	Survival Spillway	Survival Bypass	SBC or Sluice Eff.	SBC or Sluice S	Diel Pass	Qualitative Comment
JBS Improve.	LWG	Eqn.[2]	n/a	53%[1]	90%[3]	98%[3]	99%[2]	n/a	n/a	68%[2]	
JBS Improve.	LGS	Eqn.[2]	n/a	53%[2]	90%[3]	98%[3]	98%[2]	n/a	n/a	68%[2]	Reduced stress
Ext.-length screens	LMN	Eqn.[2]	n/a	56%[2]	90%[3]	98%[3]	98%[2]	n/a	n/a	83%[2]	Higher FGE than at LWG due to fish more smolted
Gas Fast Track	IHR	Eqn.[2]	100% night, 45 kcfs day, 45kcfs 24-hrs	54%[2]	90%[3]	98%[3]	98%[2]	n/a	n/a	50%[2]	
JBS Improvements	MCN	1:1[3]	Invol only-155 kcfs PH capacity	62%[1]	90%[3]	98%[3]	99%[2]	n/a	n/a	50%[2]	
Raised spill crest	JDA	Eqn.[9]	180 kcfs or 60%	60%[7]	90%[3]	98%[3]	98%[2]	n/a	98%[2]	50%[2]	Raised crest flow = 14 k/bay
	TDA	1.7:1[6]@ 40%, 1.2:1@ 64%	230 kcfs or 40%	3%[8]	90%[1]	98%[2]	n/a	18%[11]	96%[2]	50%[3]	
Surface Bypass	Bon I		175 kcfs day[13]	35%[10]	92%[12]		98%[2]	55%[2]	96%[2]		
		1:1[2]	175 kcfs night			98%[5]				50%[3]	
Corner Coll.	Bon II			40%[2]	94%[4]		98%[2]	60%[2]	96%[2]		

Sources: [1] NMFS(2000c).
[2] Based on observations and best professional judgment.
[3] Marmorek et al. (1998).
[4] Ledgerwood et al. (1994) reported estimate minus 3% indirect mortality.
[5] Holmes (1952).
[6] Same as spring/summer chinook.
[7] Brege et al. (1997).
[8] Estimated with 6-inch orifice passage (ends up on sluiceway).
[9] Variable spill efficiency: 5@10%, 3@20%, 2.5@30%, 2@40%, 1.5@50%, 1@60%.
[10] Monk et al. (1999).
[11] Ploskey et al. (1999). Reported numbers were doubled for effect of blocked trash racks.
[12] Based on potential improvement due to MGR installation.
[13] Assumes adult fallback problem is corrected, otherwise limit is 120 kcfs.

Table D-6. Estimates of passage parameters for juvenile SR steelhead. These values were used in SIMPAS modeling of the effects of RPA actions and FCRPS operations on action area biological requirements. Note: passage parameters shown in this table for SR steelhead are assumed to represent those of all steelhead yearling migrants.

						Survival		SBC or Sluice	SBC or Sluice		
	Proj.	**Spill Eff.**	**Spill Cap**	**FGE**	**Turbine**	**Spillway**	**Bypass**	**Eff.**	**S**	**Diel Pass**	**Qualitative Comments**
Gas Fast Track	LWG	Eqn.[5]	80 kcfs	81%[3]	93%[5]	98%[1,5]	98%[1]	n/a	n/a		TDG abate. during forced spill
			12-hr spill							76%[1,18]	
Improved Spill			24-hr spill							50%[5]	Reduced forebay delay/predation/stress
SBS w/BGS, spill		Eqn.[5,11]		81%[3]						50%	
SBS Ph w/SWI+BGS				81%[3]		98%[1,5]		29%[5,16]	98%[5]	50%	Could increase fish guidance efficiency
SBS Ph w/SWI-BGS				81%[3]				17%[5,16]			
JBS Improve.		Eqn.[5]					99%[5]				Reduced stress, direct loading
Gas Fast Track	LGS	Eqn.[5]	70 kcfs	81%[3]	93%[1]	100%[1]	98%[5]	n/a	n/a		TDG abate. during forced spill
			12-hr spill							76%[5]	
Improved Spill			24-hr spill							50%[5]	Reduced foreb.delay/pred/stress
SBS w/BGS, spill		Eqn.[5,11]		81%[3]						50%[5]	
SBS PH w/SWI+BGS				81%[3]		100%[1]		29%[5,16]	98%[5]	50%[5]	Could increase FGE.
SBS Ph w/SWI-BGS				81%[3]				17%[5,16]			
Gas Fast Track	LMN	Eqn. [5]	70 kcfs		93%[5]	99%[12]	99%[5,12]	n/a	n/a	50%[5,7]	TDG abate. during forced spill
			12-hr spill							50%[5,7]	
Ext-length screens				84%[5]							
Improved spill			24-hr spill							50%[5]	Reduced foreb. delay/pred/stress
SBS w/BGS, spill		Eqn.[5,11]								50%[5]	

Table D-6, continued.

JBS outfall relocation						99%[5]					
24-hr spill	IHR	Eqn.[6]	105 kcfs	93%[1]	90%[5]	98%[5]	98%[5]	n/a	n/a	50%[5,8]	TDG increased
24-hr spill	IHR		45 kcfs day	93%[1]	90%[5]	98%[5]	98%[5]	n/a	n/a	50%[5,8]	TDG reduced
Gas Fast Track	MCN	1:1[2,5]	135 kcfs	89%[3]	90%[2,5]	98%[2,5]	98%[5]	n/a	n/a	50%[5]	
12-hr spill			160 kcfs							50%[5]	
24-hr spill			160 kcfs							50%[5]	TDG increased, reduced delay/stress
JBS Improve.							99%[5]				Reduced stress, direct loading
Surf. Bypass						98%[5]	98%[5]				
Gas Fast Track	JDA	Eqn.[17]	180 kcfs	73%[9]	90%[2,5]	98%[2,5]	98%[2,5]	n/a	n/a	50%[1]	
Ext.-length screens				94%[14]							FGE based on prototype testing
Raised S. crest		Eqn.[5,11]								50%[5]	
I/T sluice relo.	TDA	1.6[5,18] @64%	230 kcfs	3%[5]	90%[1]	98%[5]	n/a		98%[5]	50%[3,5]	Reduced stress
Surface bypass								22%[4]			Sluice eff. =12% + 10% improve.
Gas Fast Track			30-45% to 230 kcfs			98%[5]					3% gatewell orifice passage
Surface bypass		1.7:1[4,5] @40%								50%	
JBS Improve.	Bon I			85%[13]			98%[2,5]	22%[5,10]	98%[5]		
MGRs	Bon I				92%[5,15]						
Surface bypass	Bon I			85%[1]			98%[5]			50%[5]	
Gas Fast Track		1:1[2,5]	175 kcfs			98%[2,5]				50%[2]	135 kcfs 24-hrs interim operation
JBS Improve.	Bon II			60%[5]	90%[1,5]		98%[2,5]	n/a	n/a		
Corner Coll.	Bon II							62%[5,19]	98%[5]		

Sources:
[1] NMFS (2000c).
[2] Marmorek et al. (1998).
[3] NMFS (1998).
[4] Ploskey et al. (1999) (percent of total project passage).
[5] Best professional judgment.
[6] Eppard et al. (2000).
[7] Mean of 1988 and 1989 hydroacoustic estimates (McFaden 1988, Ransom and Sullivan 1989).
[8] 1986 hydroacoustic estimate (Sullivan et al. 1986).
[9] NMFS (2000a).
[10] NMFSs (2000b) (percent of powerhouse passage).
[11] Variable spill efficiency: 5@10%, 3@20%, 2@40%, 1.5@50%, 1@60% spill.
[12] Based on calibration using 1999 Little Goose tailwater to Lower Monumental tailwater reach survival estimate.
[13] Monk et al. (1999).
[14] Brege et al. (1997).
[15] Based on potential improvement due to MGRs.
[16] Adams and Rondorf (1999).
[17] Hansell et al. (1999).
[18] BioSonics (1999).
[19] Hensleigh et al. (1998).

Empirical reach survival data were partitioned into survival estimates for each of the FCRPS projects where data were available. Because data were only available as far downstream as Lower Monumental Dam, reach survival estimates from the head of Lower Granite pool to the tailrace of Lower Granite Dam, from the tailrace of Lower Granite Dam to the tailrace of Little Goose Dam, and from the tailrace of Little Goose Dam to the tailrace of Lower Monumental Dam were used. Each tailrace-to-tailrace reach survival estimate in Table D-7 can be partitioned into its component pool and dam survival estimates. To estimate survival through each reservoir, the appropriate empirical measurement of reach survival was divided by the modeled dam survival estimates for the same project (i.e., from the SIMPAS analysis). At Little Goose Dam, for example, the 1994 reach survival of spring chinook salmon of 0.830 (the empirical reach survival value shown in Table D-7), was divided by 0.975 (the SIMPAS dam survival estimate), to obtain the pool survival value of 0.852. The model was calibrated with no spill at Lower Granite, Little Goose, and Lower Monumental dams, as the system was operated with no spill until May 10 in 1994.

Pool survivals for FCRPS projects downstream from Lower Monumental Dam were estimated for mixed stock (hatchery and wild) Snake River yearling chinook salmon by developing a per-mile survival rate through Lower Granite, Little Goose, and Lower Monumental pools. After determining the actual reservoir miles for each of the five mainstem FCRPS dams downstream from Lower Monumental, the per-mile survival rate was applied to each pool to obtain a pool survival estimate. The assumption was that applying a constant per-mile survival rate through the Ice Harbor Dam and the four lower Columbia River projects would be representative through these FCRPS reservoirs, as empirical data were unavailable to define pool survival rates more accurately at these projects.

Table D-7. Reach survival rates of juvenile yearling chinook salmon during 1994 (tailrace to tailrace).

Survival	Lewiston to LWG	LWG to LGS	LGS to LMN	LMN to IHR	IHR to MCN	MCN to JDA	JDA to TDA	TDA to BON
Reach Survival (Empirical)	0.936	0.830	0.847	0.89[1]	0.858[1]	0.773[1]	0.845[1]	0.829[1]
Pool Survival (Modeled)	0.967	0.852	0.906	0.909	0.882	0.796	0.931	0.874
Dam Survival (Modeled)	0.968	0.975	0.935	0.979	0.972	0.971	0.908	0.949

[1] Calculated from per-mile survival rate in Lower Granite, Little Goose, and Lower Monumental pools.

Yearling Chinook Salmon, 1995. Estimates of pool survival in 1995, which was an average to slightly above average water year, were based on empirical (PIT-tag) reach survival data from 1995 (Table D-8). Pool survival estimates for mixed stock yearling chinook in 1995 were developed in the same manner as yearling chinook in 1994 except for the Lower Monumental to Ice Harbor and Ice Harbor to McNary pools. For 1995, NMFS now has empirical data for the Lower Monumental to McNary reach. The square root of this empirical value was used for each reach estimate because these reaches are approximately the same length. Because data were available only as far downstream as McNary Dam, NMFS applied the approach described above for yearlings in 1994 for the reach below Lower Monumental Dam to estimate yearling pool survivals for 1995 in the reach below McNary Dam.

Table D-8. Project survival rates (tailrace to tailrace) of juvenile yearling chinook salmon in 1995.

Survival	Lewiston to LWG	LWG to LGS	LGS to LMN	LMN to IHR	IHR to MCN	MCN to JDA	JDA to TDA	TDA to BON
Reach Survival (Empirical)	0.906	0.882	0.925	0.936[1]	0.936[1]	0.852[2]	0.872[2]	0.869[2]
Pool Survival (Calculated)	0.930	0.895	0.972	0.859	0.962	0.878	0.960	0.926
Dam Survival (Modeled)	0.974	0.985	0.952	0.976	0.973	0.970	0.908	0.939

[1] Calculated from Lower Monumental to McNary reach survival data.
[2] Calculated from per-mile survival rate from Lower Granite to McNary Dam.

Yearling Chinook Salmon, 1996. Estimates of pool survival in 1996, which was an above-average water year (i.e., 130% of average runoff from April through August, measured at Lower Granite Dam over the 71-year [1929 through 1999] water record), were based on empirical (PIT-tag) reach survival data for mixed stock yearling chinook from 1996 (Table D-9). Pool survival rates were estimated as described above for 1995.

Table D-9. Project survival rates of juvenile yearling chinook salmon in 1996 (from tailrace to tailrace).

Survival	Lewiston to LWG	LWG to LGS	LGS to LMN	LMN to IHR	IHR to MCN	MCN to JDA	JDA to TDA	TDA to BON
Reach Survival (Empirical)	0.979	0.926	0.929	0.870[1]	0.870[1]	0.844[2]	0.869[2]	0.870[2]
Pool Survival (Modeled)	1.000	0.940	0.977	0.893	0.893	0.871	0.957	0.922
Dam Survival (Modeled)	0.979	0.986	0.951	0.974	0.974	0.969	0.908	0.944

[1] Calculated from Lower Monumental to McNary reach survival data.
[2] Calculated from per-mile survival rate from Lower Granite to McNary Dam.

Yearling Chinook Salmon, 1997. Estimates of pool survival in 1997, which was one of the highest runoff years on record[3], were based on empirical (PIT-tag) reach survival data for combined hatchery and wild yearling chinook from 1997 (Table D-10). Pool survivals, including the Lower Granite pool, were estimated as described above for the 1994 and 1995 year cases.

Table D-10. Project survival rates of juvenile yearling chinook salmon in 1997 (from tailrace to tailrace).

Survival	Lewiston to LWG	LWG to LGS	LGS to LMN	LMN to IHR	IHR to MCN	MCN to JDA	JDA to TDA	TDA to BON
Reach Survival (Empirical)	0.913[1]	0.942	0.894	0.893[2]	0.893[2]	0.835[1]	0.865[1]	0.869[1]
Pool Survival (Calculated)	0.937	0.955	0.942	0.916	0.916	0.857	0.853	0.913
Dam Survival (Modeled)	0.974	0.986	0.949	0.975	0.975	0.972	0.908	0.952

[1] Calculated from per-mile survival rate from Little Goose to McNary Dam.
[2] Calculated from Lower Monumental to McNary reach survival data.

Yearling Chinook Salmon, 1998. Estimates of pool survival in 1998, which was a near average water runoff year, were based on empirical (PIT-tag) reach survival data for combined hatchery and wild yearling chinook from 1998 (Table D-11). Pool survivals were estimated as described above for the 1994 and 1995 years. Because data were available only as far downstream as John Day Dam, NMFS used the approach described above for yearlings in 1994 for the reach below Lower Monumental to estimate 1998 yearling pool survivals in the reach below John Day Dam, i.e., John Day tailrace to Bonneville Dam tailrace.

Yearling Chinook Salmon, 1999. The 1999 passage year was an above-average flow year in the context of the 71-year water record (1929 through 1999). It was also the first year for which survival estimates for combined wild and hatchery yearling chinook were available for the full FCRPS reach (from the head of Lower Granite pool to the tailrace of Bonneville Dam). Empirical reach survival data were partitioned into tailrace-to-tailrace survival estimates for each of the FCRPS projects (Table D-12) (W. Muir, NMFS, NWFSC, Cook, Washington, pers. comm.). Pool survivals were then estimated as described above for 1994.

[3] The 1997 April through August modified runoff volume at Lower Granite Dam was 35.3 maf, or 155% of the 71-year (1929 though 1999) average. The Columbia River runoff volume at The Dalles Dam over the same period was 111.1 maf, or 121% of average.

Table D-11. Project survival rates of juvenile yearling chinook salmon in 1998 (from tailrace to tailrace).

Survival	Lewiston to LWG	LWG to LGS	LGS to LMN	LMN to IHR	IHR to MCN	MCN to JDA	JDA to TDA	TDA to BON
Reach Survival (Empirical)	0.924	0.985	0.853	0.957[1]	0.957[1]	0.822	0.877[2]	0.880[2]
Pool Survival (Calculated)	0.950	1.000	0.898	0.981	0.984	0.848	0.966	0.937
Dam Survival (Modeled)	0.973	0.985	0.950	0.975	0.973	0.970	0.908	0.940

[1] Calculated from Lower Monumental to McNary reach survival data.
[2] Calculated from per-mile survival rate from Lower Granite to John Day Dam.

Table D-12. Project survival rates of juvenile yearling chinook salmon in 1999 (from tailrace to tailrace).

Survival	Lewiston to LWG	LWG to LGS	LGS to LMN	LMN to IHR	IHR to MCN	MCN to JDA	JDA to TDA	TDA to BON
Reach Survival (Empirical)	0.941	0.950	0.924	0.951[1]	0.951[1]	0.853	0.893[2]	0.911[2]
Pool Survival (Calculated)	0.967	0.965	0.973	0.975	0.978	0.880	0.984	0.970
Dam Survival (Modeled)	0.973	0.985	0.950	0.976	0.973	0.969	0.908	0.939

[1] Calculated from Lower Monumental to McNary reach survival data.
[2] Calculated from John Day to Bonneville reach survival data.

Using the approach described for 1994 yearling chinook to partition project survivals into pool and dam survivals, the Biological Effects Team's preliminary estimate of dam passage survival at Lower Monumental Dam (0.950) was lower than at the other lower Snake River projects, due largely to relatively high estimates of turbine and spillway survival derived from the low end of the range presented in the NMFS White Paper on dam passage (Table 9 in NMFS 2000c). The lower survival values were initially chosen to achieve a conservative result. However, the resulting SIMPAS estimate of dam passage survival was so low that when it was evaluated with the empirically-derived estimate of reach survival it resulted in an estimate of reservoir survival greater than 1, a highly unlikely outcome. To adjust for this, the Biological Effects Team considered the values for the turbine, spillway, and other passage parameters at Lower

Monumental Dam that were reported in NMFS (2000c), as well as other means of partitioning the reach survival between the dam and reservoir components. In the end, the Biological Effects Team decided to raise spill and turbine survival rates to values similar to those of Lower Granite and Ice Harbor. This provided a Lower Monumental pool survival estimate of 0.973, a value similar to that of the other Snake River pools.

The Biological Effects Team made another exception to its general approach for The Dalles and Bonneville dams. Because there is no juvenile fish PIT-tag detection facility at The Dalles Dam, the empirical reach survival data spanned the reach between the John Day and Bonneville tailraces. Estimated dam survival at the two projects was removed from the reach survival estimate leaving a pool survival estimate for both reservoirs. A per-mile survival rate was determined from this estimate and used to calculate reach survival for each project, using methods described above for the 1994 year case.

Subyearling Chinook Salmon, 1994 to 1999

Subyearling Chinook Salmon, 1994. No empirical information is available for the survival of subyearling chinook salmon below Lower Granite Dam in 1994. Thus, project survival estimates were not developed for subyearling chinook for 1994.

Subyearling Chinook Salmon, 1995. Empirical PIT-tag reach survival information from 1995 were available for wild subyearling fall chinook salmon from the point of release to Lower Granite Dam. In 1995, data for the reach between the Lower Granite and Lower Monumental tailraces were limited to hatchery fish.

The Biological Effects Team selected the survival of wild fish during 1995 to estimate the reach from release to Lower Granite Dam and to represent 1995 flow augmentation and temperature control operations. The measured reach survival (66.8%), divided by the modeled survival at Lower Granite Dam (94.2%), provided an estimate of the survival through Lower Granite pool of approximately 71% (Table D-13). The 1995 reach survival data for hatchery fish were used for the reach from Lower Granite to Lower Monumental Dam.

Pool survivals for projects downstream from Lower Monumental Dam were estimated for subyearling Snake River fall chinook salmon in the same manner as for yearling chinook in 1994. The assumption was that applying a constant per-mile survival rate through the Ice Harbor Dam and the four Lower Columbia River projects would be representative in those reservoirs, as data were unavailable to better define the pool survival rates at these projects. Another consideration was that although empirical data indicate that subyearling chinook salmon tend to migrate at a faster rate as they move downstream (which implies decreased exposure to predators), the number of predators increases through the lower Columbia River. Thus, these two factors tend to balance each other.

Table D-13. Project survival rates (tailrace to tailrace) of juvenile subyearling chinook salmon in 1995.

Survival	Release to LWG	LWG to LGS	LGS to LMN	LMN to IHR	IHR to MCN	MCN to JDA	JDA to TDA	TDA to BON
Reach Survival (Empirical)	0.668	0.890	0.795	0.878[1]	0.820[1]	0.738[1]	0.815[1]	0.804[1]
Pool Survival (Calculated)	0.709	0.944	0.846	0.897	0.867	0.771	0.921	0.858
Dam Survival (Modeled)	0.942	0.942	0.939	0.978	0.946	0.957	0.884	0.937

[1] Calculated from per-mile survival rate in Little Goose and Lower Monumental pools.

Subyearling Chinook Salmon, 1996. Estimates of pool survival for subyearling chinook salmon during 1996 were based on empirical (PIT-tag) reach survival data from 1996 (Table D-14). Pool survivals were derived as described above for 1995. Because data were available only as far downstream as Lower Monumental Dam, NMFS used the approach described above for subyearlings at downstream projects in 1995 to estimate pool survivals of subyearlings for 1996.

Table D-14. Project survival rates of juvenile subyearling chinook salmon in 1996 (from tailrace to tailrace).

Survival	Lewiston to LWG	LWG to LGS	LGS to LMN	LMN to IHR	IHR to MCN	MCN to JDA	JDA to TDA	TDA to BON
Reach Survival (Empirical)	0.479	0.898	0.782	0.873[1]	0.828[1]	0.727[1]	0.811[1]	0.791[1]
Pool Survival (Calculated)	0.508	0.953	0.828	0.892	0.860	0.760	0.917	0.850
Dam Survival (Modeled)	0.942	0.942	0.944	0.979	0.963	0.957	0.884	0.931

[1] Calculated from per-mile survival rate in Little Goose and Lower Monumental pools.

Subyearling Chinook Salmon, 1997. Estimates of pool survival for subyearling chinook salmon during 1997 were based on empirical (PIT-tag) reach survival data from 1996 (Table D-15). Pool survivals were derived as described above for the 1995 year case. Because data were available only as far downstream as Lower Monumental Dam, the Biological Effects Team used the approach described above for subyearlings at downstream projects in 1995 to estimate pool survivals of subyearlings for 1997.

Table D-15. Project survival rates of juvenile subyearling chinook salmon in 1997 (from tailrace to tailrace).

Survival	Lewiston to LWG	LWG to LGS	LGS to LMN	LMN to IHR	IHR to MCN	MCN to JDA	JDA to TDA	TDA to BON
Reach Survival (Empirical)	0.353	0.566	0.644	0.635[1]	0.546[1]	0.340[1]	0.639[1]	0.504[1]
Pool Survival (Calculated)	0.375	0.601	0.682	0.649	0.566	0.355	0.722	0.543
Dam Survival (Modeled)	0.942	0.942	0.944	0.978	0.964	0.957	0.884	0.928

[1] Calculated from per-mile survival rate in Little Goose and Lower Monumental pools.

Subyearling Chinook Salmon, 1998. Estimates of pool survival for subyearling chinook salmon during 1998 were based on empirical (PIT-tag) reach survival data from 1998 (Table D-16). Pool survivals were derived as described above for 1995. Because data were available only as far downstream as Lower Monumental Dam, the NMFS used the approach described above for subyearlings at downstream projects in 1995 to estimate pool survivals of subyearlings in 1998.

Table D-16. Project survival rates of juvenile subyearling chinook salmon in 1998 (from tailrace to tailrace).

Survival	Lewiston to LWG	LWG to LGS	LGS to LMN	LMN to IHR	IHR to MCN	MCN to JDA	JDA to TDA	TDA to BON
Reach Survival (Empirical)	0.558	0.771	0.921	0.878[1]	0.830[1]	0.737[1]	0.815[1]	0.802[1]
Pool Survival (Calculated)	0.592	0.818	0.976	0.897	0.866	0.770	0.921	0.857
Dam Survival (Modeled)	0.942	0.942	0.944	0.979	0.958	0.957	0.884	0.936

[1] Calculated from per-mile survival rate in Little Goose and Lower Monumental pools.

Subyearling Chinook Salmon, 1999. Estimates of pool survival for subyearling chinook salmon during 1999 were based on empirical (PIT-tag) reach survival data from 1999 (Table D-17). Pool survivals were derived as described above for 1995. Because data were available only as far downstream as Lower Monumental Dam, the Biological Effects Team used the approach described above for subyearlings at downstream projects in 1995 to estimate pool survivals of subyearlings for 1999.

Table D-17. Project survival rates of juvenile subyearling chinook salmon in 1999 (from tailrace to tailrace).

Survival	Lewiston to LWG	LWG to LGS	LGS to LMN	LMN to IHR	IHR to MCN	MCN to JDA	JDA to TDA	TDA to BON
Reach Survival (Empirical)	0.766	0.665	0.890	0.804[1]	0.743[1]	0.595[1]	0.762[1]	0.703[1]
Pool Survival (Calculated)	0.813	0.706	0.943	0.821	0.771	0.623	0.861	0.757
Dam Survival (Modeled)	0.942	0.942	0.944	0.979	0.964	0.955	0.884	0.929

[1] Calculated from per-mile survival rate in Little Goose and Lower Monumental pools.

Steelhead, 1994 to 1999

Steelhead, 1994. Pool survival estimates for juvenile hatchery steelhead in 1994 were developed in the same manner as with yearling chinook salmon (above). Survival data are shown in Table D-18.

Table D-18. Project survival rates of juvenile steelhead during 1994 (tailrace to tailrace).

Survival	Lewiston to LWG	LWG to LGS	LGS to LMN	LMN to IHR	IHR to MCN	MCN to JDA	JDA to TDA	TDA to BON
Reach Survival (Empirical)	0.900[1]	0.844	0.892	0.908[1]	0.882[1]	0.813[1]	0.858[1]	0.850[1]
Pool Survival (Calculated)	0.927	0.892	0.959	0.927	0.905	0.835	0.945	0.899
Dam Survival (Modeled)	0.971	0.946	0.930	0.980	0.975	0.974	0.908	0.945

[1] Calculated from per-mile survival rate in Little Goose and Lower Monumental pools.

Steelhead, 1995. Pool survival estimates for juvenile hatchery steelhead in 1995 were developed in the same manner as for yearling chinook in 1994 and 1995. Survival data are shown in Table D-19.

Table D-19. Project survival rates of juvenile steelhead in 1995 (from tailrace to tailrace).

Survival	Lewiston to LWG	LWG to LGS	LGS to LMN	LMN to IHR	IHR to MCN	MCN to JDA	JDA to TDA	TDA to BON
Reach Survival (Empirical)	0.944	0.899	0.950	0.926[1]	0.926[1]	0.884[2]	0.881[2]	0.887[2]
Pool Survival (Calculated)	0.967	0.925	1.000	0.946	0.950	0.908	0.970	0.945
Dam Survival (Modeled)	0.976	0.972	0.950	0.979	0.975	0.974	0.908	0.939

[1]Calculated from survival data for Lower Monumental to McNary reach.
[2]Calculated from per-mile survival rate from Lower Granite to McNary pools.

Steelhead, 1996. Pool survival estimates for juvenile hatchery steelhead in 1996 were developed in the same manner as for yearling chinook in 1994 and 1995. Survival data are shown in Table D-20.

Table D-20. Project survival rates of juvenile steelhead in 1996 (from tailrace to tailrace).

Survival	Lewiston to LWG	LWG to LGS	LGS to LMN	LMN to IHR	IHR to MCN	MCN to JDA	JDA to TDA	TDA to BON
Reach Survival (Empirical)	0.934	0.938	0.937	0.889[1]	0.889[1]	0.860[2]	0.873[2]	0.878[2]
Pool Survival (Calculated)	0.957	0.967	0.988	0.908	0.911	0.884	0.962	0.930
Dam Survival (Modeled)	0.976	0.970	0.948	0.979	0.976	0.973	0.908	0.944

[1]Calculated from survival data for Lower Monumental to McNary reach.
[2]Calculated from per-mile survival rate in Little Goose and Lower Monumental pools.

Steelhead, 1997. Empirical reach survival estimates for combined hatchery and wild hatchery steelhead were available from Lower Granite through Bonneville Dam; however, individual reach survivals were not available for reaches below Lower Monumental Dam. The Lower Monumental to Ice Harbor and the Ice Harbor to McNary reaches were calculated as explained for 1995 yearling chinook. The reaches and pool survivals for projects below McNary Dam were calculated using a per-mile survival rate derived from the empirical McNary to Bonneville reach survival estimate and calculation techniques explained for 1999 yearling chinook. Survival data are shown in Table D-21.

Steelhead, 1998. Pool survivals were calculated for combined hatchery and wild steelhead in 1997, except that an empirical reach estimate was used for the McNary to John Day reach. Survival data are shown in Table D-22.

Table D-21. Project survival rates of juvenile steelhead in 1997 (from tailrace to tailrace).

Survival	Lewiston to LWG	LWG to LGS	LGS to LMN	LMN to IHR	IHR to MCN	MCN to JDA	JDA to TDA	TDA to BON
Reach Survival (Empirical)	0.963	0.966	0.902	0.913[1]	0.913[1]	0.851[2]	0.870[2]	0.880[2]
Pool Survival (Calculated)	0.987	0.995	0.953	0.932	0.935	0.874	0.958	0.924
Dam Survival (Modeled)	0.976	0.971	0.946	0.979	0.977	0.974	0.908	0.952

[1]Calculated from survival data for Lower Monumental to McNary reach.
[2]Calculated from per-mile survival rate from McNary to Bonneville Dam.

Table D-22. Project survival rates of juvenile steelhead in 1998 (from tailrace to tailrace).

Survival	Lewiston to LWG	LWG to LGS	LGS to LMN	LMN to IHR	IHR to MCN	MCN to JDA	JDA to TDA	TDA to BON
Reach Survival (Empirical)	0.925	0.930	0.889	0893[1]	0.893[1]	0.831	0.897[2]	0.918[2]
Pool Survival (Calculated)	0.949	0.959	0.939	0.912	0.916	0.854	0.988	0.977
Dam Survival (Modeled)	0.975	0.970	0.947	0.979	0.975	0.974	0.908	0.940

[1]Calculated from survival data for Lower Monumental to McNary reach.
[2]Calculated from per-mile survival rate from McNary to Bonneville Dam.

Steelhead, 1999. Pool survivals were calculated the same way they were for combined hatchery and wild steelhead, 1998. Survival data are shown in Table D-23.

Table D-23. Project survival rates of juvenile steelhead in 1999 (from tailrace to tailrace).

Survival	Lewiston to LWG	LWG to LGS	LGS to LMN	LMN to IHR	IHR to MCN	MCN to JDA	JDA to TDA	TDA to BON
Reach Survival (Empirical)	0.908	0.926	0.915	0.913[1]	0.913[1]	0.920	0.840[2]	0.812[2]
Pool Survival (Calculated)	0.931	0.954	0.966	0.932	0.936	0.945	0.925	0.865
Dam Survival (Modeled)	0.975	0.970	0.947	0.979	0.975	0.973	0.908	0.939

[1]Calculated from survival data for Lower Monumental to McNary reach.
[2]Calculated from per-mile survival rate from John Day to Bonneville Dam.

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