US Army Corps
of Engineers®
Portland District

WILLAMETTE VALLEY SYSTEM OPERATIONS AND MAINTENANCE

FINAL ENVIRONMENTAL IMPACT STATEMENT

APPENDIX E: FISH AND AQUATIC HABITAT ANALYSES

PART 2 – CHAPTER 5 THROUGH CHAPTER 8

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CHAPTER 5 - EFFECTS OF FLOW BELOW WILLAMETTE VALLEY SYSTEM DAMS ON CHINOOK SALMON AND STEELHEAD HABITAT AND SURVIVAL

5.1 INTRODUCTION

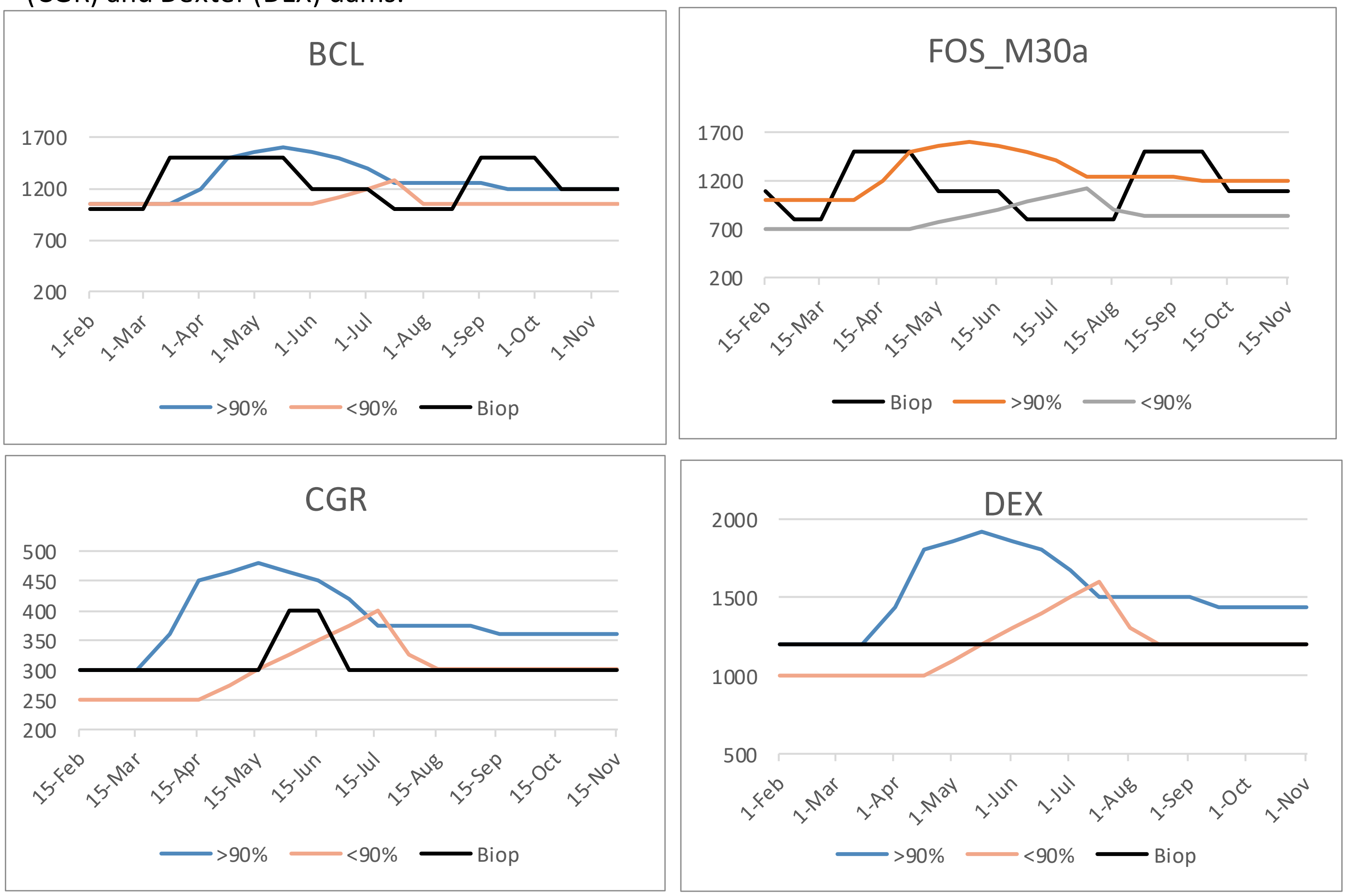
For managing discharge of water from WVS dams, an instream flow regime was developed to protect habitat needs of UWR Chinook and steelhead. Populations of these species occur below WVS dams in the Santiam, McKenzie and Middle Fork rivers. The NAA applies minimum flow levels defined in NMFS 2008 Biop on the Willamette Project. For EIS Alternatives 1 through 4, the minimum flow levels applied in the alternatives are defined under EIS Measure 30a. Measure 30a was revised based on EIS cooperator input as Measure 30b and is applied under Alternative 5.

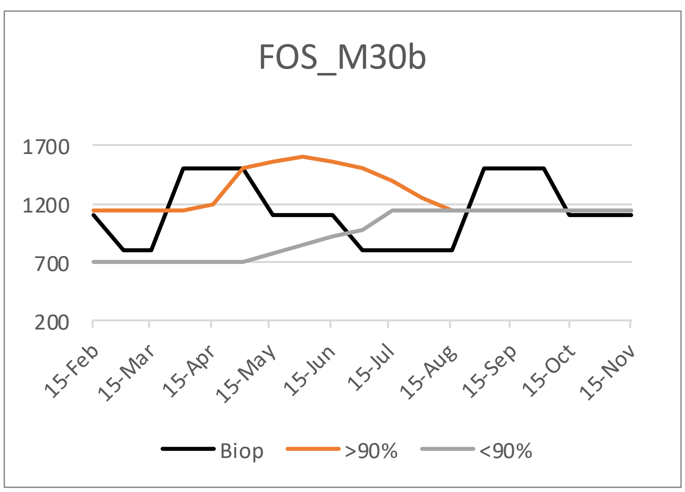
5.2 MINIMUM FLOWS

Under Measure 30a, the mainstem Willamette River minimum flow levels at Salem (5000 cfs) and Albany (4500 cfs) would be in place in all water year types and in all months except April 1 to June 30. Minimum flows during April and May at Salem will be 10,000 cfs, and 8,000 cfs in June for purposes of water temperature management in the mainstem. In addition, flow from the WVS reservoirs would also be used adaptively during April-June in each year to reduce and stabilize water temperature during important migration timeframes for UWR spring Chinook and UWR steelhead, mitigating warmer air temperatures to the extent possible. Minimum flow levels are met or exceeded using stored water to supplement natural flow during the conservation season. Flow in addition to meeting the minimum flow levels would also be released from storage to achieve specified temperature targets.

For the tributaries under Measure 30a, two minimum flow level regimes were defined for release below the lower dams in the four tributaries directly affecting UWR Chinook and steelhead. Between the two regimes for each tributary, the minimum flow regime to be applied would be assessed according to the storage achieved in real-time (less than or greater than 90 percent of the rule curve) every 2 weeks between February 1 and June 1. After June 1, the tributary minimum flow regime applied on June 1 would be followed for the remainder of the conservation season.

Figure 5-1. Minimum tributary releases (cfs) below WVS dams defined for EIS Measure 30a and 30b. Minimum targets are the same under Measure 30a and 30b for Big Cliff (BCL), Cougar (CGR) and Dexter (DEX) dams.





Note differences axis values.

Table 5-1. Threshold Flows (kcfs) at which flow augmentation could provide cooler temperatures in each time-frame and an associating water temperature threshold of which not to exceed. Flows provided in Kcfs; temperature estimate in degrees F based on Stratton ,et.,al.(in press). Applied in both EIS Measure 30a and 30b.

	Apr-May	Jun01-15	Jun15-30
Air Temperature Threshold (F)	Flow (kcfs) Needed To Keep Below 64°F Water Temperature	Flow (kcfs) Needed To Keep Below 68°F Water Temperature	Flow (kcfs) Needed To Keep Below 69°F Water Temperature
74	8.7	6.4	5.9
75	9.0	6.6	6.0
76	9.3	6.9	6.2
77	9.6	7.2	6.5
78	9.9	7.5	6.7
79	10.3	7.8	6.9
80	10.7	8.1	7.2
81	11.2	8.5	7.5
82	11.7	8.9	7.9
83	12.2	9.4	8.2
84	12.7	9.9	8.6
85	13.4	10.4	9.0
86	14.0	11.0	9.5
87	14.7	11.8	10.1
88	15.4	12.7	10.6
89	16.4	13.7	11.3
90	17.4	14.9	12.0
91	18.6	16.1	12.9
92	19.8	17.7	14.0
93		19.6	14.8

Table 5-2. Mainstem Minimum Flow Thresholds included under Measure 30b.

Time Period	Water Supply Forecast Percent of 30 Year Average	Salem Minimum Flow, cfs (7 Day Moving Average)	Salem Minimum Flow, cfs (Instantaneous)	Albany Minimum Flow, cfs
April	<80%	12,000	12,000	–
–	80-100%	15,000	13,000	–
–	>100%	17,800	14,300	–
May	<80%	10,000	8,000	–
–	80-100%	13,000	12,000	–
–	>100%	15,000	12,000	–
June 1 - 15	<80%	8,000	8,000	4,500
–	80-100%	10,000	10,000	4500
–	>100%	13,000	10,500	4500
June 16 - 30	<80%	5,500	5,500	4,500
–	>=80%	7,000	7,000	4500
July	<80%	5,000	5,000	4,500
–	>=80%	6,000	5,500	4500
August	<80%	5,000	5,000	4,500
–	>=80%	6,500	6,000	4500
September	<80%	5,000	5,000	4,500
–	>=80%	7,000	6,500	4500
October	<80%	7,500	6,000	4,500
–	>=80%	10,000	8,000	4500

5.3 FLOWS RESULTING FROM EIS ALTERNATIVES

[insert] – information should demonstrate the differences in flow levels below dams between the NAA and each alternative. Refer reader to outflow plots from Appendix D, Section 1.5, and DEIS Table 3.2-2, etc, or copy into this section?

5.4 METHODS - FISH EFFECTS FROM FLOWS

5.4.1 Flow-Habitat Relationships

For juvenile spring Chinook in the North Santiam and McKenzie, habitat availability s a function of flow was modeled by USGS for the WVS EIS alternatives for all years in the period of record (1936 to 2019) using methods documented in White et al. (2022; also see Peterson et al. 2022). For juvenile Chinook and steelhead USGS used habitat suitability criteria developed by Hansen et al. (2023). Years were categorized as high, normal or low water years based on the 25th and

75th percentiles of Willamette-at-Salem unregulated flow estimated for the Mar 15-Oct 15 timeframe in each year. Habitat modeling included flows modeled under the EIS NAA, each EIS alternative, and the EIS near term operational measure (NTOM).

Adult Chinook and steelhead spawning habitat was estimated for all years in the period of record (1936 to 2019) using weighted usable area relationships from R2 (R2 Resources 2013) and RDG (RDG 2015) below WVS dams for each alternative and compared to the NAA. Years were categorized as high, normal or low water years based on the estimated unregulated flow at Salem for the March 15 - October 15 timeframe in each year. Habitat availability was compared by summarizing the percentage of days flows were greater than those providing 80%, 90% or 100% of the maximum weighted usable area (MWUA) determined by R2 and RDG for reaches where spawning densities are typically highest below WVS dams based on Sharpe et al. 2015, 2016, and 2018: Reach 1 on the North Santiam, Reach 1 on the South Santiam, Transect 7 on the South Fork McKenzie, and Transect 10 on the Middle Fork (Table 1).

Table 5-3. Flows (cfs) providing 80%, 90% and 100% of the maximum weighted usable area (WUA) of the available spawning habitat for spring Chinook salmon and winter steelhead below WVS Dams. Flows are for Reach 1 on the North Santiam (R2 Resources 2013), Reach 1 on the South Santiam (R2 Resources 2013), Transect 7 on the South Fork McKenzie (RDG 2015), and Transect 10 on the Middle Fork (RDG 2015) for the lower bound of each habitat-flow curve.

WUA level	Chinook salmon spawning, Aug15-Nov01				Winter steelhead spawning, Mar15-Jun01	
	Big Cliff	Foster	Cougar	Dexter	Big Cliff	Foster
80%	889	449	242	1800	867	533
90%	1011	567	319	2176	1000	685
100%	1286	1140	472	2800	1286	1140

Note: Flows are for Reach 1 on the North Santiam (R2 Resources 2013), Reach 1 on the South Santiam (R2 Resources 2013), Transect 7 on the South Fork McKenzie (RDG 2015), and Transect 10 on the Middle Fork (RDG 2015) for the lower bound of each habitat-flow curve.

5.4.2 Flow-Survival Relationships

Juvenile and adult fish survival below the dam is affected by downstream factors including flow, temperatures, and physical channel conditions. Often, water management decisions involve tradeoffs among multiple objectives or legal authorities. The USGS, Oregon Cooperative Fish and Wildlife Research Unit, Department of Fish and Wildlife, and Oregon State University developed models of UWR spring Chinook and winter steelhead to characterize water management tradeoffs and effects on key habitat features (Peterson et al. 2022). These models, dependent on a given hydrology and water temperature regime, predict four different life history outcomes: 1) the number of Chinook reaching emergence and surviving to swim-up, 2) the number of Chinook adult equivalents, 3) the number of outmigrating winter steelhead, and 4) the survival rate of age-1 juvenile steelhead. Model predictions were driven by a number of life history and habitat inputs such as temperature, habitat-discharge relationships, and territory size. Descriptions and assumptions of the four models can be found in Peterson et al. (Peterson et al. 2022) and in Chapter 5 of Appendix E. All models operated on a weekly time step that began in the eighth week of the year and ran through April of the following year. Models are only assessing below dam spawning and juvenile rearing. Hydrology inputs were based on ResSim model results provided by the Corps for the alternatives. Water temperature inputs were based on CE-QUAL-W2 model results provided by the alternatives. The models produced predictions for each sub-basin for each alternative, in each year of three representative water years in which water temperatures and hydrology inputs were applied (2011, 2015 and 2016). Model predictions (using median habitat criteria results provided by Peterson et al.) for alternatives were compared to the NAA (BiOp flows). Results were compared by summarizing the alternative results as a percentage of the NAA due to the multiple survival models and differences in their output units, survival.

Survival of Chinook and steelhead was modeled for WVS EIS Alternatives 1 through 4, and the No Action Alternative (NAA). Results for Alternative 2b were considered representative of Alternative 5 due to similarity in the river hydrology and water temperatures for these alternatives.

5.5 RESULTS - FISH EFFECTS FROM FLOWS

5.5.1 North Santiam

Juvenile habitat

For juvenile spring Chinook, there was little difference found in habitat availability between the alternatives and the NTOM when compared to the NAA in the North Santiam below Big Cliff Dam. The greatest differences was for Alternative 3a which had less juvenile habitat available during summer months, likely due to delaying refill of some reservoirs associated with fish passage measures included in this alternative.

Table 5-4. Habitat available, as a percentage of the habitat available under the No Action Alternative (NAA), for juvenile spring Chinook in the North Santiam under each WVS EIS alternative and the near-term operational measures (NTOM). Highlighted cells indicate if percentage is less than or greater than 5% different from the NAA.

	alt1	alt2a	alt2b	alt3a	alt4	alt5	NTOM
Water Year Type: High							
Jan	100.0	100.0	100.0	100.6	100.0	100.0	100.0
Feb	100.0	100.0	100.0	97.9	100.0	100.0	100.0
Mar	100.0	100.0	100.0	95.0	100.0	100.0	100.0
Apr	101.4	100.2	100.2	97.2	100.2	100.2	100.2
May	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Jun	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Jul	100.0	102.6	102.6	100.0	102.6	102.6	102.6
Aug	99.8	103.4	103.4	99.8	103.4	103.4	103.4
Sep	100.0	96.8	96.8	92.0	96.8	96.8	96.8
Oct	100.0	100.0	100.0	96.5	100.0	100.0	100.0
Nov	100.0	100.0	100.0	101.1	100.0	100.0	100.0
Dec	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Water Year Type: Low							
Jan	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Feb	100.0	100.0	100.0	99.9	100.0	100.0	100.0
Mar	100.0	100.0	100.0	92.9	100.0	100.0	100.0
Apr	102.8	101.6	101.6	97.4	101.6	101.6	101.6
May	98.8	99.6	99.6	96.8	99.6	99.6	99.6
Jun	97.8	99.2	99.2	98.7	99.2	99.2	99.2
Jul	99.7	103.4	103.4	90.2	103.4	103.4	103.4
Aug	99.8	100.7	100.7	85.5	100.7	100.7	100.7
Sep	93.8	95.3	95.3	93.9	95.3	95.3	95.3
Oct	100.3	99.0	99.0	97.8	99.0	99.0	99.0
Nov	100.0	100.0	100.0	100.5	100.0	100.0	100.0
Dec	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Water Year Type: Normal							
Jan	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Feb	100.0	100.0	100.0	97.3	100.0	100.0	100.0
Mar	100.0	100.0	100.0	95.1	100.0	100.0	100.0
Apr	101.4	100.2	100.2	96.3	100.2	100.2	100.2
May	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Jun	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Jul	99.9	102.9	102.9	99.7	102.9	102.9	102.9
Aug	99.8	103.4	103.4	92.0	103.4	103.4	103.4
Sep	97.9	96.8	96.8	85.9	96.8	96.8	96.8
Oct	100.0	100.0	100.0	96.2	100.0	100.0	100.0
Nov	100.0	100.0	100.0	101.1	100.0	100.0	100.0
Dec	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Adult Habitat

The number and percentage of days spawning habitat was available for Chinook salmon at flows providing >80% and >90% of the MWUA was similar (within 5%) to the NAA under the alternatives during normal and high water year types compared to the NAA, except for Alternative 3a. In low water year types, there were more days above the MWUA levels under these alternatives compared to the NAA. Alternative 3a was a notable exception to this pattern, providing less days compared to the NAA at all MWUA flow levels in all water year types compared to the NAA.

For winter steelhead, flows were at or above the 80% and 90% MWUA levels for the entire 79 day period of March 15 to June 1 under the NAA and under the alternatives in all water year types, with the exception of Alternative 3a which had fewer days under the low flow years. The number of days at or above the 100% MWUA level was less than 79 under both the NAA and the alternatives, with generally fewer days under the alternatives compared to the NAA.

Table 5-5. Number of days flows were at or above maximum weighted usable area (MWUA) levels for Chinook salmon spawning during August 15 to November 1 (79 day period) below Big Cliff Dam under three water year categories for each alternative.

	Number of days at or above MWUA flow level					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
NAA						
High	79	79	48	79.0	79.0	61.0
Low	3	2	1	66.3	65.5	43.9
Normal	46	46	29	78.2	78.2	59.5
Alt 1						
High	79	79	37	79.0	79.0	53.2
Low	63	62	0	78.2	78.2	24.7
Normal	46	46	0	78.2	78.2	46.7
Alt 2a						
High	79	79	32	79.0	79.0	64.8
Low	48	47	0	77.5	77.5	20.3
Normal	46	46	32	78.2	78.2	56.4
Alt 2b						
High	79	79	32	79.0	79.0	64.8
Low	48	47	0	77.5	77.5	20.3
Normal	46	46	32	78.2	78.2	56.5
Alt 3a						
High	0	0	0	47.5	46.5	4.5
Low	0	0	0	18.9	16.7	0.9
Normal	0	0	0	28.9	27.3	2.3
Alt 3b						
High	79	79	76	79.0	79.0	77.8
Low	60	60	6	78.1	78.1	54.6

Normal	46	46	45	78.2	78.2	76.8
Alt 4						
High	79	79	32	79.0	79.0	64.8
Low	48	47	0	77.5	77.5	20.3
Normal	46	46	32	78.2	78.2	56.4
Alt 5						
High	79	79	32	79.0	79.0	64.8
Low	48	47	0	77.5	77.5	20.3
Normal	46	46	32	78.2	78.2	56.4

Table Note: Flows providing 80%, 90% and 100% of the MWUA are listed in Table.

Table 5-6. The minimum and average number of days, as a percentage of the WVS EIS No Action Alternative (NAA), flows were greater than flow levels providing 80% (lower bound; LB), 90% (lower bound; LB) and 100% maximum weighted usable area (MWUA) for Chinook salmon spawning during August 15 to November 1 (79 day period) below Big Cliff Dam under three water year categories.

	Days flows greater than MWUA flow level as a Percent of the NAA					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
Alt 1						
High	100%	100%	77%	100%	100%	87%
Low	2100%	3100%	0%	118%	119%	56%
Normal	100%	100%	0%	100%	100%	79%
Alt 2a						
High	100%	100%	67%	100%	100%	106%
Low	1600%	2350%	0%	117%	118%	46%
Normal	100%	100%	110%	100%	100%	95%
Alt 2b						
High	100%	100%	67%	100%	100%	106%
Low	1600%	2350%	0%	117%	118%	46%
Normal	100%	100%	110%	100%	100%	95%
Alt 3a						
High	0%	0%	0%	60%	59%	7%
Low	0%	0%	0%	28%	26%	2%

Normal	0%	0%	0%	37%	35%	4%
Alt 3b						
High	100%	100%	158%	100%	100%	127%
Low	2000%	3000%	600%	118%	119%	125%
Normal	100%	100%	155%	100%	100%	129%
Alt 4						
High	100%	100%	67%	100%	100%	106%
Low	1600%	2350%	0%	117%	118%	46%
Normal	100%	100%	110%	100%	100%	95%
Alt 5						
High	100%	100%	67%	100%	100%	106%
Low	1600%	2350%	0%	117%	118%	46%
Normal	100%	100%	110%	100%	100%	95%

Table Notes: Colored cells indicates the Alternative differs by more than 5% from the No Action Alternative. Flows providing 80%, 90% and 100% of the MWUA are listed in Table. When there were zero days of occurrence under the NAA, a percentage could not be calculated and "na" was entered.

Table 5-7. Number of days flows were at or above maximum weighted usable area (MWUA) for winter steelhead salmon spawning during March 15 to June 1 (79 day period) below Big Cliff Dam under three water year categories for each alternative.

	Number of days at or above MWUA flow level					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
NAA						
High	79	79	77	79.0	79.0	78.1
Low	79	79	68	79.0	79.0	76.7
Normal	79	79	75	79.0	79.0	78.0
Alt 1						
High	79	79	15	79.0	79.0	50.0
Low	79	79	0	79.0	79.0	9.2
Normal	79	79	0	79.0	79.0	44.5
Alt 2a						
High	79	79	17	79.0	79.0	53.5
Low	79	79	0	79.0	79.0	18.0

Normal	79	79	1	79.0	79.0	50.5
Alt 2b						
High	79	79	17	79.0	79.0	53.5
Low	79	79	0	79.0	79.0	18.0
Normal	79	79	1	79.0	79.0	50.5
Alt 3a						
High	79	79	73	79.0	79.0	77.8
Low	63	48	37	77.6	75.4	68.9
Normal	77	77	63	79.0	78.9	77.9
Alt 3b						
High	79	79	17	79.0	79.0	52.7
Low	79	79	0	79.0	79.0	16.2
Normal	77	75	0	79.0	78.9	48.9
Alt 4						
High	79	79	17	79.0	79.0	53.5
Low	79	79	0	79.0	79.0	18.0
Normal	79	79	1	79.0	79.0	50.6
Alt 5						
High	79	79	17	79.0	79.0	53.5
Low	79	79	0	79.0	79.0	18.0
Normal	79	79	1	79.0	79.0	50.5

Table Note: Flows providing 80%, 90% and 100% of the MWUA are listed in Table.

Table 5-8. The minimum and average number of days, as a percentage of the WVS EIS No Action Alternative (NAA), flows were greater than flow levels providing 80% (lower bound; LB), 90% (lower bound; LB) and 100% maximum weighted usable area (MWUA) for winter steelhead spawning during March 15 to June 1 (79 day period) below Big Cliff Dam under three water year categories.

	Days flows greater than MWUA flow level as a Percent of the NAA					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
Alt 1						
High	100%	100%	19%	100%	100%	64%
Low	100%	100%	0%	100%	100%	12%

Normal	100%	100%	0%	100%	100%	57%
Alt 2a						
High	100%	100%	22%	100%	100%	68%
Low	100%	100%	0%	100%	100%	23%
Normal	100%	100%	1%	100%	100%	65%
Alt 2b						
High	100%	100%	22%	100%	100%	69%
Low	100%	100%	0%	100%	100%	23%
Normal	100%	100%	1%	100%	100%	65%
Alt 3a						
High	100%	100%	95%	100%	100%	100%
Low	80%	61%	54%	98%	95%	90%
Normal	97%	97%	84%	100%	100%	100%
Alt 3b						
High	100%	100%	22%	100%	100%	67%
Low	100%	100%	0%	100%	100%	21%
Normal	97%	95%	0%	100%	100%	63%
Alt 4						
High	100%	100%	22%	100%	100%	68%
Low	100%	100%	0%	100%	100%	23%
Normal	100%	100%	1%	100%	100%	65%
Alt 5						
High	100%	100%	22%	100%	100%	69%
Low	100%	100%	0%	100%	100%	23%
Normal	100%	100%	1%	100%	100%	65%

Table Notes: Colored cells indicates the Alternative differs by more than 5% from the No Action Alternative. Flows providing 80%, 90% and 100% of the MWUA are listed in Table.

Survival

For Chinook in the North Santiam, survival modeling results were mixed when compared to the NAA. For Chinook spawning effectiveness (Chinook redds surviving until swim-up model), Alternatives 2a, 2b and 4 provided similar (within 5%) to better survival compared to the NAA in all water years. In the dry (2015) and moderate (2016) years, Alternatives 1, 3a and 3b provided lower survival, but higher survival in the wet year (2011).

For juvenile Chinook in wet or dry years, similar to better survival was estimated for Alternatives 1, 3a, 3b and 4 compared to the NAA.

For steelhead juveniles (Steelhead trout Age-1 model), results were similar (within 5%) or better compared to the NAA in the dry and moderate water years modeled under Alternatives 1, 2a, 2b and 4. Survival was poor for juveniles under Alternative 3a in all water years modeled. For steelhead smolt survival, results were similar for all alternatives and water years compared to the NAA.

Table 5-9. Percent difference from the NAA in estimated survival scores of spring Chinook and winter steelhead in the North Santiam below Big Cliff Dam for three simulation years.

	Chinook redds surviving until swim-up	Chinook salmon adult equivalents	Steelhead trout smolt survival	Steelhead trout Age-1
Alt1				
2011	25%	-4%	0%	-7%
2015	-38%	15%	-3%	20%
2016	-5%	-59%	-3%	-1%
Alt2a				
2011	35%	-5%	0%	-6%
2015	3%	-28%	-2%	16%
2016	4%	-49%	-1%	3%
Alt2b				
2011	32%	-3%	0%	2%
2015	-4%	-11%	-2%	19%
2016	2%	-54%	-1%	1%
Alt3a				
2011	61%	-4%	0%	-4%
2015	-30%	-3%	-5%	-43%
2016	-8%	-43%	-3%	-7%
Alt3b				
2011	5%	4%	0%	-10%
2015	-8%	-4%	0%	45%
2016	-17%	-58%	-2%	37%
Alt4				
2011	33%	-2%	0%	-2%
2015	-2%	17%	-2%	1%
2016	-1%	-58%	-2%	-9%

Table Notes: Colored cells indicate the Preferred Alternative is different by 5% or more from the No Action Alternative. Percentages calculated from results presented in WVS EIS Appendix E, Chapter 5, Tables 5-5, 5-6 and 5-7.

5.5.2 South Santiam

Juvenile Habitat

Habitat available for juvenile spring Chinook in the North Santiam and McKenzie was modeled by USGS for the WVS EIS Alternatives for all years in the period of record (1936 to 2019) using methods documented in White et al. (2022) and Peterson et al. (2022), applying habitat suitability criteria developed by Hansen et al. (2023). Models are currently being completed by USGS to provide similar modeling in the South Santiam and Middle Fork, and will be applied to help validate assumptions used for development of Measure 30 a and b as part of the adaptive management plan (Appendix N). Although results are not available at this time, habitat for juvenile Chinook and steelhead does not appear to be limiting below WVS dams in the Willamette (Myers et al. 2022; Peterson et al. 2022; Scheuerell et al. 2021). NOAA NWFSC did not include juvenile rearing capacity in models of population performance (see Myers et al. 2022 included as Appendix E, Chapter 7), either under existing or the proposed improved fish passage conditions and when considering the adult return levels predicted under the DPEIS alternatives as modeled. Their conclusion assumed that many juveniles emigrate from the headwater (above dam) reaches to rear downstream, and that hatchery salmon and steelhead released below dams emigrate quickly to the ocean and do not affect rearing natural origin juveniles (email communication from J. Myers to R. Piaskowski, 11/03/22). Peterson et al. (2022), similarly indicates habitat availability may not be a limiting factor for juveniles when evaluating survival of Chinook and steelhead in the Willamette with respect to stream flows below dams. R2 found habitat for juvenile Chinook and steelhead rearing decreased with increasing flow (R2 Resources 2014). Scheuerell et al. (2021) found a negative effect of winter-spring flows during the year Chinook smolts would have been migrating to sea on the overall productivity of the population.

Adult Habitat

The number and percentage of days spawning habitat was available for Chinook salmon at flows providing >80% and >90% of the MWUA was similar (within 5%) of the NAA under the alternatives during normal and high water year types compared to the NAA. In low water year types, there were more days above the 80%, 90% and 100% MWUA flow levels under all alternatives compared to the NAA, with the exception of Alternative 3b. In normal water years there were few days under Alternative 3a, 3b and 5 at or above the 90% MWUA flow level compared to the NAA. At the 100% MWUA flow level, there were fewer days under all the alternatives compared to the NAA.

For winter steelhead, the number and percentage of days spawning habitat was available at flows providing >80% and >90% of the MWUA was also similar (within 5%) of the NAA under the alternatives during normal and high water year types compared to the NAA. In low water year types, there were more days above the 90% MWUA flow level under all alternatives compared to the NAA, with the exception of Alternative 3b. In normal water years there were few days under Alternative 3a, 3b and 5 at or above the 90% MWUA flow level compared to the NAA. At the 100% MWUA flow level, there were fewer days under all the alternatives compared to the NAA.

Table 5-10. Number of days flows were at or above maximum weighted usable area (MWUA) for Chinook salmon spawning during August 15 to November 1 (79 day period) below Foster Dam under three water year categories for each alternative.

	Number of days at or above MWUA flow level					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
NAA						
High	79	79	45	79.0	79.0	51.9
Low	3	1	0	73.1	72.2	38.7
Normal	46	46	29	78.2	77.8	50.4
Alt 1						
High	78	78	10	78.9	78.9	33.6
Low	78	78	0	79.0	79.0	19.1
Normal	46	46	0	78.1	78.1	26.4
Alt 2a						
High	78	78	78	79.0	79.0	78.9
Low	79	79	30	79.0	79.0	63.8
Normal	46	46	14	78.2	78.2	74.5
Alt 2b						
High	78	78	78	79.0	79.0	78.9
Low	79	79	30	79.0	79.0	63.8
Normal	46	46	14	78.2	78.2	74.5
Alt 3a						
High	78	78	78	79.0	79.0	78.9
Low	79	79	30	79.0	79.0	63.8
Normal	46	46	14	78.2	78.2	74.5
Alt 3b						
High	7	6	0	67.6	66.3	11.6
Low	0	0	0	34.6	33.1	3.9
Normal	1	1	0	47.0	45.7	6.0
Alt 4						
High	79	79	79	79.0	79.0	79.0
Low	79	79	0	79.0	79.0	49.7

Normal	46	46	0	78.2	78.2	68.5
Alt 5						
High	78	78	78	79.0	79.0	78.9
Low	79	79	59	79.0	79.0	77.4
Normal	46	46	46	78.2	78.2	78.1

Table 5-11. The minimum and average number of days, as a percentage of the WVS EIS No Action Alternative (NAA), flows were greater than flow levels providing 80% (lower bound; LB), 90% (lower bound; LB) and 100% maximum weighted usable area (MWUA) for Chinook salmon spawning during August 15 to November 1 (79 day period) below Foster Dam under three water year categories.

	Days flows greater than MWUA flow level as a Percent of the NAA					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
Alt 1						
High	99%	99%	22%	100%	100%	65%
Low	2600%	7800%	na	108%	109%	49%
Normal	100%	100%	0%	100%	100%	52%
Alt 2a						
High	99%	99%	173%	100%	100%	152%
Low	2633%	7900%	na	108%	109%	165%
Normal	100%	100%	48%	100%	101%	148%
Alt 2b						
High	99%	99%	173%	100%	100%	152%
Low	2633%	7900%	na	108%	109%	165%
Normal	100%	100%	48%	100%	101%	148%
Alt 3a						
High	99%	99%	173%	100%	100%	152%
Low	2633%	7900%	na	108%	109%	165%
Normal	100%	100%	48%	100%	101%	148%
Alt 3b						
High	9%	8%	0%	86%	84%	22%
Low	0%	0%	na	47%	46%	10%
Normal	2%	2%	0%	60%	59%	12%

Alt 4						
High	100%	100%	176%	100%	100%	152%
Low	2633%	7900%	na	108%	109%	128%
Normal	100%	100%	0%	100%	101%	136%
Alt 5						
High	99%	99%	173%	100%	100%	152%
Low	2633%	7900%	na	108%	109%	200%
Normal	100%	100%	159%	100%	101%	155%

Notes: Colored cells indicates the Alternative differs by more than 5% from the No Action Alternative. Flows providing 80%, 90% and 100% of the MWUA are listed in Table. When there were zero days of occurrence under the NAA, a percentage could not be calculated and "na" was entered.

Table 5-12. Number of days flows were at or above maximum weighted usable area (MWUA) for winter steelhead salmon spawning during March 15 to June 1 (79 day period) below Foster Dam under three water year categories for each alternative.

	Number of days at or above MWUA flow level					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
NAA						
High	79	79	76	79.0	79.0	78.6
Low	79	70	38	79.0	78.6	65.0
Normal	79	79	62	79.0	79.0	73.8
Alt 1						
High	79	79	62	79.0	79.0	75.8
Low	79	79	0	79.0	79.0	26.5
Normal	79	79	29	79.0	79.0	59.9
Alt 2a						
High	79	79	65	79.0	79.0	76.0
Low	79	76	0	79.0	78.6	36.9
Normal	79	78	49	79.0	79.0	71.7
Alt 2b						
High	79	79	65	79.0	79.0	76.0
Low	79	76	0	79.0	78.6	36.9
Normal	79	78	49	79.0	79.0	71.7

Alt 3a						
High	79	79	65	79.0	79.0	76.0
Low	79	72	0	79.0	78.0	36.9
Normal	79	74	49	79.0	78.9	71.7
Alt 3b						
High	79	79	69	79.0	79.0	76.0
Low	79	60	40	79.0	76.0	61.3
Normal	79	64	51	79.0	78.4	68.1
Alt 4						
High	79	79	65	79.0	79.0	76.6
Low	79	79	0	79.0	79.0	38.0
Normal	79	79	49	79.0	79.0	71.7
Alt 5						
High	79	79	68	79.0	79.0	76.4
Low	79	75	0	79.0	78.6	38.8
Normal	79	73	56	79.0	78.9	73.5

Table 5-13. The minimum and average number of days, as a percentage of the WVS EIS No Action Alternative (NAA), flows were greater than flow levels providing 80% (lower bound; LB), 90% (lower bound; LB) and 100% maximum weighted usable area (MWUA) for winter steelhead spawning during March 15 to June 1 (79 day period) below Foster Dam under three water year categories.

	Days flows greater than MWUA flow level as a Percent of the NAA					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
Alt 1						
High	100%	100%	82%	100%	100%	96%
Low	100%	113%	0%	100%	101%	41%
Normal	100%	100%	47%	100%	100%	81%
Alt 2a						
High	100%	100%	86%	100%	100%	97%
Low	100%	109%	0%	100%	100%	57%
Normal	100%	99%	79%	100%	100%	97%
Alt 2b						

High	100%	100%	86%	100%	100%	97%
Low	100%	109%	0%	100%	100%	57%
Normal	100%	99%	79%	100%	100%	97%
Alt 3a						
High	100%	100%	86%	100%	100%	97%
Low	100%	103%	0%	100%	99%	57%
Normal	100%	94%	79%	100%	100%	97%
Alt 3b						
High	100%	100%	91%	100%	100%	97%
Low	100%	86%	105%	100%	97%	94%
Normal	100%	81%	82%	100%	99%	92%
Alt 4						
High	100%	100%	86%	100%	100%	98%
Low	100%	113%	0%	100%	101%	58%
Normal	100%	100%	79%	100%	100%	97%
Alt 5						
High	100%	100%	89%	100%	100%	97%
Low	100%	107%	0%	100%	100%	60%
Normal	100%	92%	90%	100%	100%	100%

Survival

For Chinook spawning effectiveness (Chinook redds surviving until swim-up model), results were better than the NAA in all water years under Alternative 4. Results were also better in dry years compared to the NAA for Alternatives 1, 2a, 2b, and 3a. In most other cases results were poorer under the alternatives compared to the NAA.

For Chinook juvenile (Chinook salmon adult equivalents), results for the alternatives were similar (within 5%) or better than the NAA in most cases. The exceptions were under Alternative 2a in the moderate (2016) and wet (2015) years modeled, and in the wet year under Alternative 2b.

For steelhead smolt survival, results for the alternatives were similar (within 5%) or better than the NAA in all cases.

For juvenile steelhead (Steelhead trout Age-1), results were similar or worse in each water year modeled under Alternatives 1, 2a and 3b compared to the NAA. Results were similar or better in each water year modeled under Alternatives 4. In other alternatives results were mixed, depending on water year, when compared to the NAA.

Table 5-14. Percent difference from the NAA in estimated survival of spring Chinook and winter steelhead in the South Santiam below Foster Dam for three simulation years.

	Chinook redds surviving until swim-up	Chinook salmon adult equivalents	Steelhead trout smolt survival	Steelhead trout Age-1
Alt1				
2011	11%	0%	0%	-17%
2015	37%	16%	-4%	-11%
2016	-11%	-5%	-5%	-15%
Alt2a				
2011	-39%	-12%	0%	-19%
2015	54%	29%	-3%	3%
2016	-39%	-19%	-3%	-21%
Alt2b				
2011	-37%	-25%	0%	-20%
2015	51%	51%	-3%	12%
2016	-36%	13%	-3%	-21%
Alt3a				
2011	-37%	0%	0%	-25%
2015	54%	7%	-4%	84%
2016	-39%	-3%	-4%	31%
Alt3b				
2011	40%	48%	0%	0%
2015	-100%	1%	-4%	-9%
2016	-60%	17%	-4%	-40%
Alt4				
2011	51%	1%	0%	5%
2015	37%	7%	-3%	15%
2016	0%	5%	-3%	0%

Table Notes: Colored cells indicate the Preferred Alternative is different by 5% or more from the No Action Alternative. Percentages calculated from results presented in WVS EIS Appendix E, Chapter 5, Tables 5-5, 5-6 and 5-7.

5.5.3 McKenzie

Juvenile Habitat

For habitat for spring Chinook juvenile in the McKenzie River, there was little difference found between the alternatives and the NTOM when compared to the NAA. Habitat was less than 5% of the that occurring under the NAA in either March or April (or both) under Alternatives 2b and 5 depending on water year type. Otherwise, habitat was within 5% of that available under the NAA in all other months for all alternatives and the NTOM (with a minor exception under Alternative 3a compared to the NAA when habitat available was about 6% greater in November).

Table 5-15. Habitat available, as a percentage of the habitat available under the No Action Alternative (NAA), for juvenile spring Chinook in the McKenzie and South Fork McKenzie below Cougar Dam under each WVS EIS alternative and the near-term operational measures (NTOM). Highlighted cells indicate if percentage is less than or greater than 5% different from the NAA.

	alt1	alt2a	alt2b	alt3a	alt4	alt5	NTOM
Water Year Type: High							
Jan	100.0	100.0	101.0	100.0	100.0	101.1	100.0
Feb	100.0	100.0	97.1	96.5	100.0	96.8	95.6
Mar	100.0	100.0	90.3	95.1	100.0	88.6	95.5
Apr	100.0	100.0	92.7	95.3	100.0	94.6	98.3
May	100.0	100.0	98.2	100.0	100.0	98.0	101.0
Jun	100.0	100.0	100.7	100.7	100.0	100.9	100.0
Jul	100.0	100.0	100.0	100.0	100.0	100.0	99.6
Aug	100.0	99.9	99.8	99.9	99.9	99.8	100.0
Sep	100.0	100.0	99.9	100.0	100.0	99.9	100.2
Oct	100.0	100.0	101.1	101.3	100.0	100.8	100.7
Nov	100.0	100.0	104.0	105.8	100.0	104.3	101.8
Dec	100.0	100.0	101.9	100.8	100.0	101.8	100.0
Water Year Type: Low							
Jan	100.0	100.0	100.7	100.0	100.0	100.7	100.0
Feb	100.0	100.0	98.6	98.3	100.0	97.9	97.2
Mar	100.0	100.0	93.2	97.5	100.0	95.9	97.2
Apr	102.6	102.6	99.8	100.7	102.6	100.2	101.2
May	101.7	100.9	100.5	100.6	100.9	100.7	101.9
Jun	100.1	100.0	100.0	100.0	100.0	100.0	100.0
Jul	100.2	100.0	99.9	99.9	100.0	99.9	100.0
Aug	100.2	100.1	99.5	99.5	100.1	99.5	99.9
Sep	100.4	100.2	99.3	100.0	100.3	99.2	100.0
Oct	99.4	100.2	99.7	99.7	100.1	99.5	100.0
Nov	100.0	100.0	100.1	100.0	100.0	100.0	100.0
Dec	100.0	100.0	102.4	101.5	100.0	102.1	100.0
Water Year Type: Normal							

Jan	100.0	100.0	101.0	100.0	100.0	101.6	100.0
Feb	100.0	100.0	96.7	96.9	100.0	96.7	95.8
Mar	100.0	100.0	90.9	95.3	100.0	91.4	95.6
Apr	100.2	100.2	94.0	95.8	100.2	95.6	100.1
May	100.0	100.0	99.1	100.0	100.0	99.6	102.4
Jun	100.0	100.0	100.1	100.1	100.0	100.2	100.2
Jul	100.1	100.0	99.9	100.0	100.0	99.9	100.0
Aug	100.0	99.9	99.6	99.6	99.9	99.6	99.8
Sep	100.0	100.0	99.6	100.0	100.0	99.7	100.2
Oct	100.0	100.0	100.0	99.9	100.0	99.9	100.3
Nov	100.0	100.0	102.6	103.0	100.0	102.4	100.9
Dec	100.0	100.0	101.0	100.1	100.0	100.7	100.0

Adult Habitat

The percentage of days spawning habitat was available for Chinook salmon at flows >80%, >90%, and >100% MWUA levels was much lower under the alternatives compared to the NAA in all water year types. This reflects that under Alternatives 2b, 3a, 3b and 5 there is a deep draft of the reservoir in spring, to near the elevation of the diversion tunnel to provide downstream passage for fish, resulting in limited to no water storage available to augment stream flows during the later summer and fall Chinook salmon spawning season. Alternatives 1, 2a and 4 provide similar habitat availability as the NAA, particularly in normal and high water years.

Table. 5-16 Number of days flows were at or above maximum weighted usable area (MWUA) for Chinook salmon spawning during August 15 to November 1 (79 day period) below Cougar Dam under three water year categories for each alternative.

	Number of days at or above MWUA flow level					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
NAA						
High	79	79	50	79.0	79.0	64.0
Low	27	25	0	71.6	70.8	24.3
Normal	46	46	6	78.2	78.2	53.4
Alt 1						
High	79	79	44	79.0	79.0	62.7
Low	14	12	10	71.0	70.0	36.6
Normal	46	46	28	78.2	78.2	51.4
Alt 2a						
High	79	79	42	79.0	79.0	61.3
Low	4	0	0	70.3	68.0	40.6

Normal	46	46	23	78.2	78.2	52.2
Alt 2b						
High	75	0	0	78.8	19.9	19.5
Low	0	0	0	39.0	3.6	3.4
Normal	8	0	0	56.8	8.9	8.7
Alt 3a						
High	21	13	0	68.6	57.9	6.4
Low	0	0	0	32.7	21.6	0.0
Normal	3	0	0	43.9	33.8	2.2
Alt 3b						
High	75	0	0	78.8	19.9	19.6
Low	0	0	0	39.0	3.6	3.4
Normal	8	0	0	56.8	8.9	8.7
Alt 4						
High	79	79	44	79.0	79.0	61.0
Low	4	0	0	70.6	68.7	40.3
Normal	46	46	23	78.2	78.2	52.8
Alt 5						
High	75	0	0	78.7	19.2	18.8
Low	0	0	0	39.0	3.6	3.4
Normal	8	0	0	56.5	8.8	8.6

Table 5-17. The minimum and average number of days, as a percentage of the WVS EIS No Action Alternative (NAA), flows were greater than flow levels providing 80% (lower bound; LB), 90% (lower bound; LB) and 100% maximum weighted usable area (MWUA) for Chinook salmon spawning during August 15 to November 1 (79 day period) below Cougar Dam under three water year categories.

	Days flows greater than MWUA flow level as a Percent of the NAA					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
Alt 1						
High	100%	100%	88%	100%	100%	98%
Low	52%	48%	na	99%	99%	150%
Normal	100%	100%	467%	100%	100%	96%

Alt 2a						
High	100%	100%	84%	100%	100%	96%
Low	15%	0%	na	98%	96%	167%
Normal	100%	100%	383%	100%	100%	98%
Alt 2b						
High	95%	0%	0%	100%	25%	30%
Low	0%	0%	na	55%	5%	14%
Normal	17%	0%	0%	73%	11%	16%
Alt 3a						
High	27%	16%	0%	87%	73%	10%
Low	0%	0%	na	46%	30%	0%
Normal	7%	0%	0%	56%	43%	4%
Alt 3b						
High	95%	0%	0%	100%	25%	31%
Low	0%	0%	na	55%	5%	14%
Normal	17%	0%	0%	73%	11%	16%
Alt 4						
High	100%	100%	88%	100%	100%	95%
Low	15%	0%	na	99%	97%	166%
Normal	100%	100%	383%	100%	100%	99%
Alt 5						
High	95%	0%	0%	100%	24%	29%
Low	0%	0%	na	55%	5%	14%
Normal	17%	0%	0%	72%	11%	16%

Notes: Colored cells indicates the Alternative differs by more than 5% from the No Action Alternative. Flows providing 80%, 90% and 100% of the MWUA are listed in Table. When there were zero days of occurrence under the NAA, a percentage could not be calculated and "na" was entered.

Survival

For Chinook adults (Chinook redds surviving until swim-up model), results were similar (within 5%) or higher compared the NAA in Alternatives 1, 2a and 4. For other alternatives results were similar or lower, depending on water year.

For Chinook juvenile (Chinook salmon adult equivalents), results were similar or higher compared to the NAA for Alternatives 3a and 3b, and similar to lower for other alternatives, depending on water year. Notably, for Alternatives 3a and 3b results were better in all water years compared to the NAA.

Table 5-18. Percent difference from the NAA in estimated survival of spring Chinook in the South Fork and mainstem McKenzie below Cougar Dam for three simulation years.

	Chinook redds surviving until swim-up	Chinook salmon adult equivalents
Alt1		
2011	-1%	1%
2015	7%	-36%
2016	-3%	-9%
Alt2a		
2011	-2%	1%
2015	9%	-34%
2016	2%	-4%
Alt2b		
2011	-7%	1%
2015	4%	-32%
2016	-9%	3%
Alt3a		
2011	-1%	4%
2015	0%	8%
2016	-9%	11%
Alt3b		
2011	-7%	6%
2015	0%	20%
2016	-8%	3%
Alt4		
2011	-1%	-10%
2015	7%	22%
2016	0%	1%

Table Notes: Colored cells indicate the Preferred Alternative is different by 5% or more from the No Action Alternative. Percentages calculated from results presented in WVS EIS Appendix E, Chapter 5, Tables 5-5, 5-6 and 5-7.

5.5.4 Middle Fork WILLAMETTE RIVER

Juvenile Habitat

Habitat available for juvenile spring Chinook in the North Santiam and McKenzie was modeled by USGS for the WVS EIS Alternatives for all years in the period of record (1936 to 2019) using methods documented in White et al. (2022) and Peterson et al. (2022), applying habitat suitability criteria developed by Hansen et al. (2023). Models are currently being completed by USGS to provide similar modeling in the South Santiam and Middle Fork, and will be applied to help validate assumptions used for development of Measure 30 a and b as part of the adaptive management plan (Appendix N). Although results are not available at this time, habitat for juvenile Chinook and steelhead does not appear to be limiting below WVS dams in the Willamette (Myers et al. 2022; Peterson et al. 2022; Scheuerell et al. 2021). NOAA NWFSC did not include juvenile rearing capacity in models of population performance (see Myers et al. 2022 included as Appendix E, Chapter 7), either under existing or the proposed improved fish passage conditions and when considering the adult return levels predicted under the DPEIS alternatives as modeled. Their conclusion assumed that many juveniles emigrate from the headwater (above dam) reaches to rear downstream, and that hatchery salmon and steelhead released below dams emigrate quickly to the ocean and do not affect rearing natural origin juveniles (email communication from J. Myers to R. Piaskowski, 11/03/22). Peterson et al. (2022), similarly indicates habitat availability may not be a limiting factor for juveniles when evaluating survival of Chinook and steelhead in the Willamette with respect to stream flows below dams. R2 found habitat for juvenile Chinook and steelhead rearing decreased with increasing flow (R2 Resources 2014). Scheuerell et al. (2021) found a negative effect of winter-spring flows during the year Chinook smolts would have been migrating to sea on the overall productivity of the population.

Adult Habitat

For spawning habitat availability for Chinook salmon below Dexter Dam, in low and normal years, the number of days flows under all alternatives at 80% and 100% were greater than the number of days at the levels under the NAA. Alternative 3a had fewer days at each MWUA level compared to the NAA in all water year types. Compared to the NAA, Alternative 5 performed the best, and generally outperformed the NAA in low and normal water year types.

Table 5-19. Number of days flows were at or above maximum weighted usable area (MWUA) for Chinook salmon spawning during August 15 to November 1 (79 day period) below Big Cliff Dam under three water year categories for each alternative.

	Number of days at or above MWUA flow level					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
NAA						
High	60	47	10	72.9	47.0	33.8
Low	0	47	0	28.3	47.0	2.6
Normal	2	47	0	64.1	47.0	22.1
Alt 1						
High	46	34	11	59.2	48.2	30.5
Low	12	9	4	39.0	32.3	16.3

Normal	39	18	5	52.2	44.2	24.2
Alt 2a						
High	38	27	5	55.9	46.7	37.2
Low	4	2	0	38.5	23.7	5.8
Normal	21	9	0	54.8	40.5	24.8
Alt 2b						
High	48	30	2	63.6	51.2	35.4
Low	0	0	0	47.5	34.6	7.0
Normal	20	11	0	62.9	49.5	24.6
Alt 3a						
High	11	5	2	39.1	24.7	23.3
Low	0	0	0	8.9	2.9	2.2
Normal	0	0	0	25.5	14.2	12.8
Alt 3b						
High	62	53	14	70.6	61.9	49.2
Low	8	1	0	49.8	36.5	10.9
Normal	32	11	0	69.0	58.3	34.6
Alt 4						
High	42	29	7	56.4	46.9	37.8
Low	4	2	0	37.4	21.4	6.1
Normal	22	8	0	54.6	39.9	25.0
Alt 5						
High	56	38	14	67.4	53.6	36.4
Low	0	0	0	42.1	32.5	6.2
Normal	35	22	0	67.7	53.9	32.8

Table 5-20. The minimum and average number of days, as a percentage of the WVS EIS No Action Alternative (NAA), flows were greater than flow levels providing 80% (lower bound; LB), 90% (lower bound; LB) and 100% maximum weighted usable area (MWUA) for Chinook salmon spawning during August 15 to November 1 (79 day period) below Big Cliff Dam under three water year categories.

	Days flows greater than MWUA flow level as a Percent of the NAA					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
Alt 1						
High	77%	72%	110%	81%	103%	90%
Low	na	19%	na	138%	69%	622%
Normal	1950%	38%	na	81%	94%	109%
Alt 2a						
High	63%	57%	50%	77%	99%	110%
Low	na	4%	na	136%	50%	222%
Normal	1050%	19%	na	85%	86%	112%
Alt 2b						
High	80%	64%	20%	87%	109%	105%
Low	na	0%	na	168%	74%	265%
Normal	1000%	23%	na	98%	105%	111%
Alt 3a						
High	18%	11%	20%	54%	52%	69%
Low	na	0%	na	31%	6%	85%
Normal	0%	0%	na	40%	30%	58%
Alt 3b						
High	103%	113%	140%	97%	132%	146%
Low	na	2%	na	176%	78%	416%
Normal	1600%	23%	na	108%	124%	156%
Alt 4						
High	70%	62%	70%	77%	100%	112%
Low	na	4%	na	132%	46%	235%
Normal	1100%	17%	na	85%	85%	113%
Alt 5						
High	93%	81%	140%	92%	114%	108%
Low	na	0%	na	149%	69%	236%

Normal	1750%	47%	na	106%	115%	148%

Notes: Colored cells indicates the Alternative differs by more than 5% from the No Action Alternative. Flows providing 80%, 90% and 100% of the MWUA are listed in Table. When there were zero days of occurrence under the NAA, a percentage could not be calculated and "na" was entered.

Survival

For Chinook adults (Chinook redds surviving until swim-up model), results were better compared to the NAA in all water years for Alternatives 1 and 2b, and worse in all water years for Alternative 3a. Results were mixed, depending on water year for the other alternatives, with Alternatives 2a and 4 performing better than the NAA in the dry year (2015).

For Chinook juveniles (Chinook salmon adult equivalents), results were similar or better for all alternatives compared to the NAA in the dry (2015) and moderate (2016) year modeled. Results were poorer in the wet (2011) year modeled for all alternatives compared to the NAA, except for Alternative 2a.

Table 5-21. Percent difference from the NAA in estimated survival of spring Chinook in the Middle Fork below Dexter Dam for three simulation years.

	Chinook redds surviving until swim-up	Chinook salmon adult equivalents
Alt1		
2011	43%	-25%
2015	140%	3%
2016	13%	8%
Alt2a		
2011	5%	6%
2015	134%	7%
2016	-9%	3%
Alt2b		
2011	13%	-11%
2015	53%	9%
2016	16%	7%
Alt3a		
2011	-23%	-22%
2015	-6%	-3%
2016	-46%	-1%
Alt3b		
2011	17%	-16%
2015	-25%	2%

2016	23%	4%
Alt4		
2011	-9%	-19%
2015	60%	6%
2016	-3%	0%

Table Notes: Colored cells indicate the Preferred Alternative is different by 5% or more from the No Action Alternative. Percentages calculated from results presented in WVS EIS Appendix E, Chapter 5, Tables 5-5, 5-6 and 5-7.

5.5.5 Mainstem Willamette RIVER Juvenile Habitat – Albany

Results for spring Chinook juvenile habitat in the mainstem Willamette in the Albany Reach (as defined by White et al. (2022) showed variation in habitat availability under the alternatives compared to the NAA. Generally, alternatives provided similar to somewhat lower habitat availability compared to the NAA in winter months, similar to higher habitat availability in spring months, and mixed results in summer and fall. In low water year types these same patterns occurred, but habitat in April and May was higher in all the alternatives compared to the NAA. Alternative 3a showed the most difference from the NAA, with lower habitat availability in spring and higher availability in summer compared to the NAA, likely due to delaying refill of some reservoirs associated with fish passage measures included in this alternative.

Table 5-22. Habitat available, as a percentage of the habitat available under the No Action Alternative (NAA), for juvenile spring Chinook in the Albany Reach (as defined in White et al. 2022) under each WVS EIS alternative and the near-term operational measures (NTOM).

	alt1	alt2a	alt2b	alt3a	alt4	alt5	NTOM
Water Year Type: High							
Jan	100.0	100.0	102.0	101.5	100.0	102.1	102.8
Feb	100.0	100.0	95.9	91.0	100.0	95.8	92.4
Mar	100.0	100.0	89.2	71.9	100.0	90.7	90.5
Apr	100.0	100.0	93.3	80.9	100.0	94.6	84.2
May	100.0	100.0	97.5	88.2	100.0	97.8	102.0
Jun	100.0	100.0	100.7	107.1	100.0	101.0	104.1
Jul	98.6	100.0	101.6	100.3	100.0	101.4	95.3
Aug	97.7	105.0	105.1	108.2	104.7	104.9	105.8
Sep	102.6	103.4	104.9	115.1	103.5	104.8	99.5
Oct	107.6	95.7	104.0	112.3	93.5	102.1	98.1
Nov	100.0	99.2	105.1	123.8	99.4	106.8	115.3
Dec	100.0	100.0	102.8	105.6	100.0	102.4	101.8
Water Year Type: Low							
Jan	100.0	100.0	102.6	103.8	100.0	102.6	106.4
Feb	100.0	100.0	96.1	92.1	100.0	95.8	92.1
Mar	100.0	100.0	86.2	63.6	100.0	90.1	88.6
Apr	132.6	131.0	117.1	105.8	131.1	109.8	107.2

May	131.9	121.1	117.0	108.2	121.5	112.1	113.2
Jun	107.5	97.5	100.4	103.7	97.6	100.2	100.5
Jul	93.0	99.0	99.4	100.1	99.1	99.3	99.4
Aug	93.5	100.1	100.4	106.2	99.9	100.3	101.7
Sep	93.5	99.9	100.0	103.5	100.0	100.2	102.1
Oct	100.6	94.0	97.4	103.5	94.7	99.3	95.2
Nov	95.2	96.6	98.8	100.1	94.7	99.5	93.2
Dec	100.2	100.6	103.8	107.4	100.7	103.7	103.8
Water Year Type: Normal							
Jan	100.0	100.0	101.7	100.8	100.0	102.1	103.2
Feb	100.0	100.0	95.6	90.1	100.0	95.6	91.4
Mar	100.0	100.0	86.1	63.4	100.0	88.5	88.1
Apr	108.4	108.6	95.5	77.9	107.8	97.5	85.1
May	106.4	102.2	100.0	91.3	102.5	100.4	109.6
Jun	101.6	98.2	100.7	107.8	98.2	101.3	104.3
Jul	94.6	100.1	100.6	100.4	100.0	100.8	99.3
Aug	97.0	103.8	103.9	108.7	103.8	104.3	105.1
Sep	99.5	103.2	103.6	109.8	103.4	102.4	102.8
Oct	104.8	92.4	100.8	110.1	92.8	96.8	93.8
Nov	98.6	96.4	103.8	121.0	93.2	107.6	109.8
Dec	100.0	100.0	103.5	109.6	100.1	103.9	104.8

Table notes: Highlighted cells indicate if percentage is less than or greater than 5% different from the NAA.

5.5.6 Mainstem Willamette RIVER Juvenile Habitat - Salem

Modeling results for spring Chinook juvenile habitat in the mainstem Willamette in the Salem Reach (as defined by White et al. (2022) showed that habitat availability was similar to higher during nearly all months and water year types under Alternatives 1, 2a, 2b and 5 compared to the NAA. In particular, generally more habitat was available in a majority of the months under Alternatives 2a and 2b compared to the NAA in all water year types. Under Alternative 3a and the NTOM, less habitat was available compared to the NAA during spring, likely due to delaying refill of some reservoirs associated with fish passage measures included in these alternatives.

Table 5-23. Habitat available, as a percentage of the habitat available under the No Action Alternative (NAA), for juvenile spring Chinook in the Salem Reach (as defined in White et al. 2022) under each WVS EIS alternative and the near-term operational measures (NTOM).

	alt1	alt2a	alt2b	alt3a	alt4	alt5	NTOM
Water Year Type: High							
Jan	100.0	362.7	365.3	110.3	100.0	106.9	107.8
Feb	100.0	306.3	296.1	91.0	100.0	97.7	91.3
Mar	100.1	349.5	315.9	66.7	100.4	94.1	92.7
Apr	101.5	376.7	347.7	76.4	100.6	96.8	89.1
May	100.0	273.2	264.8	88.9	100.0	98.2	101.1

Jun	100.0	182.4	186.0	101.9	100.0	99.9	101.3
Jul	100.0	99.4	99.3	99.3	98.9	99.2	97.9
Aug	100.0	98.4	98.3	100.0	99.8	100.0	100.0
Sep	102.1	103.5	103.6	102.8	101.8	99.3	95.0
Oct	100.0	122.1	123.2	103.4	99.7	91.6	91.7
Nov	99.9	246.0	257.5	121.5	100.2	106.7	110.0
Dec	100.0	324.4	340.6	116.8	100.0	104.5	107.5
Water Year Type: Low							
Jan	100.0	351.7	355.7	113.6	100.0	108.8	110.6
Feb	100.0	203.9	203.5	93.3	100.0	98.3	92.9
Mar	100.5	166.3	163.9	67.9	101.3	96.0	94.3
Apr	120.6	157.1	157.3	101.5	118.1	111.0	104.7
May	112.6	129.9	130.4	102.0	110.7	108.9	106.4
Jun	102.1	104.3	104.3	100.4	98.9	99.7	100.4
Jul	99.8	98.2	98.2	100.0	99.7	99.6	100.0
Aug	100.0	98.3	98.3	99.5	100.0	100.0	100.0
Sep	100.1	99.5	99.6	100.0	100.7	100.0	100.0
Oct	99.6	102.2	102.3	99.9	99.8	96.7	97.5
Nov	91.3	166.9	171.3	100.2	95.1	96.5	95.2
Dec	100.1	389.4	397.3	115.0	100.3	106.6	107.3
Water Year Type: Normal							
Jan	100.0	409.7	413.5	111.5	100.0	108.4	109.2
Feb	100.0	304.9	293.8	90.2	100.0	97.7	92.3
Mar	100.3	267.6	249.1	62.5	100.7	93.8	92.4
Apr	105.5	216.5	210.4	79.9	105.1	99.8	92.9
May	102.5	164.2	162.6	92.6	100.7	99.2	103.8
Jun	101.1	116.0	116.5	101.8	97.9	99.3	100.6
Jul	99.6	98.3	98.3	99.5	99.1	99.2	98.9
Aug	99.9	98.2	98.2	99.8	99.8	100.0	100.0
Sep	101.5	101.1	101.4	101.9	101.6	99.7	99.4
Oct	99.7	113.8	115.3	102.3	99.5	91.1	91.9
Nov	97.3	199.7	205.6	118.2	98.5	107.7	107.9
Dec	100.0	286.2	293.8	114.8	100.1	106.2	107.1

Table notes: Highlighted cells indicate if percentage is less than or greater than 5% different from the NAA.

5.5.7 Summary for Priority Lifestage and Water Year Type

Optimal flows for adult and juvenile salmon and steelhead habitat and survival differ. Where tradeoffs must be considered, both lifestage and water year type are aspects important to consider for prioritization.

There is a higher likelihood of adult upstream migrants' effectively reproducing compared to the likelihood of a younger life stage doing so. Upstream migrating adults are much closer in both time and space to contributing to population reproduction than younger life stages. Young life stages must migrate downstream and survive rearing in the ocean before returning as adults to reproduce, and as such subject to significant levels of mortality from factors which cannot be controlled by management actions. Therefore, management targeting adults is expected to have a much larger effect on population abundance.

In addition to lifestage priority considerations, performance in dry years is likely more important to consider compared to normal and wet year types. There is more storage available in normal and wet years providing real-time flexibility to achieve management objectives. Furthermore, the effects of hot air temperatures on water temperatures can be exacerbated in dry years when flows are lower, increasing effects of dry water years on salmon and steelhead. In the North Santiam in the dry years, the alternatives (with the exception of 3a) provided more days above the 80% and 90% MWUA spawning flow levels compared the NAA for Chinook, and the same number of days for steelhead. Fewer days were provided under Alternative 3a compared to the NAA. Chinook survival to egg swim up was similar to the NAA (within 5%) under Alternatives 2a, 2b and 4, and lower than the NAA under the other alternatives. A model of adult steelhead to egg swim up was not completed. Results for the smolt and juvenile steelhead models in the dry year showed similar to higher survival in all alternatives except 3a compared to the NAA.

In the South Santiam in the dry years, the alternatives (with the exception of 3b) provided more days above the 80% and 90% MWUA spawning flow levels compared the NAA for Chinook, and the same or higher number of days for steelhead spawning. Under Alternative 3b compared to the NAA fewer days were provided meeting MWUA Chinook spawning flows and results were mixed for steelhead spawning. Chinook survival to egg swim up was higher under all alternatives compared to the NAA with the exception of 3b. A model of adult steelhead to egg swim up was not completed. Results for the smolt and juvenile steelhead models in the dry year showed similar to higher survival in all alternatives compared to the NAA, except for Age-1 steelhead under Alternatives 1 and 3b.

In the McKenzie, the alternatives provided fewer days above the MWUA spawning flow levels compared the NAA. Conversely, Chinook survival to egg swim up was similar to higher under all alternatives compared to the NAA. This may be because although spawning habitat availability changes, it is adequate under the alternatives, and the combined effects on survival for upstream migrating adults into the McKenzie and survival of their eggs during incubation is better. Given these results, monitoring will be important during implementation to ensure spawning habitat availability is not limiting.

In the Middle Fork below Dexter Dam, the alternatives provided fewer days above the MWUA spawning flow levels compared the NAA. Chinook survival to egg swim up was higher under

Alternatives 1, 2a, 2b, and 4 compared to the NAA, and lower under Alternatives 3a and 3b. UWR steelhead are not present in the McKenzie.

When looking specifically at the draft preferred alternative (represented by alternative 2b in this assessment) with the priorities of effective adult spawning in dry years, similar to more days above the 80% and 90% MWUA flow spawning levels for Chinook and steelhead were provided compared to the NAA in the North and South Santiam below WVS dams, and fewer days for Chinook in the South Fork McKenzie and Middle Fork below WVS dams. Chinook survival to egg swim up was similar to higher under the draft preferred alternative compared to the NAA in all sub-basins, despite there being fewer days at flows above the MWUA spawning levels in the South Fork McKenzie and Middle Fork. Steelhead survival was not modeled for adults to egg swim up. Steelhead juvenile and smolt survival was similar to higher in the North Santiam and South Santiam under the draft preferred alternative compared to the NAA in all sub-basins.

Table 5-24. Summary of flows were greater than levels providing 80% (lower bound; LB), 90% (lower bound; LB) and 100% maximum weighted usable area (MWUA) for Chinook salmon spawning during August 15 to November 1 (79 day period) below Big Cliff Dam in dry years for each alternative compared to the NAA.

	Days flows greater than MWUA flow level as a Percent of the NAA					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
Alt 1	=/+	=/+	-	=/+	=/+	-
Alt 2a	=/+	=/+	-	=/+	=/+	-
Alt 2b	=/+	=/+	-	=/+	=/+	-
Alt 3a	-	-	-	-	-	-
Alt 3b	=/+	=/+	=/+	=/+	=/+	=/+
Alt 4	=/+	=/+	-	=/+	=/+	-
Alt 5	=/+	=/+	-	=/+	=/+	-

Table Note: highlighted cells > or < 5% of NAA.

Table. Summary of flows were greater than levels providing 80% (lower bound; LB), 90% (lower bound; LB) and 100% maximum weighted usable area (MWUA) for winter steelhead spawning during March 15 to June 1 (79 day period) below Big Cliff Dam in dry years for each alternative compared to the NAA.

	Days flows greater than MWUA flow level as a Percent of the NAA					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
Alt 1	=/+	=/+	-	=/+	=/+	-
Alt 2a	=/+	=/+	-	=/+	=/+	-
Alt 2b	=/+	=/+	-	=/+	=/+	-
Alt 3a	-	-	-	=/+	=/+	-

Alt 3b	=/+	=/+	-	=/+	=/+	-
Alt 4	=/+	=/+	-	=/+	=/+	-
Alt 5	=/+	=/+	-	=/+	=/+	-

Table Note: highlighted cells > or < 5% of NAA.

Table 5-25. Percent difference from the NAA in estimated survival for spring Chinook and winter steelhead in the Middle Fork below Big Cliff Dam in a hot and dry year, 2015.

	Chinook redds surviving until swim-up	Steelhead trout smolt survival	Steelhead trout Age-1
Alt1	-38%	-3%	20%
Alt2a	3%	-2%	16%
Alt2b	-4%	-2%	19%
Alt3a	-30%	-5%	-43%
Alt3b	-8%	0%	45%
Alt4	-2%	-2%	1%

Table 5-26. Summary of flows were greater than levels providing 80% (lower bound; LB), 90% (lower bound; LB) and 100% maximum weighted usable area (MWUA) for Chinook salmon spawning during August 15 to November 1 (79 day period) below Foster Dam in dry years for each alternative compared to the NAA.

	Days flows greater than MWUA flow level as a Percent of the NAA					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
Alt 1	=/+	=/+	-	=/+	=/+	-
Alt 2a	=/+	=/+	-	=/+	=/+	=/+
Alt 2b	=/+	=/+	-	=/+	=/+	=/+
Alt 3a	=/+	=/+	-	=/+	=/+	=/+
Alt 3b	-	-	-	-	-	-
Alt 4	=/+	=/+	-	=/+	=/+	=/+
Alt 5	=/+	=/+	-	=/+	=/+	=/+

Table Note: highlighted cells > or < 5% of NAA.

Table 5-27. Summary of flows were greater than levels providing 80% (lower bound; LB), 90% (lower bound; LB) and 100% maximum weighted usable area (MWUA) for winter steelhead spawning during March 15 to June 1 (79 day period) below Foster in dry years for each alternative compared to the NAA.

	Days flows greater than MWUA flow level as a Percent of the NAA					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
Alt 1	=/+	=/+	-	=/+	=/+	-
Alt 2a	=/+	=/+	-	=/+	=/+	-
Alt 2b	=/+	=/+	-	=/+	=/+	-
Alt 3a	=/+	=/+	-	=/+	=/+	-
Alt 3b	=/+	-	=/+	=/+	=/+	-
Alt 4	=/+	=/+	-	=/+	=/+	-
Alt 5	=/+	=/+	-	=/+	=/+	-

Table Note: highlighted cells > or < 5% of NAA.

Table 5-28. Percent difference from the NAA in estimated survival for spring Chinook and winter steelhead in the Middle Fork below Foster Dam in a hot and dry year, 2015.

	Chinook redds surviving until swim-up	Steelhead trout smolt survival	Steelhead trout Age-1
Alt1	37%	-4%	-11%
Alt2a	54%	-3%	3%
Alt2b	51%	-3%	12%
Alt3a	54%	-4%	84%
Alt3b	-100%	-4%	-9%
Alt4	37%	-3%	15%

Table 5-29. Summary of flows were greater than levels providing 80% (lower bound; LB), 90% (lower bound; LB) and 100% maximum weighted usable area (MWUA) for Chinook salmon spawning during August 15 to November 1 (79 day period) below Cougar Dam in dry years for each alternative compared to the NAA.

	Days flows greater than MWUA flow level as a Percent of the NAA					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
Alt 1	-	-	-	=/+	=/+	=/+
Alt 2a	-	-	-	=/+	=/+	=/+
Alt 2b	-	-	-	-	-	-

Alt 3a	-	-	-	-	-	-
Alt 3b	-	-	-	-	-	-
Alt 4	-	-	-	=/+	=/+	=/+
Alt 5	-	-	-	-	-	-

Table Note: highlighted cells > or < 5% of NAA.

Table 5-30. Percent difference from the NAA in estimated survival for spring Chinook and winter steelhead in the Middle Fork below Cougar Dam in a hot and dry year, 2015.

	Chinook redds surviving until swim-up
Alt1	7%
Alt2a	9%
Alt2b	4%
Alt3a	0%
Alt3b	0%
Alt4	7%

Table 5-31. Summary of flows were greater than levels providing 80% (lower bound; LB), 90% (lower bound; LB) and 100% maximum weighted usable area (MWUA) for Chinook salmon spawning during August 15 to November 1 (79 day period) below Dexter Dam in dry years for each alternative compared to the NAA.

	Days flows greater than MWUA flow level as a Percent of the NAA					
	Minimum			Average		
	80% MWUA	90% MWUA	100% MWUA	80% MWUA	90% MWUA	100% MWUA
Alt 1	-	-	-	=/+	-	=/+
Alt 2a	-	-	-	=/+	-	=/+
Alt 2b	-	-	-	=/+	-	=/+
Alt 3a	-	-	-	-	-	-
Alt 3b	-	-	-	=/+	-	=/+
Alt 4	-	-	-	=/+	-	=/+
Alt 5	-	-	-	=/+	-	=/+

Table Note: highlighted cells > or < 5% of NAA.

Table 5-32. Percent difference from the NAA in estimated survival for spring Chinook and winter steelhead in the Middle Fork below Dexter Dam in a hot and dry year, 2015.

	Chinook redds surviving until swim-up
Alt1	140%
Alt2a	134%
Alt2b	53%
Alt3a	-6%
Alt3b	-25%
Alt4	60%

5.6 REFERENCES

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CHAPTER 6 - ASSESSMENT OF THE EFFECT OF WILLAMETTE VALLEY SYSTEM OPERATIONS AND MANAGEMENT ALTERNATIVES ON RESIDENT FISHES SOUGHT BY ANGLERS IN WILLAMETTE VALLEY RESERVOIRS

6.1 INTRODUCTION

Under the NAA, many WVS reservoirs undergo a partial reservoir drawdown each fall for flood risk management. Exceptions include re-regulation projects (Big Cliff and Dexter) which fluctuate on a daily but not seasonable basis, and Fall Creek which is fully evacuated each fall and then refilled during the conservation season as other WVS reservoirs. Under the NAA, pool elevations are managed to maintain the minimum conservation pool elevations from mid-November or December 1 (depending on the reservoir) to February 1 annually, except during storm events when water is temporarily captured in reservoirs. Refill begins in February each year following pre-defined water management diagrams (i.e. rule curves). This operating regime has occurred since the dams were constructed several decades ago. Measures in the WVS EIS include 1) continuing with a similar reservoir operating regime, 2) deeper drawdowns in the fall (Measure 40) and 3) deeper drawdowns in the spring (Measure 720). Different combinations of these operating regimes are included in the WVS EIS alternatives.

Resident fish occurring in WVS reservoirs provide recreational fishing opportunity. Annual water level fluctuations have important effects on habitat availability and downstream passage rates, and therefore fish survival, productivity and abundance. Some fish species are annually stocked in larger WVS reservoirs, supplementing their availability regardless of contributions from natural reproduction or reductions in abundance from conditions within the reservoirs or downstream passage/entrainment rates.

This assessment was completed to estimate the potential effects for resident fish, particularly those targeted for sport fishing in the larger reservoirs. The assessment focused on the following fish species commonly targeted in local recreational fisheries:

- Kokanee (*Oncorhynchus nerka*)
- Smallmouth bass (*Micropterus dolomieu*)
- Crappie (*Pomoxis* spp.)
- Rainbow trout (*Oncorhynchus mykiss*)

The assessment focused on the following reservoirs which have relatively larger recreational fisheries than others in the WVS:

- Detroit
- Green Peter
- Lookout Point
- Hills Creek

6.2 ASSESSMENT APPROACH

To assess the effects of EIS alternatives on the abundance of resident fishes commonly targeted by sport anglers in WVS reservoirs, reservoir conditions were qualitatively related to effects on spawning, rearing, foraging, predation risk, and risk of entrainment downstream through the dams. To accomplish this, life history information for targeted fish species was summarized. Available reports and information shared by WVS EIS Cooperating Agencies was also reviewed to assess the effects of water level fluctuations on spawning, rearing, foraging, predation risk, and risk of entrainment. However very limited information was available to relate reservoir volume to these factors. After reviewing species life history information, distribution and passage data, assumptions were developed to relate changes in reservoir volume to these factors and develop effect criteria associated with changes in reservoir volume. Reservoir elevations were then summarized for each alternative based on modeling completed using RES-SIM (EIS Appendix B), and the effects of each alternative on fish availability in WVS reservoirs was assigned. Stocking practices were then considered, which help to mitigate the effects of changes in reservoir volume and maintain availability of fish for angling, before assigning effect categories for each reservoir by alternative.

6.3 REVIEW OF FISH LIFE HISTORY

6.3.1 Rainbow Trout

Life history and habitat use patterns – Rainbow trout occur in Detroit, Green Peter, Lookout Point and Hills Creek reservoirs. From USGS (2023):

> Rainbow trout are a deep-bodied, compressed species with a typical trout body shape, a moderately large head, and a mouth that extends back behind the eyes. Rainbow trout have highly variable coloration: those that live in lakes are silvery with a dark olive-green color on the back, though the dorsal coloration is sometimes a deep steely blue, mostly in fish that live offshore in deep lakes or in small fish that have not yet spawned. Numerous spots are present on the back and extend about two-thirds of the way to the lateral line down the sides. The sides are silvery and largely free of spots, the belly and ventral surface of the head are whitish, and sometimes a soft metallic-pink color is present along the sides of the body and the head (GISD, 2019). Their native range covers the Pacific Slope from Kuskokwim River, Alaska, to (at least) Rio Santa Domingo, Baja California; upper Mackenzie River drainage (Arctic basin), Alberta and British Columbia; and endorheic basins of southern Oregon (Page and Burr 1991).
> Lake fish usually spawn in lake tributaries, where the young trout feed and grow before migrating downstream after about a year. Growing to maturity in the lake takes between 2-4 years, at which time they migrate back to the tributaries to spawn. Most fish will return to the tributary in which they hatched (McDowall, 1990). Some lake populations may spawn in lake-shore gravels rather than travel into tributaries, however. Adult rainbow trout eat insects (both aquatic and terrestrial), crustaceans, molluscs, fish eggs, and small fish. Young trout feed predominantly on zooplankton (GISD, 2019).

Downstream Passage Patterns at WVS Dams – Passage of *Oncorhynchus mykiss* has been well studied at Detroit and Foster dams (e.g. Hansen et al. 2017). Several of these studies include both the anadromous form (steelhead) and resident form (rainbow trout). Steelhead would be expected to have higher passage rates than resident forms, however data are limited for quantifying this difference. Generally, passage rates increase as depths to outlets decreases and secondarily as discharge increases. Seasonally, many pass downstream when surface spill occurs in spring, and when reservoirs are drawn down in the fall. Survival depends on the size of the fish, route of passage utilized, hydraulic head over the outlet, and rate of discharge, and can range from very low to over 80% percent. Passage patterns for rainbow trout at other large WVS dams is assumed to be similar to Detroit Dam.

Stock practices in WVS reservoirs – Triploid (sterile) hatchery rainbow trout are released multiple times per year into WVS reservoirs to provide for sport fishing opportunities. These hatchery fish come from various facilities (Leaburg, Willamette, Roaring River, Wizard Falls, Marion Forks, and Desert Springs). According to the 2021 Hatchery Genetics Management Plan for rainbow trout (ODFW and USACE, 2021), up to 472,825 pounds of trout are stocked into Willamette Basin waterbodies (including WVS reservoirs and other waterbodies) annually (Table 1). For waterbodies without ESA-listed fish present, ODFW determines trout stocking levels. ODFW prepares annual reports providing the pounds and numbers of hatchery fish propagated and released (e.g. ODFW 2022, ODFW 2023). For example, in 2022, a total of 305,326 hatchery rainbow trout (totaling 44,928 pounds) were released into Detroit Reservoir. The range of annual release dates is between February and October. Releases are timed for maximum public harvest utilization and opportunities. Stocking schedules are reported online by ODFW: https://myodfw.com/fishing/species/trout/stocking-schedule. At the time of this assessment, ODFW reported that 40,400 legal sized rainbow trout would be stocked into Green Peter between April 3, 2023 and May 3, 2024, 40,000 trophy sized rainbow trout will be stocked between May 15 and June 30, 2023 into Detroit Reservoir, and 14,200 legal sized rainbow trout between February 20 and October 6, 2023 into Hills Creek Reservoir (ODFW, 2023b). Full annual stocking schedules were not available for Detroit and Hills Creek reservoirs. No trout are to be stocked into Lookout Point reservoir according to the ODFW trout stocking schedule. For this assessment, stocking of rainbow trout into Detroit, Green Peter, Hills Creek and other WVS reservoirs would continue at levels specified in the 2021 Hatchery Genetics Management Plan.

Table 6-1. Maximum pounds of trout to be released annually into ESA-listed fish waterbodies, effective beginning in 2020. Reproduced from Table 10.1-1 included in ODFW and USACE (2021)

Waterbody	Total pounds of trout
Alton Baker Canal	25,000
Bethany Pond	1,500
Billy Lake	20
Blue River Above Reservoir	3,000
Blue River Reservoir	8,000
Breitenbush River	6,700
Buck Lake	10
Canby Pond	800
Carmen Reservoir	8,000
Clear Lake	15,000
Commonwealth Lake	1,200
Cottage Grove Reservoir	30,000
Crabtree Lake	20
Crabtree Pond	5
Cronemiller Lake	200
Detroit Reservoir	59,000
Dexter Reservoir	15,000
Dorena Reservoir	30,000
Dorman Pond	2,000

EE Wilson Pond	7,300
Fall Creek above Reservoir	5,000
Fall Creek Reservoir	7,500
Foster Reservoir	16,000
Freeway Lake, East	1,800
Green Peter Reservoir	20,000
Henry Hagg Lake	27,000
Hills Creek Reservoir	30,000
Huddleston Pond	4,000
Junction City Pond	11,500
Lake Eleanor	20
Leaburg Lake	10,000
McKenzie R above Leaburg Dam	25,000
McKenzie R below Leaburg Dam	15,000
Progress Lake	1,300
Quartzville Creek	7,900
Roaring River Park	400
Row River Nature Park	5,000
Salmon Creek	7,000
Santiam R, N Fk, Above res	12,000
Sheridan Pond	3,500
Silver Cr Reservoir	6,500
Smith Reservoir	5,000
St Louis Pond	2,800
Sunnyside Pond	1,550
Timber Linn Pond	1,500
Trail Bridge Reservoir	10,000
Walling Pond	3,700
Walter Wirth Lake	10,600
Waverly Lake	2,500
Willamette R, Cst Fk	5,000
Yamhill River	1,000
Total	472,825

Table note: For waterbodies without ESA-listed fish present, ODFW determines trout stocking levels.

Stocking of hatchery rainbow trout can have detrimental effects on native fish. From USGS (2023):

> Stocking of hatchery rainbow trout in rivers has led to introduction of whirling disease into open waters in approximately 20 states including, most recently, the Madison River and its tributaries in Montana (B. Nehring and R. White, personal communication). In the Madison River, the disease has reduced the rainbow trout population by 90% (White, personal communication).

Rainbow trout have the potential to consume native fishes and compete with native salmonids (Page and Laird 1993). Introduced rainbow trout eat endangered humpback chub Gila cypha in the Little Colorado River, and may exert a major negative effect on the population there (Marsh and Douglas 1997). Fausch (1988), Clark and Rose (1997), and numerous papers cited in both, discussed several factors affecting competitive interactions between rainbow and brook trout. Rainbow trout drive nongame fishes such as suckers and squawfish from feeding territories (Li, personal communication to P. Moyle in Moyle 1976a). Introduced predatory fishes, including the rainbow trout, are likely at least partially responsible for the decline of the Chiricahua leopard frog *Rana chiricahuensis* in southeastern Arizona (Rosen et al. 1995).

6.3.2 Kokanee

Life history and habitat use patterns – Among reservoirs included in this assessment, kokanee occur in Detroit and Green Peter reservoirs. Kokanee are a non-anadromous form of the species *Oncorhynchus nerka*. Kokanee live their entire lives in freshwater. Their life span is typically 4 years long, and most die after spawning. Kokanee are native to many lakes in the Pacific Northwest, and have been introduced to many reservoirs.

Kokanee spawning occurs in September or October and can occur along lake shorelines or in tributary streams. This timing has been observed in the North Santiam above Detroit Reservoir (Wetherbee, 1965). Kokanee maturing in WVS reservoirs spawn in upstream tributaries due to the steep slopes of the nearshore areas and water level fluctuations (e.g. Wetherbee, 1965). After hatching, fry live in the gravel for about one month. As reviewed by Quinn (2005), fry emerge from stream gravels and immediately migrate to lakes. Fry generally feed on aquatic insects and zooplankton in nearshore areas. Once reaching about 50 mm in length, they move into open water where they feed on zooplankton. Growth rates are influenced by food availability and temperature. It is assumed kokanee rearing patterns are the same as those observed for sockeye.

Monzyk et al. 2012 reported that from August through October, most kokanee in Detroit Reservoir were caught in the 18-23 m (60-75 ft) depth range, with a seasonal shift towards the surface in November and December. This is consistent with other reports on vertical distribution. Distribution and diel migration of kokanee has been shown to vary in association with prey availability and fish density (Buktenica et al. 2007).

Kokanee can grow several inches in a year in Detroit Reservoir (Wetherbee, 1965). In recent years density may be affecting kokanee growth rates in Green Peter Reservoir. One fishing website reports “For the past several years, the Kokanee at Green Peter have been very abundant, but also very small, sometimes only averaging 7”, which was too small to entice many anglers to go after them” and further that “Kokanee are still over populated and running very small, like 7-9” (KPO, 2023). Similar comments were posted on other fishing websites (Apalategui, E. 2023).

It is unlikely that kokanee which move downstream of WVS dams will adopt an anadromous life history. Anadromy at least in part is genetically determined, and research on sockeye and kokanee indicates a relatively sharp division between these two forms (Quinn, 2005). Few adult sockeye are observed at adult fish collection facilities downstream from WVS dams in the North or South Santiam rivers. ODFW avoids risks of disease transference by not transporting returning adult sockeye back upstream of WVS dams.

Downstream Passage Patterns at WVS Dams - Due to the deeper vertical distribution of kokanee in summer and early fall, kokanee moving within forebays of WVS reservoirs are exposed to entrainment downstream. Outlets at both Detroit and Green Peter dams are located at depths kokanee regularly occur at during summer and fall. Rotary screwtraps operated below Detroit Dam indicate kokanee pass downstream at Detroit Dam primarily in the fall (Romer et al. 2012). Only the turbine penstocks or regulating outlets were operated in fall. The spillway was operated in summer, and passage rates were lower compared to the fall through other routes (Khan et al. 2011; Romer et al. 2012). Observations by Khan et al. (2011) using hydroacoustics to assess fish vertical distribution and passage at Detroit Dam suggests kokanee will readily use the RO when it is operated in lieu of turbines to pass the dam. Direct capture numbers for kokanee peaked in early November during RO operations (Romer et al. 2012), and a similar peak was observed in the hydroacoustic data during the same period (Khan et al. 2011). Quantitative estimates of the number or proportion of kokanee moving downstream of WVS dams are not available. Entrainment rates under existing operations have not diminished the development of popular fisheries in both Detroit and Green Peter reservoirs.

Stock practices and fishing in WVS reservoirs – Kokanee were originally stocked into Detroit Reservoir in 1959 (Wetherbee, 1965). In 2011, the Detroit reservoir was stocked with 55, 125 kokanee for a sport fishery, which is less than half of the usual stocking amount due to low egg availability (personal communication with Doug Curtis, Wizard Falls Hatchery, Camp Sherman, Oregon as cited in Khan et al. 2011). Kokanee Stocking has remained constant at 25,000 annually in October since 2016 (KPO, 2023). Information on reservoir fish stocking plans by ODFW was requested from the USACE by email from R. Piaskowski to E. Kelley and J. Ziller on May 26, 2023. . Kelley emailed reply June 15, 2023 stated kokanee are not currently stocked in Green Peter Reservoir but have been in the recent past. For this assessment It was assumed stocking of kokanee into Detroit and Green Peter reservoirs would continue or resume as needed to maintain fishing opportunity.

Recent changes in stocking practices have apparently improved survival of hatchery kokanee released into Detroit Reservoir. Compared to previous practices, kokanee have been released at a larger size (6-7 inches) and later in the summer or early fall in recent years to reduce predation on kokanee by stocked hatchery rainbow trout (Gearing, 2023). Many kokanee are 11 to 12 inches when caught by anglers from Detroit Reservoir. Assuming similar growth rates as reported by Wetherbee (1965), then these fish were either stocked into the reservoir the prior year, or at most 2 years prior, before being caught.

Per ODFW Willamette Zone fishing regulations (ODFW 2023c), kokanee are included in trout limits for which there is an 8 inch minimum length. However, in Green Peter Reservoir, Lookout Point Reservoir there is no size limit for those which can be removed by angling.

According to one website covering fishing in WVS reservoirs, “Detroit Lake also has increasingly become one of the very best kokanee lakes around, and in some serious kokanee anglers’ opinions it has overtaken Green Peter Reservoir as the best kokanee fishing spot anywhere in Western Oregon” (Apalategui 2023b). Elise Kelly, ODFW fish biologist said “natural production at the lake accounts for 50 to 70% of the catch taken from the [Detroit] reservoir" (Gearing, 2023). Hatchery stocked kokanee would therefore account for the remaining 30-50% of the catch.

6.3.3 Smallmouth Bass

Life History and Habitat Use Patterns – Smallmouth bass occur in Green Peter, Lookout Point Reservoir and potentially Hills Creek Reservoir. The Smithsonian Environmental Research Center's National Estuarine and Marine Exotic Species Information System (Smithsonian ERC, 2023) summarized the following on smallmouth bass ecology

> The Smallmouth Bass (*Micropterus dolomieu*) is a freshwater predatory fish. Adults can mature at 2 years, or as late as 9 years, but more usually at age 3–4. Virginia and California populations at age 3 to 4 range from 190 to 410 mm at these ages (Jenkins and Burkhead 1994; Moyle 2002). Spawning takes place at 16–27 C, in freshwater, often moving upstream in tributaries. Adult male fish move into shallow water, ~1 m deep, near shore, and excavate a nest in sand, gravel, or rock (Hardy 1978; Wang 1986; Jenkins and Burkhead 1993; Moyle 2002). Males guard a nesting site against other males, and court females. Females may spawn with more than one male, and males may spawn with more than female. Females can carry ~2,000–21,000 eggs. Males vigorously guard the eggs through hatching and until the larvae reach 20–30 mm. Eggs take 2.5–9 days to develop at 15–26 C (Hardy 1978; Jenkins and Burkhead 1994; Moyle 2002).
> Smallmouth Bass inhabit clear gravel-bottom runs and flowing pools of small to large rivers, and the rocky shoals of lakes (Hardy 1978; Page and Burr 1991; Wang 1986). In the Chesapeake Bay region, it is common in the Piedmont and Fall Line, the bottoms are rocky, and currents are strong, but this fish is rare in the Coastal Plain region, where currents are slower, temperatures are higher, and oxygen is lower (Jenkins and Burkhead 1993; Murdy et al. 1997). Preferred temperatures are 20–28 C, but Smallmouth Bass have been collected at 4 °C and have an experimental upper lethal temperature of 35 °C (Hardy 1978). They are rare in brackish water, but have been collected at 7.4 PSU (Hildebrand and Schroeder 1928). Smallmouth Bass tolerates dissolved oxygen of 0.9-1.0 ppm at 21 °C, but is usually associated with well-oxygenated waters (Carlander 1977). Juveniles feed on microcrustaceans and insects, and switch to fish and crayfish as they grow. Other prey include amphibians, insects, and other Smallmouth Bass (Jenkins and Burkhead 1993; Moyle 2002). The Largemouth (M. salmoides) and Spotted Bass (M. punctulatus) are potential competitors. Humans are the primary predators of adult fish as the Smallmouth is an esteemed gamefish.

From the U.S. Forest Service (USFS 2023):

> Smallmouth bass prefer large clear-water lakes (greater than 100 acres, more than 30 feet deep) and cool streams with clear water and gravel substrate. In small streams a fish's activity may be limited to just one stream pool or extend into several. Spawning occurs in the spring. Smallmouth bass are carnivorous and feed on a variety of animals such as other fish, crayfish, reptiles, amphibians, small mammals.
> When water temperatures approach 60°F males move into spawning areas. Nests are usually located near shore in lakes; downstream from boulders or some other obstruction that offers protection against strong current in streams. Mature females may contain 2000-15,000 golden yellow eggs. Males may spawn with several females on a single nest. On average each nest

> contains about 2,500 eggs, but nests may contain as many as 10,000 eggs. Eggs hatch in about 10 days if water temperatures are in the mid 50's (°F), but can hatch in 2-3 days if temperatures are in the mid-70's (°F). Males guard the nest from the time eggs are laid until fry begin to disperse, a period of up to a month.
>
> Because of its excellent sporting reputation, smallmouth bass have been stocked throughout the United States and Arizona. Minnows, crayfish, and alderfly larvae (hellgrammites) are among the most successful live baits used. Smallmouth bass now rank among the top 15 most preferred species. Life Span – Smallmouth live on average 6 – 14 years. Some specimens have been determined to be 20 years old.

ODFW describes smallmouth bass as adapted to flowing waters and do well in warm streams with deep holes and rocky ledges (ODFW 2023d). They also prefer lakes and reservoirs with rocky shorelines and limited vegetation. Adult smallmouth feed mostly on fish and crayfish. Although not native to the western U.S., they have been transplanted into several WVS reservoirs.

Downstream Passage Patterns at WVS Dams – Sampling within WVS reservoirs included in this assessment documents smallmouth bass occurrence in Lookout Point and Hills Creek reservoirs, but not Detroit Reservoir (Monzyk and others, 2011, 2014 and 2015). Email from E. Kelley dated 6.616.23) to R. Piaskowski stated smallmouth bass also occur in Green Peter Reservoir. Although smallmouth bass occur in Lookout Point and Hills Creek reservoirs, few are observed in traps below these dams (Romer and others, 2012, 2013, 2014, 2015 and 2016). Assuming trapping provides a reasonable indication of relative passage rates, it appears downstream passage under NAA operations does not result in many of these fish passaging downstream of the reservoir. However, under deep reservoir drawdowns, passage rates would be expected to increase. At Fall Creek, where the reservoir is drawdown to river bed in the fall, large numbers of resident fishes have been collected having passed downstream during the annual drawdown. If a reservoir is drawn down however with a pool remaining upstream, it is not clear how many will exit downstream. Foster Reservoir is smaller than the reservoirs included in this assessment. Although present, few crappie are observed passing downstream of Foster Reservoir. However, this may not be a good indicator of other resident fishes downstream passage rates if a reservoir pool is drawn down substantially lower than elevations occurring under the NAA, which could result in higher densities of these fish in the forebay and increase passage rates downstream. Given they are typically distributed in nearshore areas of reservoirs in vegetated areas, it is unclear how much passage rates for smallmouth bass may change except under drawdown to riverbed.

Stock practices in WVS reservoirs – No records on stocking of smallmouth bass were found. It was assumed for this assessment no stocking occurs of smallmouth bass into WVS reservoirs or tributaries flowing into WVS reservoirs.

6.3.4 Crappie

Life History and Habitat Use Patterns – White and Black Crappie occur in Lookout Point and Hills Creek reservoirs. The Smithsonian (Smithsonian ERC, 2023b) summarized the following on the ecology of crappie:

The White Crappie (*Pomoxis annularis*) is a freshwater predatory fish. Adults can mature at 1 year, but more usually 2–3 years, depending on latitude, at sizes of 142–200 mm (Hardy 1978; Jenkins and Burkhead 1994; Moyle 2002). Spawning takes place at 14–23°C, in freshwater. Adult male fish move into shallow water, ~0.1–06 m deep, near shore, and nest in colonies. Eggs may be deposited on algae, leaves, or tree roots, or in an excavation in the substrate (Hardy 1978; Wang 1986; Jenkins and Burkhead 1993; Moyle 2002). Males guard a nesting site against other males, and court females. Females may spawn with more than one male, and males may spawn with more than female. Females can carry 970–326,000 eggs. Males vigorously guard the eggs through hatching to the postlarval stage. Eggs take 1–4 days to develop at 14-24°C. The postlarvae swim in schools in shallow, weedy waters (Hardy 1978; Wang 1986; Jenkins and Burkhead 1993; Moyle 2002). Adults in Virginia typically live up to 7 years, but one specimen lived for 9 years (Jenkins and Burkhead 1993).
White Crappies inhabit sand and mud-bottomed pools and backwaters of creeks and small to large rivers, and lakes and ponds, often associated with vegetation, and often with turbid conditions. (Hardy 1978; Page and Burr 1991; Wang 1986). They appear to be tolerant of alkaline conditions and sensitive to low pH ((Jenkins and Burkhead 1993; Moyle 2002). Based on their distribution, they tolerate ice-covered waters, and temperatures at least as high as 29°C (Hardy 1978; Page and Burr 1991). White Crappies appear to be rare in brackish water, but they have been collect at 6 PSU in Delaware Bay tributaries (Hardy 1978). They tend to school and often remain near logs or other cover. Adults have long, fine gill-rakers, and are capable of feeding on zooplankton, but are also predators on aquatic insects and fishes, including Threadfin Shad (*Dorosoma petenense*) and Mississippi Silversides (*Menidia audens*) (Moyle 2002). Predators include other fishes, birds, and humans.

Black Crappies tolerate a temperature range from 4 to 32.5 °C, and survive under ice-cover in much of their range (Hardy 1978). Most estuarine records are from tidal fresh water, but specimens have been collected at a salinity of 5.9 PSU (Smith 1971). This fish is tolerant of somewhat acidic water, and is common in the Dismal Swamp of Virginia (Jenkins and Burkhead 1993). Black Crappies inhabit lakes, reservoirs, sloughs, ponds, swamps, and backwaters and pools of streams. They are often associated with vegetation and coarse woody debris (Hardy 1978; Wang 1986; Jenkins and Burkhead 1993). Young Black Crappie feed on zooplankton, and in the Delta, mysids and amphipods, while adult fish feed smaller fishes, including juveniles of Threadfin Shad (*Dorosoma petenense*) and Striped Bass (*Morone saxatilis*). Predators include other fishes, birds, and humans.

Downstream Passage Patterns at WVS Dams – Among reservoirs included in this assessment, crappie occur in Lookout Point and Hills Creek reservoirs. Sampling within WVS reservoirs included in this assessment documents crappie occurrence in Lookout Point and Hills Creek reservoirs, but not Detroit Reservoir (Monzyk and others, 2011, 2014 and 2015). No data was available for Green Peter Reservoir. Although crappie occur in Lookout Point and Hills Creek reservoirs, few are observed in traps below these dams (Romer and others, 2012, 2013, 2014, 2015 and 2016). Assuming trapping provides a reasonable indication of relative passage rates, it appears downstream passage under NAA operations does not result in many of these fishes passaging downstream of the reservoir. However, under deep reservoir drawdowns, passage rates would be expected to increase.

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Stock practices in WVS reservoirs – No records on stocking of crappie into WVS reservoirs were found. It was assumed for this assessment no stocking of crappie occurs into WVS reservoirs or tributaries flowing into WVS reservoirs.

6.4 REVIEW OF RESERVOIR FLUCTUATIONS ON AQUATIC HABITAT, PRODUCTIVITY AND FOOD WEBS

WVS dams were constructed in the western side of the Cascade Mountains and foothills. Reservoirs inundate primarily steeply sloped valleys. Reservoir water levels fluctuate significantly each year, and can undergo significant fluctuations on a daily or seasonal timeframe as well (see WVS EIS Appendix B).

Local populations of several resident fish species have been able to naturally maintain without stocking under the current operating regime (i.e. NAA) as evidenced by their presence for several years and observations of multiple size classes collected using a variety of methods (e.g. Monzyk et al. 2014; Romer et al. 2016). Changing the operation regime to fully draining reservoirs annually to riverbed (as included as a measure for Cougar Reservoir in Alternative 3b) would significantly impact the abundance of resident fish residing in the reservoir (e.g. Murphy et al. 2019), where most fish will be flushed downstream annually. This in turn will affect predation and competition between fishes in the reservoir at other times of year. Data on the effects partial annual drawdowns deeper than occurs under the NAA, as proposed under Measures 720 and 40, are not available, however would not be expected to have the same effects as a full drawdown to riverbed. Effects of deeper partial drawdowns likely depend on each species life history and distribution, diet and food availability, presence of competitors and predators, among other factors.

There is evidence that biomass and community composition of zooplankton would not be different between current partial drawdowns depicted under the NAA and deeper drawdowns as included in the alternatives. Zooplankton, biomass and community composition in Fall Creek Reservoir, which was drawn down to the streambed for a week each fall, were not different from the other WVS reservoirs sampled that were partially drawn down each fall (Murphy et al. 2020. Peak abundance occurred in June within the WVS reservoirs sampled, similar to seasonal patterns in other oligo-mesotrophic lakes.

Deeper reservoir drawdowns will temporarily change habitat available, affect the density and distribution of fish and their primary forage items (macroinvertebrates, zooplankton, prey fish). Temporary draining of a reservoir each year to riverbed could cause normally piscivorous fish (largemouth bass and rainbow trout) to switch to feeding on invertebrates and zooplankton instead of fish, but not partial drawdowns (Murphy et al. 2019b). Partial drawdowns likely do not result in the same reduction in smaller prey fish availability compared to fully draining a reservoirs.

6.5 EFFECTS CRITERIA DETERMINATION

Information to quantify the effects of different reservoir volumes on rainbow trout, kokanee, crappie or smallmouth bass growth, survival, abundance or downstream passage rates were not available. Assumptions were developed based on review of each species life history, and available information on reservoir usage patterns, stocking practices, and downstream passage information. Assessment criteria were developed based on the conservative assumption that habitat and food availability decreases, and predation risk increases, as pool volume decreases (Table 2). These effects in turn were assumed to reduce seasonal and annual growth and survival rates leading to decreased abundance (i.e. availability for anglers). There is considerable uncertainty in this assumption. Population response to significant but partial reservoir drawdowns is complex and expected to be variable. All drawdowns influence habitat availability, densities of competitors, predators and prey. As reservoir volumes decline, compulsory movements and shifts in distribution could expose individuals to increased predation or reduce foraging opportunity, especially for littoral species or life stages. Longer duration drawdowns could allow some fishes to re-establish in preferred habitat or switch food sources, however reduced volumes could reduce carrying capacity. Responses would be expected to differ with habitat available under the drawdown, duration, season, life history patterns, reservoir aquatic community composition and trophic structure, and differences in environmental conditions.

As summarized above, data indicate downstream passage rates at WVS dams are higher for rainbow trout and kokanee compared to crappie and smallmouth bass. Data also indicate that nearly all resident fishes will move downstream when a reservoir is fully evacuated to river bed (Murphy et al. 2020. However, data were not adequate to understand how passage rates would change with a partial deeper drawdowns (i.e. when a reservoir pool remains), as occurs under all alternatives for the reservoirs being assessed here. Previous summaries of fish downstream passage generally support that passage rates increase as depths to operating outlets decrease (e.g. Hansen et al. 2017; Keefer et al. 2012). It was therefore assumed that downstream passage rates of all fish species assessed would increase as reservoir elevations decreased, particularly when pool surface elevations are close to (within 25 ft) the top of available outlets at each dam (Table 3).

Final effect determinations accounted for fish stocking (Table 4). No stocking was assumed for crappie and smallmouth, and therefore the effect determinations based on reservoir volumes was applied. Where stocking has occurred in recent years for rainbow trout (Detroit, Green Peter, and Hills Creek reservoirs) and kokanee (Detroit and Green Peter reservoirs), it was assumed it would occur in the future, and thereby mitigate for the effects of reservoir volume reductions. Effects from the reservoir volume analysis were adjusted from major to moderate where average reservoir elevations were estimated to be > 50% lower than the NAA for more than 3 months per year, and from major to minor where average reservoir elevations were estimated to be > 50% lower than the NAA for 3 months or less per year. If reservoir elevation > 50% lower than the NAA for 6 or more months, then a major effect was not adjusted even when stocking was considered. This approach accounts for the positive effects of stocking to provide fish for angling while accounting for the assumed negative effects of smaller reservoir volumes on the growth and survival of stocked fish and/or naturally produced fish.

Table 6-2. Assumptions on the availability of fish targeted by anglers at different reservoir elevations and the associated effects levels assigned.

Monthly reservoir volume difference from NAA	Effect level	Assumptions
Within <10%	None/ negligible	Habitat and food availability decreases, and predation risk increases, as pool volume (elevation) decreases. These effects in turn reduce seasonal
Between 10% and 24% lower for 2 or more months/yr	Minor	
Between 25% and 50% lower for 2 or more months/yr	Moderate	

Greater than 50% lower for 2 or more months/yr	Major	and annual growth and survival rates leading to decreased fishing opportunity.

Table 6-3. Assumptions on the downstream passage effects availability of fish targeted by anglers at different reservoir elevations and the associated effects levels assigned.

Monthly reservoir volume difference from NAA	Effect level	Assumptions
Between 0% and 10% lower	None/ negligible	Downstream passage/entrainment increases as reservoir elevation decreases
Between 10% and 25% lower for 2 or more months/yr	Minor	
Between 25% and 50% lower for 2 or more months/yr	Moderate	
Greater than 50% lower for 2 or more months/yr	Major	

Table 6-4. Adjustment in effect category when accounting for stocking

Effect level based on reservoir volume	Adjustment in effect level with annual stocking	Assumption
None/ negligible	None/ negligible	NA
Minor	None/ negligible	Stocking mitigates effects of reservoir reductions on fish abundance
Moderate	Minor	Stocking substantially mitigates effects of reservoir reductions on fish abundance
Major	Moderate, unless reservoir elevation > 50% lower than the NAA for 6 or more months	Stocking partially mitigates effects of reservoir reductions on fish abundance

6.6 EFFECTS ANALYSIS

6.6.1 Detroit

Reservoir operational changes on the availability of resident fish for angling in Detroit Reservoir were estimated to result in non/negligible effects from Alternatives 1, 2a, 2b and 4 for both the availability of kokanee and rainbow trout, when considering ongoing stocking practices. Conversely Alternatives 3a and 3b were assessed to have a major and moderate effect, respectively, on the availability of kokanee and rainbow trout. Effects of Alternatives 3a and 3b reflect the assumed effects from delayed reservoir refill and/or deep reservoir drawdowns on habitat availability, food, competition, predation and downstream passage/entrainment rates. Ongoing stocking of kokanee and rainbow trout are expected to partially mitigate for these effects helping to maintain availability of these fishes for sport angling.

Table 6-5. Percent difference in average reservoir pool volume at Detroit Reservoir for each WVS EIS Alternative compared to the NAA by month.

Average Pool Volume - Percent Difference from NAA						
	Alt 1	**Alt 2a**	**Alt 2b**	**Alt 3a**	**Alt 3b**	**Alt 4**
Jan	1%	0%	0%	-16%	-16%	1%
Feb	0%	0%	0%	-22%	-5%	0%
Mar	1%	1%	1%	-65%	-3%	1%
Apr	5%	5%	5%	-82%	3%	5%
May	5%	4%	4%	-86%	3%	4%
Jun	4%	3%	3%	-85%	2%	3%
Jul	6%	1%	1%	-82%	-2%	1%
Aug	6%	-2%	-2%	-82%	-7%	-2%
Sep	9%	-2%	-2%	-81%	-14%	-2%
Oct	6%	3%	3%	-76%	-34%	3%
Nov	2%	1%	1%	-69%	-66%	1%
Dec	0%	-1%	-1%	-51%	-51%	-1%

Table 6-6. The number of months average pool elevation categories for Detroit Reservoir occur for each WVS Alternative and the associated effect category.

	Number of months average pool elevation categories occur					
Pool volume category	**Alt 1**	**Alt 2a**	**Alt 2b**	**Alt 3a**	**Alt 3b**	**Alt 4**
10-24% lower	0	0	0	2	2	0
25-50% lower	0	0	0	0	1	0
>50% lower	0	0	0	10	2	0
Effect category	None/ negligible	None/ negligible	None/ negligible	Major	Major	None/ negligible

Table 6-7. Effect determination for the availability of resident fish for sport angling in Detroit Reservoir by alternative, accounting for differences in reservoir volumes and stocking.

	Alt 1	**Alt 2a**	**Alt 2b**	**Alt 3a**	**Alt 3b**	**Alt 4**
Kokanee (w/stocking)	None/ negligible	None/ negligible	None/ negligible	Major	Moderate	None/ negligible

Rainbow trout (w/stocking)	None/ negligible	None/ negligible	None/ negligible	Major	Moderate	None/ negligible

6.6.2 Green Peter

Effects of changes in reservoir operations on the availability of resident fish for angling in Green Peter Reservoir were estimated to result in non/negligible effects from Alternative 1, minor effects from Alternative 4, and moderate to major effects from the remaining alternatives, when considering ongoing stocking practices. Moderate and major effects for 2a, 2b, 3a and 3b reflect the assumed effects from delayed reservoir refill and/or deep reservoir drawdowns on habitat availability, food, competition, predation and downstream passage/entrainment rates. Ongoing stocking of kokanee and rainbow trout are expected to partially mitigate for these effects helping to maintain availability of these fishes for sport angling.

Table 6-8. Percent difference in average reservoir pool volume at Green Peter Reservoir for each WVS EIS Alternative compared to the NAA by month.

Average Pool Volume - Percent Difference from NAA						
	Alt1	**Alt4**	**Alt2a**	**Alt2b**	**Alt3a**	**Alt3b**
Jan	-1%	-1%	-24%	-24%	-24%	-20%
Feb	0%	0%	-5%	-3%	-3%	-24%
Mar	1%	1%	0%	0%	0%	-72%
Apr	2%	2%	1%	1%	1%	-96%
May	3%	2%	2%	2%	2%	-97%
Jun	4%	0%	0%	0%	0%	-89%
Jul	6%	-5%	-5%	-5%	-5%	-91%
Aug	8%	-14%	-14%	-14%	-14%	-95%
Sep	19%	-18%	-26%	-26%	-26%	-96%
Oct	23%	-15%	-67%	-67%	-67%	-95%
Nov	4%	-7%	-92%	-92%	-92%	-94%
Dec	0%	-1%	-79%	-79%	-79%	-77%

Table 6-9. The number of months average pool elevation categories at Green Peter Reservoir occur for each WVS Alternative and the associated effect category.

	Number of months average pool elevation categories occur					
Pool volume category	**Alt 1**	**Alt 4**	**Alt 2a**	**Alt 2b**	**Alt 3a**	**Alt 3b**
10-24% lower	0	3	2	2	2	2
25-50% lower	0	0	1	1	1	0

>50% lower	0	0	3	3	3	10
Effect category	None/negligible	Minor	Major	Major	Major	Major

Table 6-10. Effect determination for the availability of resident fish for sport angling in Green Peter Reservoir by alternative, accounting for differences in reservoir volumes and stocking.

	Alt 1	Alt 4	Alt 2a	Alt 2b	Alt 3a	Alt 3b
Smallmouth (no stocking)	None/negligible	Minor	Major	Major	Major	Major
Kokanee (w/stocking)	None/negligible	Minor	Minor	Moderate	Moderate	Major
Rainbow trout (w/stocking)	None/negligible	Minor	Minor	Moderate	Moderate	Major

6.6.3 Lookout Point

Effects of changes in reservoir operations on the availability of resident fish for angling in Lookout Point Reservoir were estimated to result in non/negligible effects from Alternatives 1, 2a, 2b and 4, and major effects from Alternatives 3a and 3b. Major effects for 3a and 3b reflect the assumed effects from delayed reservoir refill and/or deep reservoir drawdowns on habitat availability, food, competition, predation and downstream passage/entrainment rates. Stocking does not occur for species assessed in this reservoir and therefore not assumed to offset the effects of reservoir operations.

Table 6-11. Percent difference in average reservoir pool volume in Lookout Point Reservoir for each WVS EIS Alternative compared to the NAA by month.

Average Pool Volume - Percent Difference from NAA						
	Alt 1	**Alt 2a**	**Alt 2b**	**Alt 3a**	**Alt 3b**	**Alt 4**
Jan	-2%	-2%	-3%	-16%	-19%	-2%
Feb	-4%	-4%	-4%	-17%	-1%	-4%
Mar	-6%	-6%	-5%	-66%	4%	-6%
Apr	-3%	-3%	-3%	-85%	6%	-3%
May	-1%	-1%	-1%	-89%	5%	-1%
Jun	1%	1%	1%	-88%	2%	1%
Jul	3%	2%	1%	-76%	-5%	2%
Aug	1%	3%	2%	-65%	-14%	3%
Sep	-2%	9%	5%	-53%	-27%	9%
Oct	0%	10%	3%	-58%	-56%	10%
Nov	2%	2%	0%	-77%	-80%	2%
Dec	-2%	-2%	-2%	-55%	-63%	-2%

Table 6-12. The number of months average pool elevation categories in Lookout Point Reservoir occur for each WVS Alternative and the associated effect category.

	Number of months average pool elevation categories occur					
Pool elevation category	**Alt 1**	**Alt 2a**	**Alt 2b**	**Alt 3a**	**Alt 3b**	**Alt 4**
10-24% lower	0	0	0	2	2	0
25-50% lower	0	0	0	0	1	0
>50% lower	0	0	0	10	3	0
Effect category	None/ negligible	None/ negligible	None/ negligible	Major	Major	None/ negligible

Table 6-13. Effect determination for the availability of resident fish for sport angling in Lookout Point Reservoir by alternative, accounting for differences in reservoir volumes and stocking.

	Alt 1	**Alt 2a**	**Alt 2b**	**Alt 3a**	**Alt 3b**	**Alt 4**
Crappie (no stocking)	None/ negligible	None/ negligible	None/ negligible	Major	Major	None/ negligible
Smallmouth (no stocking)	None/ negligible	None/ negligible	None/ negligible	Major	Major	None/ negligible

6.6.4 Hills Creek

Effects of changes in reservoir operations on the availability of resident fish for angling in Hills Creek Reservoir were estimated to result in non/negligible effects from Alternatives 1, 2a, 2b, and 4, when considering ongoing stocking practices. Minor to moderate effects were assessed for Alternatives 3a and 3b and reflect the assumed effects from delayed reservoir refill and/or deep reservoir drawdowns on habitat availability, food, competition, predation and downstream passage/entrainment rates. Ongoing stocking of rainbow trout are expected to partially mitigate for these effects helping to maintain availability of this fish species for sport angling.

Table 6-14. Percent difference in average reservoir pool volume in Hills Creek Reservoir for each WVS EIS Alternative compared to the NAA by month.

Average Pool Volume - Percent Difference from NAA						
	Alt 1	**Alt 2a**	**Alt 2b**	**Alt 3a**	**Alt 3b**	**Alt 4**
Jan	0%	-2%	-2%	-3%	-3%	-2%
Feb	0%	-1%	-2%	4%	-17%	-1%
Mar	0%	-1%	-1%	3%	-37%	-1%

Apr	5%	4%	4%	5%	-45%	4%
May	13%	12%	11%	13%	-48%	12%
Jun	18%	12%	12%	13%	-46%	12%
Jul	12%	7%	6%	-1%	-41%	7%
Aug	4%	7%	3%	-15%	-36%	8%
Sep	0%	7%	1%	-27%	-30%	7%
Oct	1%	2%	-4%	-26%	-23%	2%
Nov	-2%	-7%	-7%	-19%	-18%	-6%
Dec	-1%	-6%	-5%	-8%	-6%	-5%

Table 6-15. The number of months average pool elevation categories in Hills Creek Reservoir occur for each WVS Alternative and the associated effect category.

	Number of months average pool elevation categories occur					
Pool volume category	**Alt 1**	**Alt 2a**	**Alt 2b**	**Alt 3a**	**Alt 3b**	**Alt 4**
10-24% lower	0	0	0	2	3	0
25-50% lower	0	0	0	2	7	0
>50% lower	0	0	0	0	0	0
Effect category	None/ negligible	None/ negligible	None/ negligible	Moderate	Moderate	None/ negligible

Table 6-16. Effect determination for the availability of resident fish for sport angling in Hills Creek Reservoir by alternative, accounting for differences in reservoir volumes and stocking.

	Alt 1	**Alt 2a**	**Alt 2b**	**Alt 3a**	**Alt 3b**	**Alt 4**
Crappie (no stocking)	None/ negligible	None/ negligible	None/ negligible	Moderate	Moderate	None/ negligible
Smallmouth (no stocking)	None/ negligible	None/ negligible	None/ negligible	Moderate	Moderate	None/ negligible
Rainbow trout (w/stocking)	None/ negligible	None/ negligible	None/ negligible	Minor	Minor	None/ negligible

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CHAPTER 7 - ALTERNATIVE 5 MODELING ASSUMPTIONS

Incorporation of Alternative 5 is functionally similar Alternative 2B except that there is slightly more water released from the Santiam in the spring of dry years. Non-exceedance plots were compared for alternatives 2B and 5 (see Appendix B). Based on this assessment, it was determined that the flow management differences between alternatives 2B and 5 would be insignificant with respect to fish performance. However, to confirm this hypothesis, quantitative analysis of fish population dynamics was completed for Alternative 5.

As the DEIS was being updated to a FEIS, additional quantitative modeling was implemented to include the effects of the Near-term Operations Measures as described in Alternative 2a, and an additional implementation plan. The implementation plan describes the order and timeline for EIS actions. Since the Implementation Plan is specific to the Draft Preferred Alternative, the analyses for Chinook and steelhead up to this point in the document have assumed that EIS measures are implemented at the time of the Record of Decision. This allowed for appropriate comparisons among alternatives such that they could be evaluated according to rank of relative performance. Therefore, Alternative 5 required a more detailed description of methodology. This analysis varies from the methodology approach used for the previous alternatives in two fundamental ways: 1. It included quantitative analysis of the effects of the NTOM's and LTOM's (see Section 3.1.4.12) and 2. The NTOM's and LTOM's were considered together. Described another way, the fish performance under the NTOM's could directly influence the starting point and performance of the LTOM's.

The IPA is unique in that it accommodates implementation timing of NTOM's in conjunction with LTOM's. Because different action "start dates" must necessarily be staggered, the IPA was refined to accommodate different timelines. Individual populations might be expected to perform better or worse depending on the timeline of an implemented action. Some actions may be conditioned on one another. For example, the Cougar Dam diversion tunnel construction cannot be implemented unless hydropower is deauthorized. The deauthorization process cannot occur until a disposition study is completed to determine feasibility. Ultimately, this impacts the model timeline for evaluating listed species. Since the timing of implementation is important to understand potential effects to the species, the analysis included modeling that reflected the assumed timing described in the implementation plan for the Draft Preferred Alternative. Evaluation of the implementation plan is critical to accurately capture the effects of the proposed action. Therefore, the IPA is used to present quantitative model predictions of Alternative 5, including near- and long-term actions.

The requested additional projection runs of the IPA Life Cycle Model include UWR spring Chinook salmon and winter steelhead populations. These additional runs used the same parameter specifications, performance metrics, and years of implementation of long-term effective and safe downstream passage for juvenile Chinook salmon and winter steelhead as described in the Methodology (Section 3.1.2.1) and in the Biological Assessment (BA) report (McAllister et al. 2022). Additional runs were required to calculate performance metrics for all four sub-basins for the evaluation of NTOM's and LTOM's relative to the No Action Alternative To address the need for reasonable comparisons, three additional runs were developed and compared to the NAA:

1. NTOM-Alt2B. Apply NTOM until implementation year, then Alt2B for the 30-year management horizon.

2. NAA-Alt5. Apply NAA until implementation year, then Alt5 for the 30-year management horizon.

3. NTOM-Alt5. Apply NTOM until implementation year, then Alt5 for the 30-year management horizon.

This approach allowed us to explicitly test the following hypotheses:

1. Alternative 2B is not functionally different than Alternative 5

2. Alternative 5 performs better than the NAA

The Fish Benefits Workbook (FBW) was applied by the Corps to generate estimates of Dam Passage Efficiency (DPE) and Dam Passage Survival (DPS) under the NTOMs; DPE and DPS for each alternative were made available for use in the IPA. Alternative 5 is the same as Alternative 2B but includes different minimum flows through Green Peter specifically, so it was assumed that fish passage parameters (DPE and DPS) would be the same as under Alternative 2B. Outputs from FBW for the NTOMs were provided by the Corps to the IPA team. CE-QUAL-W2 temperature outputs were also made available for the reaches downstream of dam projects for both NTOMs and Alternative 5, as different flows may affect temperature experienced by adults and thus pre-spawn mortality (PSM). This is an important assumption as it describes how, if differences between Alternative 2B and Alternative 5 existed, the differences are manifested through downstream PSM which is related to downstream flows (i.e., it accounts for the slightly different outflows at Green Peter). Outplanting assumptions in each sub-basin under NTOMs and Alternative 5 were the same as under NAA and Alternative 2B, respectively. All derived parameter values applied in life cycle models were retained (see McAllister et al. 2022). See Appendix E, Alternative 5 Modeling Memo for additional details.

The Implementation Plan, which is part of the Adaptive Management Plan (AM Plan), identifies a prioritization of measures for implementation, a timeline for their implementation, and implementation performance criteria that must be met. It describes the sequencing of the measures in the proposed action, and links immediate operations to improve fish passage and water quality (i.e., Near-term Operations measure; NTOM's) to the longer-term (i.e., Long-term Operations/Construction measure; LTOM's) operational or structural measures, such as the downstream fish passage construction projects [The plan identifies check-ins, or points along the implementation timeline where course correction (i.e., "on-ramps/off-ramps") may be necessary based on research, monitoring, and evaluation (RM&E). The Implementation Plan is considered a roadmap that lays out a strategy and plan for implementation of the proposed action. Considerations such as basin-wide priorities including costs, risk and uncertainty, and RM&E of data gaps, have been used to shape the Implementation Plan and to develop a schedule that is both reasonable and implementable given the information available to USACE at present.

Timing of decisions for implementing management measures and/or adjustments is influenced by the operational planning for the conservation release season, which begins with the January water supply forecast and continues through October. The conservation season is approximately from March through October, including the filling season (spring) and the release season (summer). A document titled "Willamette Basin Project Conservation Release Season Operating Plan" (Conservation Plan) is prepared annually to provide flow requirements based on the basin water supply for that year. The Conservation Plan identifies flow and storage needs for each tributary and USACE reservoir in the WVS and mainstem Willamette control points based on the anticipated total system storage in mid-May, from the April forecast.

It was also necessary to make additional assumptions regarding fish translocation. The Chinook mitigation hatchery program provides conservation benefits for UWR Chinook salmon (NMFS 2019b) with demonstrated benefits to help maintain spawners below dams and for supplementing adults outplanted above WVS dams to spawn. Use of hatchery Chinook is a fundamental component included in the reintroduction strategy for spring Chinook above WVS dams (NMFS 2019b). Preparation of formal reintroduction plans for Chinook are included as a term and conditions in NMFS (2019a). Use of hatchery Chinook for supporting reintroduction is to be continued as described in HGMPs and NMFS Biological Opinion, with future reductions in hatchery production after measured improvements in fish passage at WVS dams are achieved as described in this proposed action.

Given the length of time required to implement some long-term passage actions, it was considered that steelhead may only persist at critically low abundances rendering an evaluation of long-term actions impossible. This is not the case for Chinook since a hatchery program exists for reintroduction. To address this, it was necessary to make some assumptions about steelhead during the period of the NTOM's such that steelhead were allowed to persist even if they fell below the minimum abundance before the implementation of the long-term action. NMFS and ODFW do not currently outplant natural origin returns of UWR steelhead above Detroit or Green Peter dams and have not permitted research activities involving release of natural origin steelhead eggs, juveniles, or adults above these dams due to several concerns, including reduced productivity below dams through the transport of adults above dams, poor downstream passage conditions at these dams, and concerns with transference of disease to upstream Chinook hatcheries. There are no plans to prepare formal reintroduction plans for steelhead, at the time of this writing.

For modeling the effects of Alternative 5 using the IPA it assumes future reintroduction of UWR steelhead will require an unspecified augmentation to maintain populations at least to minimum abundance thresholds until the long-term action comes online. This modeling approach is not intended to add an undescribed action under the proposed action. These assumptions are meant for exploratory purposes only to demonstrate the value of an action, should intervention for steelhead be required prior to the implementation of a long-term action. Modeling also assumes continued outplanting of hatchery Chinook above WVS dams except when natural origin adult returns to traps achieve thresholds defined in the HGMPs. For this reason, steelhead results are presented with and without translocation assumptions.

There are several key modeling assumptions for steelhead that must be made using this approach:

- The model considers only above dam populations, i.e., those populations directly impacted by blocked passage.
- Productivity is measured as the max number of recruits per spawner in the years immediately following implementation. Note, this is as opposed to reporting the long-term average productivity.
- The model only considers the length of the proposed management action (30 years into the future).
- Egg-fry survival rate as a function of eggs deposited and follows a Beverton-Holt function.
- There are six juvenile migrant types above dams within three main groups (fry, fall subyearlings, yearlings). Life history types are further broken down based on peer reviewed literature and are presented in (Appendix J).
- Reservoir survival rate of juveniles is invariant to the downstream dam passage measure applied.
- Splits for juvenile migration groups above dams are invariant to downstream dam passage measure applied.
- In two-dam models juveniles originating above and passing down through Hills Creek and Green Peter will try to pass directly through downstream dams without stopping.

- Dam passage survival and dam passage efficiency were bootstrapped from fish benefits workbook.
- Future marine survival reflects historical variation in early age marine survival.
- At sea fishing mortality rates and incidental mortality rates in terminal fisheries from CTC mortality rate assessment approximate long-term average mortality rates.
- Upstream passage has 100% survival once an adult volunteers to be translocated above a barrier. In other words, mortality processes due to prespawn mortality, temperature, handling, etc, are assumed to occur prior to volunteering to a trap.
- Spawning success of hatchery origin fish is less than natural origin fish.
- Juvenile reservoir survival does not change under different management scenarios.
- The telemetry data used to predict downstream survival is representative of long-term averages.
- The proportion of adults in each age class remains the same in the ocean phase of the life history.
- Previously measured harvest rates are representative of the long-term average.
- Juveniles can depth compensate during periods of high TDG.

The implementation plan time for the long-term measures affects the predicted performance of a species but the near-term measures do not.

In the North Santiam, measures being implemented for Alternative 5 are the same as those as for Alternative 2B. For downstream fish passage, construction of structural downstream fish passage (#392) would be implemented at Detroit Dam. For upstream passage, fish would be collected at the existing Minto adult fish facility and trucked upstream. The structural fish passage improvements allow Chinook and steelhead to access habitat above Detroit Dam, and support increased abundance and productivity compared to the NAA. Passage improvements would also support passage of a re-introduced bull trout population above Detroit Dam to access habitat below the dam and return back upstream to re-enter the spawning population, but there are a greater number of limiting factors downstream increasing potential for mortality for individuals that move downstream. Since there is not any spawning habitat available downstream of the dam, individuals must survival and migrate back upstream, be collected and trucked above Detroit Dam, in order to re-enter the spawning population.

In the South Santiam, measures being implemented for Alternative 5 are the same as those as for Alternative 2B. For downstream fish passage at Foster Dam, construction of structural downstream fish passage (#392) would be implemented. At Green Peter Dam, a deeper fall reservoir drawdowns for fish passage (#40) and spring spill would be implemented to provide downstream fish passage. An adult fish facility would also be constructed at the base of Green Peter Dam. These fish passage improvements allow Chinook and steelhead to access habitat above both Foster and Green Peter dams, supporting the potential for increased abundance and productivity compared to the NAA. Compared to above other WVS dams, the relatively lower elevation habitat above these dams may constrain productivity and survival.

The diversion tunnel at Cougar would be used for downstream passage. The reservoir will be drafted to 25 feet over the diversion tunnel during both spring and fall. This will results in a very small residual reservoir pool during these season, and limited opportunity to refill the reservoir to supplement downstream flows during spring to fall seasons. Most Chinook would be expected to pass downstream as fry in spring. It is uncertain how bull trout may respond, however some would be expected to move upstream of the reservoir while others downstream. Forage opportunity will change over time for bull trout with repeated reservoir deep drawdowns, with the potential for less prey food availability in the reservoir potentially requiring bull trout to move downstream.

Fish passage conditions are the same as under Alternative 2B. The existing adult facility at Fall Creek Dam in combination with the operational downstream passage by way of a fall reservoir deep drawdown will support maintaining the re-established Chinook sub-population above Fall Creek Dam. Construction of structural downstream fish passage (#392) would be implemented at Lookout Point Dam but not Hills Creek Dam. Upstream passage would occur using the existing adult fish facility at the base of Dexter Dam. The structural fish passage improvements allow Chinook to access habitat above Lookout Point Dam, supporting increased abundance and productivity compared to the NAA. The existing adult facility at Fall Creek Dam in combination with the operational downstream passage by way of a fall reservoir deep drawdown will support maintaining the re-established Chinook sub-population above Fall Creek Dam. At Hills Creek Dam, downstream passage occurs through existing outlets where on average downstream fish passage survival is low under the NAA dam operational regime. The existing bull trout population above Hills Creek Dam would be expected to perform the same as under the NAA.

CHAPTER 8 - LAMPREY SPECIES EFFECTS ASSESSMENT

8.1 INTRODUCTION

Three species of lamprey occur in the area of analysis: Western River Lamprey (*Lampetra ayresii*), Western Brook Lamprey (*Lampetra richardsoni*), and Pacific Lamprey (*Entosphenus tridentatus).* There is concern that both adult and juvenile life stages could be impacted by dam operations by affecting habitat access and quality. Knowledge of the abundance, distribution, and run timing of these species in the area of analysis is limited. Pacific Lamprey are the most studied and a culturally important food for local tribes. This assessment therefore focused on Pacific Lamprey. Results are assumed to generally be representative of effects on the other lamprey species occurring in the Willamette River Basin.

8.2 SUMMARY OF LIFE HISTORY AND HABITAT NEEDS

Timing and general habitat needs for Pacific lamprey are summarized in Table 1. Pacific lamprey are anadromous and adults use the Willamette River Basin for overwintering and spawning, and juveniles use it for a period of freshwater rearing that can last up to ten years (Hess et al. 2021). Maturation to the adult stage occurs after migrating to the ocean. After emerging from redds, ammocoetes rear in freshwater as eyeless filter feeders. Their distribution is constrained by the availability of fine substrates mixed with organic material and can be additionally constrained by warm water (Goertler et al. 2020). Ammocoetes burrow into soft substrates tail first. They are commonly found in tributary streams and in higher densities at the deltas of these streams as they enter the mainstem (Harris & Jolley 2011, Jolley et al. 2012). Several authors have researched water temperature effects on adult lamprey highlighting the negative impacts of warm water (Clemens 2022; Meeuwig, Bayer, and Seelye 2005).

Adult Pacific lamprey begin their spawning run by moving from the ocean into the Columbia estuary with numbers peaking in January and February then trailing into May (Weitkamp et al., 2015). They either overwinter (in some cases multiple years) in large rivers or migrate directly to smaller spawning tributaries and spawn. They spawn in gravel-bottomed tributary streams at the upstream end of riffle habitat during the summer (Beamish 1980; Clemens and Schreck 2021). Mayfield et al. (2014) conducted redd surveys for Pacific Lamprey in the Willamette Valley finding they were associated with gravel dominated pool tail outs, similar to salmonid spawning habitat. At larger scales, they found spawning lamprey selected tributaries with gravel dominated streambeds such as the Calapooia River, lower Clear Creek, and Thomas Creek (Mayfield et al. 2014). Pacific lamprey die after spawning releasing important marine derived nutrients into the streams, primarily nitrogen and phosphorus. As Figure 1 shows, run timing at Bennett Dam on the Santiam River peaks in June and July of most year (ODFW 2023).

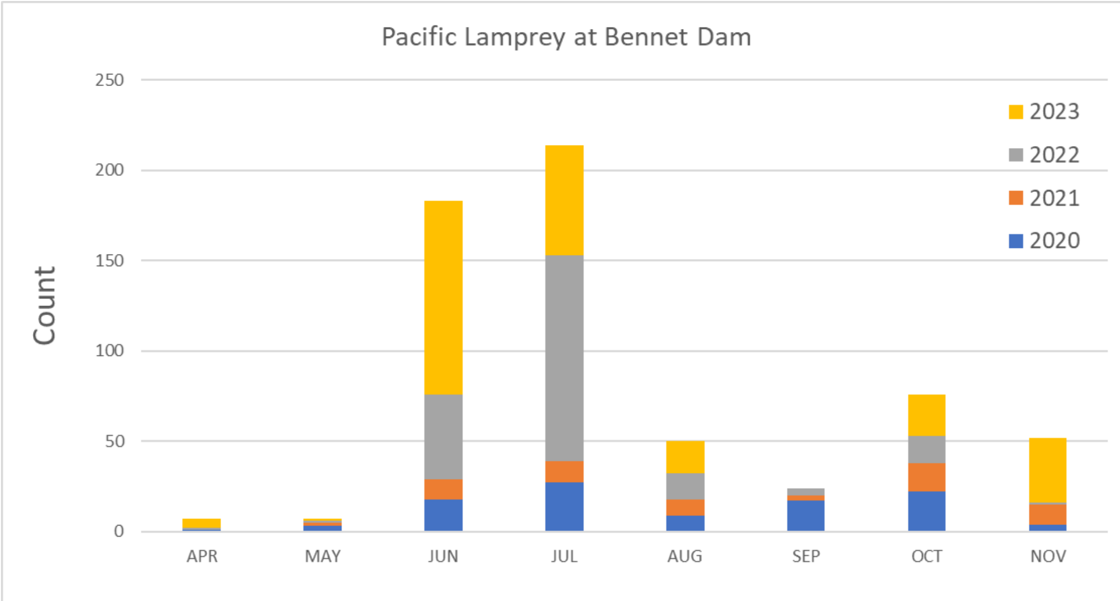

Figure 8-1. Returning adult Pacific Lamprey counts show run timing past Bennett Dam peaking in June and July on the Santiam River. Bennett Dam is downstream of Big Cliff and Detroit Dams that do not have fish passage (ODFW 2023).

Table 8-1. General freshwater timing hand habitat preferences of Pacific lamprey by life stage .

Lifestage	Timing	Habitat preferences
Spawning	March to July	See Table 2
Egg	Three to four weeks to hatch.	Gravel lamprey nest.
Larvae (ammocoetes)	Three to ten years	Soft sediment with organic matter. Burrow in tail first.
Juvenile (macrophthalmia)	February, March, and April	Mainstem migrating to ocean.
Adult – Ocean	Three to five years	Pacific Ocean – Mexico to Alaska to Kamchatka Russia
Adult - Freshwater	One to three years	Mainstem overwintering, tributaries for spawning

After hatching, the larvae (also called ammocoetes) drift downstream and burrow into silt or mud where suitable habitat occurs such as backwater areas, and stream confluences where there are lower water velocities. Here they live as eyeless, toothless filter feeders, and rear on the bottom for three to ten years (Hess et al. 2022). Larval lamprey have a patchy distribution related to environmental variables such as water velocity (low), substrate (silt), and proximity to upstream nests. Larger sized larvae are occasionally collected at Corps juvenile passage facilities at dams on the lower Columbia and Snake Rivers. The timing of their collection indicates that they may move downstream from rearing grounds after high flow events as the hydrograph declines (Mesa et al., 2015). Sheoships (2014) investigated lamprey larval use of rearing habitat in six Willamette River tributaries and found they were greater abundance in areas with mostly medium fine sand (0.25 – 0.50 mm). Larval Pacific Lamprey, one positively identified Western Brook Lamprey (144 mm TL), and several unidentified *Lampretra spp*. have been collected rearing in soft sediments in the mainstem Willamette River near Portland, OR at water depths up to 52.5 feet (16 meters) (Jolley, Silver, and Whitesel 2012).

Tribal harvest of Pacific lamprey for subsistence and ceremonial use indicates the basin wide population is in decline. At Willamette Falls, harvest has decreased from over 500,000 fish in 1946 to less than 6,000 lamprey per year in 2000 and 2001 (Clemens et al. 2023). Although not listed under the Endangered Species Act, the State of Oregon categorizes them as a Sensitive Species (Clements et al. 2020) and cited five key limiting factors: access (passage and screening at artificial obstructions), water quantity (reduced flows, flow management), water quality (high water temperature, sedimentation), physical habitat (stream and floodplain degradation), and predation by other species (particularly nonnative fishes). A tribal lead translocation program collected 240 adult Pacific Lamprey at Willamette Falls and released them upstream of the Fall Creek Reservoir in 2016 (Le et al. 2017). USACE biologists continue to collect adults that return at Fall Creek Adult Fish Facility and release them upstream of Fall Creek Reservoir.

Western River Lamprey and Western Brook Lamprey are genetically similar but have divergent life histories. Western River lamprey are anadromous moving downstream through the area of WVS EIS analysis to the ocean. Western Brook are not anadromous and stay in freshwater. It has recently been suggested the two should share the same scientific name (*L. ayresii*), but retain their common names which would emphasize the differing life histories (Carim et al. 2023). In this analysis, it is assumed that the effects to Pacific lamprey would be similar to the effect to Western River and Western Brook lamprey.

8.3 METHODS

Passage for lamprey was not included at WVS dams when they were constructed and therefore access to and from habitat upstream of most WVS dams has been blocked since their construction. The current distribution of Pacific lamprey is constrained downstream of WVS dams in the Willamette River Basin with the exception of Fall Creek Dam.

For this assessment, it was assumed that Pacific lamprey passage would occur at Fall Creek Dam in the Middle Fork Willamette Subbasin under all alternatives and would also occur at Monroe, Stroda, and Cox drop structures in the Long Tom River Subbasin under Alternatives 1 and 4 over the 30-year implementation timeframe. No passage would occur at other WVS dams under any alternative.

Efforts to reintroduce Pacific lamprey above Fall Creek Dam by the Confederated Tribes of the Grand Ronde occurred recently, and any adults returning to Fall Creek Dam would be collected at the Fall Creek Adult Fish Facility and released upstream of Fall Creek Reservoir. Downstream passage would be provided via the annual reservoir drawdown to streambed each fall which is proposed to continue under all of the WVS EIS alternatives.

In the Long Tom River Subbasin, upstream passage of salmon and Pacific lamprey at the Monroe, Stroda, and Cox drop structures would be provided by structural modifications for fish passage under Alternatives 1 and 4. Effective downstream fish passage would be available because water flows freely over these structures. The drop structures are considered "run of river" dams, which means there is no water storage function for the dams. As water enters the ponded area behind the dams from upstream, it exits over the dams at the same rate and has no effect on flows downstream. The primary function of the dam is to dissipate energy of the river and reduce scour as it falls over these low head dams. There are no unscreened water diversions occurring in association with water pooled behind the drop structures. Detailed designs have not been developed for drop structure passage improvements, and future NEPA compliance will be completed once available.

Pacific lamprey passage features would be integrated into the new Green Peter, Hills Creek, and Blue River Adult Fish Facilities that would be constructed under various action alternatives. However, it was assumed that these facilities would remain inaccessible to Pacific Lamprey during the 30-year implementation timeframe due to other impassable downstream dams (i.e., WVS Foster and Lookout Point Dams, and non-federal Leaburg Dam) because there are no known plans to reintroduce Pacific lamprey above these dams by any State, Tribal, or Federal resource agencies, or any other entities.

This assessment was designed to account for differences in the WVS EIS alternatives among the following factors previously identified in other assessments by state and federal lamprey biologists (Clemens et al. 2020; Poirier, Gray, and Clemens 2023):

1. Regulated flow effects on spawning and incubation habitat availability
2. Regulated flow down-ramping effects on rearing habitat dewatering
2. Frequency of water temperatures above 20°C discharged from dams
4. Sediment transport effects from operation of reservoirs and dams on larval rearing habitat availability
5. Habitat access

Sediment and substrate availability, channelization, streamside vegetation, are present and recruitment of large wood into streams are some of the primary attributes relating to physical habitat. An assessment of sediment transport is provided in Appendix C.

Total dissolved gas (TDG) can be above Oregon Department of Environmental Quality standards of 110% (Oregon Secretary of State 2023) as modeled in Appendix D, [Water Temperature and

Total Dissolved Gas Methodology]). Recent work documents lamprey's vulnerability to gas bubble trauma from high TDG, but the effects are generally sublethal (Liedtke et al. 2023). Total dissolved gas (TDG) levels were assessed separately in the WVS EIS.

Other identified factors for the decline of lamprey are chemical pollution and presence of exotic fish (ODFW 2005). These factors were not included in the assessment because either these were not expected to change between the NAA and alternatives (chemical pollution), or no data were available to assess their effects (competition or predation risks for lamprey by exotic fish).

8.3.1 Spawning and Incubation

Quantified relationships between habitat availability for Pacific lamprey and stream flows in the Willamette River Basin are not available. Relationships have been developed for spring Chinook salmon and winter steelhead. Spawning habitat needs for Pacific lamprey are similar to Chinook salmon and steelhead (Bjornn and Reiser 1991; Mayfield et al. 2014; Geist and Dauble 1998; Gunckel et al. 2009). Although the range of substrate sizes used by steelhead and Chinook salmon for spawning can be higher, those reported for use by spawning lamprey are general within the range of those used by steelhead and Chinook salmon (Table 2.[Comparison of spawning habitat attributes]). Therefore, spawning habitat availability assessed for winter steelhead and spring Chinook salmon for Pacific lamprey (Appendix E [NewChapter_fish_flow_effects_summary] was considered representative of Pacific lamprey with adjustments for lamprey spawning periods.

Table 8-2. Comparison of spawning habitat attributes for Pacific Lamprey reported by Gunkel et al. (2009) to those applied as preferred criteria for assessing winter steelhead and spring Chinook reported in Appendix E, Chapter [flow effects analysis summary].

		Pacific Lamprey		Winter Steelhead		Spring Chinook	
	UNITS	RANGE	MEDIAN	RANGE	~MID-POINT	RANGE	~MID-POINT
Redd water depth	ft	0.5-3.4	1.4	1.0-3.0	2	1.0-8	4
Velocity	ft/s	0.6-3.3	2	1.5-3.5	2.5	1.5-3.5	2.5
Substrate	in	1.0-3.5	1.9	0.3-6	4.5	0.3-6	5

Flows below WVS dams where Upper Willamette River winter steelhead and spring Chinook salmon spawning occurs were assessed based on development of weighted usable area relationships reported by R2 Resources (2013) and RDG (2014). Winter steelhead were assessed in the North Santiam River and South Santiam River Subbasins, and spring Chinook salmon in those subbasins and in the McKenzie River and Middle Fork Willamette River Subbasins. Based on the comparison of spawning habitat attributes discussed above, spawning attributes for winter steelhead were applied for the North Santiam River and South Santiam River Subbasins.

Lacking information for steelhead in the other two reaches, Chinook attributes were applied for the McKenzie and Middle Fork (Table 3 [Comparison of flows developed by R2 and RDG providing 80%, 90% and 100%]).

Table 8-3. Comparison of flows providing 80%, 90% and 100% weighted usable area habitat for spring Chinook and winter steelhead spawning (R2 Resources 2013 and RDG 2014) and those applied for assessment of Pacific lamprey spawning habitat.

	Chinook spawning				Winter steelhead spawning		Pacific Lamprey spawning			
	Big Cliff	Foster	Cougar	Dexter	Big Cliff	Foster	Big Cliff	Foster	Cougar	Dexter
WUA	Flow	Flow	Flow	Flow	Flow	Flow	Flow	Flow	Flow	Flow
80%	889	449	242	1800	867	533	867	533	242	1800
90%	1011	567	319	2176	1000	685	1000	685	319	2176
100%	1286	1140	472	2800	1286	1140	1286	1140	472	2800

Flows for the 80% and 90% levels were taken from the lower end of the flow-habitat curve relationship for spring Chinook and winter steelhead.

To assess changes in spawning habitat availability, the number of days flow levels during the spawning season were above 80%, 90% and 100% weighted usable area levels for lamprey spawning were summarized. Pacific lamprey spawn timing was assessed as March 15 to August 1, covering both the active spawning season and egg incubation. Spawn timing was cited by Mayfield et al. (2014) as occurring primarily in spring months. USFWS (2023) reports that spawning occurs between March and July depending upon location within their range. Gunckel et al. (2009) reported spawning in the Umpqua River, Oregon between April and early June. Egg incubation is reported to last for 3 to 4 weeks (WDFW 2024).

8.3.2 Rearing

Although stream flows naturally fluctuate, regulated streams can have greater and more frequent stage changes. Dewatering has been found to substantially affect spatial distribution and abundance of larval lampreys in freshwater ecosystems (Harris et al. 2020). The WVS dams are operated to maintain down ramping rates at or below 0.1 ft/hour (3 cm/hr) during nighttime hours and 0.2 ft/hour (6 cm/hr) during daytime hours during non-flood control operations. NMFS (2008) biological opinion stated it was their goal for down ramping rates not to exceed these rates to minimize stranding of juvenile fish and aquatic invertebrates and desiccation of redds. Liedtke et al. (2020) evaluated larval Pacific lamprey emergence under different dewatering rates in the laboratory and found the mean movement rates for study groups ranged from 19.0 to 44.4 centimeters per minute [cm/min]). Therefore, it was assumed that the current ramping rates are adequate to allow larval lamprey to emerge and avoid stranding. Models used to estimate river flow below dam operate on a daily time step. The frequency at which stream flow declines 1 ft or more over two or more days was used to assess effects of flow management on larval Pacific Lamprey under the alternatives.

8.3.3 Water Temperature

Water Temperatures at or above 20℃ were found to increase stress in Pacific lamprey resulting in habitat loss and above 26.6℃ pre-spawn mortalities have been documented (Clemens 2022). In addition, lab studies investigating egg development at several temperatures found that temperatures above 20℃ led to an increased number of developmental abnormalities in both Pacific and Western Brook lamprey (Meeuwig, Bayer, and Seelye 2005). To assess the effects of the NAA and WVS EIS alternatives on lamprey, the percent of days water temperatures in each subbasin below WVS dams was above 20℃ were summarized.

8.3.4 Sediment Transport

WVS dams block transport of both fine and coarse sediment downstream, affecting habitat formation and maintenance for larval lamprey and other aquatic species. Sheoships (2014) surveyed six Willamette Valley tributary streams and found larval Pacific lamprey were most abundant in areas with mostly medium sand (0.25 – 0.50 mm).

Sediment transport is expected to increase when reservoirs are drawn down lower under measures included in the WVS EIS alternatives compared to NAA conditions (Schenk and Bragg 2021). Reservoir drawdowns to streambed would result in higher levels of sediment releases than partial drawdowns. Fall Creek and Cougar Dam are two locations where measures in the WVS EIS alternatives include drawdowns to streambed. Sediment materials passing downstream would include sands and possible coarser grain sizes, as well as finer silts and clay materials.

Substantial sediment releases would be expected below Cougar Dam in the first few years of drawdowns to streambed since this reservoir has not been drawn down repeatedly to streambed for several years, then reductions in discharged sediment would occur as sediment currently stored in the reservoir is depleted. In the long term, sediment passing Cougar Dam is expected to be higher than NAA levels because the drawn down reservoir would not trap as much incoming sediment from the watershed.

At other locations, there are no measures for reservoir drawdowns to streambeds (i.e. reservoir pools would remain under all alternatives). Residual pools would continue to reduce the transport of sand and larger sized materials downstream of the dams. Sediment materials released at these locations are expected to be finer grain than sand, primarily silts and clays when reservoirs are drawn down. Finer grained sediments would be expected to deposit in connected backwaters and within channels in the first few years after deeper drawdowns are implemented.

Sediments transported downstream during reservoir drawdowns to streambed would provide positive and negative effects for lamprey. Increased sediment transport should increase habitat for larval lamprey over a multi-year timeframe. The magnitude and durations of these habitat changes are uncertain, and therefore our assessment only considered if there is a positive change in habitat formation potential below WVS dams. Silt transported during drawdowns could negatively affect spawning/incubation habitat and rearing habitat for ammoecetes. Where deeper drawdowns are implemented, silt stored in the reservoirs would be transported downstream and is expected to deposit primarily in lower gradient areas, and to a lesser extent in main channels. These deposits would be expected to substantially impact areas used for lamprey rearing by partially or fully covering sand and organic areas with silt. Gravel areas in main channels used for spawning could also be impacted, either seasonally or in certain years when larger releases of silt occur. Higher flows however are expected flush gravel areas in future years.

Daily reservoir elevations estimated for the NAA and each action alternative are included in Appendix B; see [Appendix A Chapter 5] for non-exceedance plots. For ease of reference, Table 4 [Summary of major reservoir operational differences] summarizes key reservoir operational differences among alternatives, driven by downstream fish passage operational measures, which affect sediment discharge downstream of WVS dams.

Table 8-4. Summary of major reservoir operational differences among EIS alternatives with potential to change sediment delivery downstream.

Alt	LOP	HCR	FCR	CGR	BLU	GPR	DET
1			fall deep drawdown				
2A			fall deep drawdown			spring spill fall deep drawdown	
2B			fall deep drawdown	spring & fall deep drawdown		spring spill fall deep drawdown	
3A	spring & fall deep drawdown	spring spill fall deep drawdown	fall deep drawdown	spring & fall deep drawdown (RO)	fall deep drawdown	spring spill fall deep drawdown	**spring & fall deep drawdown**
3B	spring spill fall deep drawdown	spring & fall deep drawdown	fall deep drawdown	spring & fall deep drawdown (DT)	fall deep drawdown	**spring & fall deep drawdown**	spring spill fall deep drawdown

4			fall deep drawdown				
5			fall deep drawdown	spring & fall deep drawdown (DT)		spring spill fall deep drawdown	

Analysis of sediment supply changes is included in Appendix C. Qualitative summaries on sediment supply are included in the Appendix C tables 2-12 to 2-19:

- Table 2-12. Alternative 1- Qualitative Sediment Supply Metric
- Table 2-13. Alternative 2A - Qualitative Sediment Supply
- Table 2-14. Alternative 2B - Qualitative Sediment Supply
- Table 2-15. Alternative 3A - Qualitative Sediment Supply
- Table 2-16. Alternative 3B - Qualitative Sediment Supply
- Table 2-17. Alternative 4 - Qualitative Sediment Supply
- Table 2-18. Alternative 5 - Qualitative Sediment Supply
- Table 2-19. NTOM - Qualitative Sediment Supply

We used the information on sediment delivery from Appendix C and accounted for the major reservoir operational differences among the alternatives to qualitatively characterize the effects on lamprey spawning/incubation and larval-stage rearing habitat.

8.3.5 Habitat Access

Historically, Pacific lamprey were found throughout the Willamette River Basin. Currently, the upstream extent of their range is truncated by dams (Poirier, Gray, and Clemens 2023). Clemens et al. (2023) estimates that 32% of available stream habitat basin wide is blocked by major federal and non-federal dams. Where there are no barriers to upstream migration, Pacific lamprey are capable of spawning in a wide diversity of stream sizes and underlying geologic types (Mayfield et la. 2014). Information on the spawning distribution of Pacific lamprey across the action area for this EIS is lacking. However, habitats used for spawning are similar to those for salmonids (*Oncorhynchus* spp.) (Stone 2006; Bjornn and Reiser 1991). Therefore, spawning information for steelhead and Chinook salmon reported by Bond et al. (2017) was used to represent Pacific lamprey spawning distribution.

For this assessment, it was assumed that Pacific lamprey passage would continue to be provided at Fall Creek Dam under the NAA and all action alternatives. Additionally, Pacific lamprey passage would be provided at the Monroe, Stroda, and Cox drop structures under

Alternatives 1 and 4 through integrated Pacific lamprey features included in passage improvements for ESA-listed species at these structures.

To assess the effects of WVS EIS operations, access to habitat and passage survival was considered when qualitatively assessing changes to population attributes.

8.4 RESULTS

8.4.1 Spawning and Incubation

Flows from 1936 to 2019 were categorized as high, normal, or low water years based on the 25th and 75th percentiles of Willamette-at-Salem unregulated flow estimated for the Mar 15-Oct 15 timeframe in each year. For years in each water year category (high, low, normal), the minimum number of days flow levels during the spawning and incubation season (March 15 to August 1) under the NAA were above 80%, 90% and 100% weighted usable area levels are summarized in Table 5 [Minimum number of days across years flows under the NAA]. The percent difference in the number of days under each alternative from the NAA is also included in the Table.

Under the NAA, below Big Cliff, Foster and Cougar dams, flows remain above the 80% and 90% WUA levels during the 140-day spawning and incubation period in normal and high water years. Flows were below the 80% and 90% WUA levels for a portion of the period in dry years below Big Cliff and Foster. Downstream of Dexter Dam flows were below the 80% and 90% WUA levels a majority of the time in all water year types. Few. days at these WUA levels occurred below Dexter compared to the other locations.

Under Alternatives 1, 2A and 4, the number of days at or above the 80% and 90% WUA areas during the spawning and incubation period was similar or greater than the NAA downstream of Big Cliff, Foster, and Cougar Dams. There were fewer days when flows were > 100% WUA levels downstream of these dams compared to the NAA. Under Alternative 2B, patters were similar except below Cougar, were fewer days at or above WUA flow levels occurred due to the deep reservoir drawdown. Fewer days at each WUA levels occurred below Dexter compared to the other locations for these Alternatives.

Alternatives 3a and 3b include deep reservoir drawdowns at multiple reservoirs, which effect downstream flows. The number of days at or above the 80% and 90% WUA areas during the spawning and incubation period was lower than the NAA downstream of Big Cliff and Cougar dams under Alternative 3a and below Foster and Cougar dams in Alternative 3b. However, there were more days above WUA levels below Dexter Dam compared to the NAA under these Alternatives.

Table 8-5. Minimum number of days across years flows under the NAA were at or above maximum weighted usable area (MWUA) levels for spawning during March 15 to August 1 (140 day period) below WVS dams under three water year categories, and amount of time flows were at or above each category under each EIS action alternative as a percentage of the NAA.

	Big Cliff			Foster			Cougar			Dexter		
Alternative	>80 %	>90%	>100%	>80%	>90%	>100%	>80%	>90%	>100%	>80%	>90%	>100%
NAA												
High	140	140	89	140	140	105	140	140	45	38	27	15
Low	117	117	68	140	113	38	140	140	37	15	5	0
Normal	140	140	75	140	140	72	140	140	58	52	40	0
1												
High	100 %	100%	45%	100%	100%	63%	100%	100%	91%	103%	100%	127%
Low	120 %	120%	0%	100%	124%	0%	100%	100%	111%	40%	40%	(0 days)
Normal	100 %	100%	0%	100%	100%	44%	100%	100%	64%	33%	28%	(3 days)
4												
High	100 %	100%	88%	100%	100%	120%	100%	100%	82%	61%	78%	133%
Low	120 %	120%	24%	100%	124%	42%	100%	100%	70%	13%	40%	(0 days)
Normal	100 %	100%	83%	100%	100%	106%	100%	100%	43%	21%	15%	(0 days)
2A												
High	100 %	100%	88%	100%	100%	120%	100%	100%	84%	61%	78%	133%
Low	120 %	120%	24%	100%	121%	42%	100%	100%	78%	13%	20%	(0 days)
Normal	100 %	100%	83%	100%	99%	106%	100%	100%	41%	21%	15%	(0 days)
2B												
High	100 %	100%	88%	100%	100%	120%	99%	66%	200%	61%	81%	133%
Low	120 %	120%	24%	100%	121%	42%	70%	51%	81%	47%	120%	(0 days)
Normal	100 %	100%	83%	100%	99%	106%	74%	61%	122%	27%	20%	(0 days)
3A												
High	79 %	74%	98%	100%	100%	120%	100%	93%	200%	232%	300%	313%

Low	54%	41%	54%	100%	118%	42%	70%	51%	81%	207%	200%	(5 days)
Normal	62%	57%	84%	100%	96%	108%	76%	64%	122%	131%	120%	(20 days)
3B												
High	100%	100%	88%	100%	89%	66%	99%	66%	200%	179%	167%	247%
Low	120%	120%	24%	84%	53%	105%	70%	51%	141%	180%	280%	(0 days)
Normal	99%	97%	21%	94%	51%	71%	77%	64%	122%	129%	105%	(4 days)

Table Notes: Texted colored with yellow indicate the alternative percentage is within 5% of the NAA.

Text colored with green indicate the alternative percentage is more than 5% higher than the NAA. Non-filled cells indicate the alternative percentage are 5% lower than the NAA. When there were zero days within a MWUA flow category under the NAA, a percentage was not calculated for the alternatives, and the number of days meeting the flow category is reported instead.

8.4.2 Rearing

Ammocoetes are present year-round, and so effects assumed can occur in all days of the year. Flows from 1936 to 2019 were categorized as high, normal or low water years based on the 25th and 75th percentiles of Willamette-at-Salem unregulated flow estimated for the Mar 15-Oct 15 timeframe in each year. There were very few days (5 or less) down-ramping below each dam exceeded 1 ft/day for more than 1 day (Table 6 [The median number of days annually, by water year type, that down-ramping]). This was the case for all alternatives, locations and under each water year type. In most cases, there were zero to 1 days. The criteria was exceeded more below Fall Creek Dam than other locations under all the alternatives.

Table 8-6. The median number of days annually, by water year type, that down-ramping below each dam exceeded 1 ft/day for more than 1 day.

Location	Type	Alt_1	Alt_2a	Alt_2b	Alt_3a	Alt_3b	Alt_4	Alt_ LTM	Alt_ NAA	Alt_ Interim
Big Cliff Dam	High	0	0	0	1	2	0	0	0	0
	Low	0	0	0	1	1	0	0	0	0
	Normal	1	1	1	1	2	1	1	1	0
Cougar Dam	High	0	0	0	0	0	0	0	0	0
	Low	0	0	0	0	0	0	0	0	0
	Normal	0	0	0	0	0	0	0	0	0
Dexter Dam	High	1	1	1	1	2	1	0	3	0
	Low	0	0	0	0	0	0	0	1	0

	Normal	1	1.5	1.5	0	1	1.5	1	2.5	0
Fall Creek Dam	High	5	4	4	4	4	5	4	4	2
	Low	3	3	3	3	2	3	3	2	3
	Normal	4	4	4	4	5	4	4	5	4
Foster Dam	High	3	3	3	3	1	2	2	3	2
	Low	0	1	1	1	1	0	1	0	1
	Normal	1.5	2	2.5	2	1	1	2	1	2

Table Notes: Alt_LTM = long term measures under Alternative 5. Alt_Interim = Interim measures under Alternative 5.

8.4.3 Water Temperature

Monthly maximum water temperatures in three different years were modeled under each alternative (2011 = cool/wet, 2015 = hot/dry, 2016 = moderate/dry) following methods reported in Appendix D [Water Temperatures and Total Dissolved Gas Methodology]. Results are reported in Table 7 [Monthly maximum water temperatures].

For 2011 conditions, monthly maximum water temperatures only exceeded 68 degrees (20 degrees Celsius) in August at mainstem locations (Salem and Albany). This occurred under all alternatives. Differences between months at each location were generally the same among the alternatives.

In 2015, monthly maximum water temperatures exceeded 68 degrees (20 degrees Celsius) in June, July and August at mainstem locations under all alternatives. This was also the case below Dexter Dam in July and August. Below Hills Creek Dam, monthly maximum water temperatures exceeded 68 degrees in July and/or August under Alternatives 2a, 2b, 3b, and 5.

In 2016, patterns were very similar to 2011.

Table 8-7. Monthly maximum water temperatures (Fahrenheit) for three water years by location and WVS EIS alternative.

Year and Location	Alt1	Alt2a	Alt2b	Alt3a	Alt3b	Alt4	Alt5	NAA
2011								
ALBO								
Apr	49.6	49.6	49.4	49.5	49.7	49.7	49.4	49.5
May	53.3	53	52.8	53.4	53.5	53.3	52.8	53.1
Jun	59.4	58.8	58.8	60.5	60.1	59.4	58.8	58.8
Jul	67.7	66.8	66.9	67.9	68	67.8	66.9	66.8
Aug	69.2	68.8	68.5	69.7	70	70.1	68.6	68
Sep	63.3	62.4	62.8	64.2	62.5	63.7	63	62.8
Oct	55.1	56.7	57.1	56.9	55.3	55	56.8	56.7

Year and Location	Alt1	Alt2a	Alt2b	Alt3a	Alt3b	Alt4	Alt5	NAA
BCLO								
Apr	42.3	42.2	42.3	42.3	42.5	42.3	42.2	42.4
May	45.6	45.6	45.6	45.2	46.6	45.6	45.6	45.4
Jun	50.3	50.2	50.2	48.9	50.9	50.3	50.2	48.8
Jul	56.9	56.7	56.7	54.2	58	56.7	56.7	53.9
Aug	60.3	59.8	59.8	59.1	56	59.8	59.8	56.4
Sep	56.9	56.9	56.9	60.5	45.3	56.9	56.9	53.7
Oct	51.1	51.1	51.1	53.8	50.1	51.1	51.1	49.5
CGRO								
Apr	42.5	42.5	41.5	42.2	41.5	42.5	41.6	42.5
May	45.6	44.8	43.8	44.5	43.8	44.8	43.7	45.6
Jun	49.4	48.2	46.4	47.1	46.3	48.2	46.4	49.4
Jul	55.7	54.3	52.4	50.4	52.3	54.4	53	55.7
Aug	58.8	58	58.2	54	58.3	57.9	64.4	58.7
Sep	56.4	56.5	56.8	56.9	56.8	56.5	61.9	56.4
Oct	49.6	49.9	53.5	55.8	53.4	49.9	51.6	49.6
DEXO								
Apr	46.6	46	46.1	46.7	46.6	46.7	46.2	45.9
May	49.6	48.3	48.3	49.5	50.1	49.8	48.3	48.3
Jun	53.7	51.5	51.5	54.7	54.7	54.1	51.5	51.5
Jul	61	56.5	56.5	61.9	61.5	61.9	56.4	56.5
Aug	64.7	59.8	59.5	65.6	66.9	66.9	59.4	59.2
Sep	62.6	60.1	60.3	64.4	57.7	64.1	60.4	60.4
Oct	52.6	59.2	59.2	58.1	54.3	52.6	59.1	58.9
HCRO								
Apr	44.4	44.3	44.3	45.9	45.8	45.3	44.4	44.3
May	45.9	45.8	45.8	47.9	48.5	47.7	45.9	45.8
Jun	47.9	47.9	47.9	51	51	49.9	47.9	47.9
Jul	49.3	49.3	49.3	57.7	53.8	59	49.3	49.3
Aug	51.3	50.6	50.9	62.5	55.7	62.6	50.9	51.1
Sep	54.6	55.5	55.2	51.1	57.7	56.2	55.2	54.7
Oct	57.6	58.6	58.7	52.1	59.6	53.1	58.5	58.3
SLMO								
Apr	49.1	49.1	49	48.9	49.2	49.1	49	49.1
May	52.9	52.7	52.7	52.9	53.2	52.9	52.7	52.6
Jun	58.8	58.4	58.4	59.5	59.3	58.7	58.4	58.1
Jul	67.6	66.5	66.7	67.4	67.2	67	66.7	66.8
Aug	70.4	69.9	69.8	70.5	70.1	70.3	69.8	69.2
Sep	64.2	62.4	62.7	63.7	61.9	64.2	62.7	62.7
Oct	54.6	55.5	55.6	55.9	54.6	54.6	55.5	55.5

Year and Location	Alt1	Alt2a	Alt2b	Alt3a	Alt3b	Alt4	Alt5	NAA
SSFO								
Apr	44.8	44.8	44.7	44.6	44.4	44.8	44.7	44.5
May	48.5	48.3	48.3	47.6	46.9	48	48.3	46.6
Jun	53.2	52.7	52.7	51.5	51.6	52	52.6	49.9
Jul	58.7	56.2	56.2	57.3	55.1	54.6	56.2	56.8
Aug	65	64.1	64.1	64.2	58	60.9	64	56.2
Sep	62.1	54.6	54.6	54.8	64.7	57.3	54.8	52.4
Oct	52.6	52.9	52.9	52.9	59.6	51.8	52.6	51.6
2015								
ALBO								
Apr	55.3	55.1	54.7	54.9	54.7	55.3	54.7	54.5
May	62.8	61.8	61.9	62.4	61.9	62.2	61.5	60.9
Jun	70.9	69.6	69.8	71.1	70.1	70	69.9	70.5
Jul	73.9	74.1	74.2	74.9	75.4	74.4	74.4	75.3
Aug	71.8	72.9	72.9	73.1	73.4	72.4	73	73.3
Sep	65.1	64.8	64.8	65	65	64.8	64.8	64.9
Oct	58.9	59.2	59.1	59.2	60	59	59	59.1
BCLO								
Apr	46.9	46.9	46.9	47.3	46.4	46.9	46.9	46.5
May	52.4	52.4	52.4	53.6	49.2	52.4	52.4	50.5
Jun	57.9	57.7	57.7	62.2	52.9	57.7	57.7	55.5
Jul	61.8	61.4	61.4	69	58	61.4	61.4	58.6
Aug	61.5	61.5	61.5	68.5	61.4	61.5	61.5	60.5
Sep	57.3	57.4	57.4	63.8	56.6	57.4	57.4	60.8
Oct	53.2	53.6	53.6	58.8	55	53.6	53.6	60.1
CGRO								
Apr	46.5	46.5	46.1	46.6	46.1	46.5	46.3	46.3
May	50	50.4	50.2	50.8	49.4	50.4	50.4	50.2
Jun	56.9	56.3	56.2	56	54.9	56.6	56	57
Jul	60.8	59	57.3	60.1	56.4	59	57.2	62.1
Aug	59.5	57.8	55.4	61.7	54.9	57.8	55.5	61
Sep	56.2	56.7	51.1	59.1	50.6	56.6	50.9	56.8
Oct	52.5	53.9	48.2	55.4	48	53.8	48.2	54.9
DEXO								
Apr	53.8	52.7	52.5	53.3	52.5	53.9	52.7	52.1
May	59.4	57.1	56.7	59.4	56.4	59.1	56.5	55.9
Jun	65.4	62.5	62.1	66.1	62.1	63.9	62.2	63.5
Jul	69.8	69.1	68.5	71.1	69.7	70.2	68.7	70.3
Aug	68.9	70.8	70.4	72.7	72.1	69.8	70.2	73.1
Sep	65.7	67.2	68	68.3	68.2	66.5	68.6	69

Year and Location	Alt1	Alt2a	Alt2b	Alt3a	Alt3b	Alt4	Alt5	NAA
Oct	60.9	63.8	64	63.1	63.6	61.5	64.2	63.6
HCRO								
Apr	47.9	47.9	48.1	51.2	50.9	51.2	48.3	48.6
May	49.1	50.7	51.1	56.4	55.6	54.2	52.4	52.1
Jun	54.4	58.2	59	57	60.4	58.6	62.2	55.4
Jul	63	67.1	69.2	65.4	68.8	65.5	74	59.9
Aug	67.5	72.1	72.1	64.8	70.6	66.4	72.5	64.1
Sep	65.2	66.5	66.6	65.1	68	65.1	66.8	64.6
Oct	61.2	61.6	61.8	62.6	64	61.2	62	63.9
SLMO								
Apr	55.1	55.1	54.9	54.8	54.5	55.2	54.8	54.2
May	62.8	62.1	62.1	62.6	62	62.2	61.8	60.5
Jun	72	70.5	70.9	72.4	71.1	70.6	70.9	71
Jul	75.1	74.4	74.5	75.6	75.7	74.5	74.4	76.3
Aug	72.5	72.9	72.9	73.6	74.6	72.5	72.6	75
Sep	65.1	64.6	64.6	65.3	65.3	64.7	64.7	65.9
Oct	59.1	59.6	59.5	59.7	60.5	59.4	59.8	59.9
SSFO								
Apr	49.2	49.2	49.2	48.9	49.3	49.2	49.2	48.3
May	54.1	54.6	54.6	54	54.4	54.1	54.2	51
Jun	62	62.6	62.6	60.8	62.7	61.4	61.3	56.7
Jul	66.4	56.5	56.6	57	71.5	55.7	55.3	61.2
Aug	67.7	56.2	56.2	56.5	72.5	56.4	55.9	69.5
Sep	62.6	56.8	56.8	57.1	66.7	58	59.4	66
Oct	56.5	60.3	60.2	60.9	61.1	60.2	61.3	61
2016								
ALBO								
Apr	56	55.7	55.8	55.6	56	55.9	55.6	55.1
May	61.5	60.4	60.3	61	61	61.1	59.7	59.4
Jun	69	66.8	67.1	68.9	68.5	68.1	66.5	66.7
Jul	71.2	71	71	72.5	73.1	72.3	71	71.1
Aug	71.9	71.7	71.6	72.9	71.2	72.6	71.7	71.9
Sep	64.4	65.8	65.8	65.6	63.9	64.7	65.8	65.8
Oct	56.5	57.5	57.5	57	56.7	56.5	57.5	57.5
BCLO								
Apr	46.9	46.7	46.7	47	46.8	46.7	46.7	46.9
May	52.2	52.1	52.1	52.1	52.1	52.1	52.1	50.7
Jun	57.4	57	57	58.4	57.1	57	57	55.3
Jul	61.5	61.1	61.1	63.7	48.9	61.1	61.1	50
Aug	61.7	61.4	61.4	67.3	52.1	61.4	61.4	51.8

Year and Location	Alt1	Alt2a	Alt2b	Alt3a	Alt3b	Alt4	Alt5	NAA
Sep	57.2	57	57	63.1	52.8	57	57	54.5
Oct	51.1	51.2	51.2	53.9	53.5	51.2	51.2	53.2
CGRO								
Apr	45.6	45.8	45.5	46.3	45.5	45.6	46.1	45.7
May	49.8	49.7	48.5	50.4	49.1	49.6	50.1	49.6
Jun	56.5	55.3	52.9	54.3	53.5	55.7	53.5	56
Jul	60.1	59.2	55.7	57.4	55.8	59.3	55.2	60.9
Aug	60.7	58.5	55.7	60.3	55.7	60.5	55.1	58.6
Sep	56.4	53.2	50.6	58.6	50.6	55.9	50.2	51.9
Oct	49.7	49.1	47.6	52.8	47.6	49.6	47.7	49.1
DEXO								
Apr	52.6	50.5	50.5	52.2	52.2	52.7	50.5	50.2
May	57.2	52.8	52.8	56.5	56	57.2	52.5	52.5
Jun	62.9	57.1	57.2	63.3	61.7	62.3	57.3	57.3
Jul	65.3	61.6	61.5	67.9	68	67	61.5	61.7
Aug	67.5	64.8	64.9	69.4	61.3	68.9	65.3	65.7
Sep	62.1	65.6	65.8	66.4	59.5	63.1	66.1	66.3
Oct	54.6	60.5	60.6	59.1	57.6	54.5	60.9	60.4
HCRO								
Apr	46.7	46.7	46.7	50.1	49.9	50.2	46.7	46.9
May	48	48.1	48.1	53.6	54	53.8	48.7	49.9
Jun	49.4	50.5	50.4	60.1	59	58	52.7	54.3
Jul	52.5	52.3	52.2	62.4	64.4	65.8	54.4	56.4
Aug	59	59	60.1	56.3	69.2	62.9	64.6	61.9
Sep	61.7	61.7	64.3	57.6	67.7	56.4	65	63
Oct	58.8	59.4	59	55.4	59.5	52.5	56.4	59.8
SLMO								
Apr	56	55.8	55.6	55.4	55.6	55.9	55.6	55.5
May	62	60.9	60.8	61.2	61.4	61.3	60.4	60
Jun	69.5	67.3	67.6	69.5	68.6	68	67.3	67.1
Jul	71.9	71.6	71.6	73.1	72.1	72	71.6	71.1
Aug	73	72.4	72.3	73.8	72	72.8	72	72.3
Sep	64.8	64.1	64.3	64.3	63.7	64.3	64.4	64.4
Oct	55.4	55.9	55.9	55.7	55.7	55.6	56	56.2
SSFO								
Apr	49.4	49.7	49.7	48.9	49.3	49.7	49.7	48.6
May	54.2	54.3	54.3	53.7	54.1	53.7	54	50.9
Jun	60.8	60.9	60.9	60.3	60.7	59.5	60.8	54.7
Jul	64.8	64.6	64.6	65.3	65.8	61	64.8	58.6
Aug	67.2	60.3	60.3	60.3	71.2	58.8	57.2	57

Year and Location	Alt1	Alt2a	Alt2b	Alt3a	Alt3b	Alt4	Alt5	NAA
Sep	62.8	54.6	54.6	54.8	66.4	55.2	53.8	55.4
Oct	54	54	54	54.1	54.8	53.1	54.5	55.3

Cells highlighted in red indicate when maximum water temperatures were greater than 68 degrees (20 degrees Celsius) in the mainstem Willamette River at Salem and Albany.

8.4.4 Sediment Transport

NAA - WVS reservoirs are only partially drawdown under the NAA, with the exception of Fall Creek Dam, to the existing minimum conservation pool elevations. Although there are sediments entering the reservoir from upstream each year, the vast majority of these settle out within each reservoir. Sediment processes due to annual operations within the reservoir are limited with only the finest grained sediments able to resuspend during drawdowns and pass the reservoir (including those accumulating each year from annual upstream inputs). Downstream of these dams, lack of sediment delivery would affect habitat availability for lamprey over time.

Assuming no other major changes in the watershed downstream of WVS dams occur altering the ambient levels of sediment inputs in the watershed area downstream of each WVS dam, the availability of larval rearing habitat would be expected to slowly decline due to the lack of inputs of sediment and coarse organic matter from upstream of WVS dams. Similarly for spawning areas, the lack of gravel-sized and larger materials being transported below WVS dams would be expected to negatively affect areas with suitable gravel sized substrates for building redds. However, due to the high abundance of gravel areas currently existing (R2 Resources 2009), the availability of areas with suitable gravel conditions is not expected to become substantially limiting during the period of this analysis.

Reservoir elevations under the NAA would continue to be managed under the existing rule curves and therefore existing, low levels of sediment discharge would continue below WVS dams.

Sediment discharges from Fall Creek Dam are expected to contribute to maintenance of lamprey spawning and rearing habitat downstream of the dam. Fall Creek Reservoir would continue to be drawn down to streambed annually, as has occurred since 2011. Substantial quantities of fine sediments were released below the dam within the first few years following 2011, and then sediment releases have declined. Similar to those occurring in more recent years, lower levels of sediment releases are expected under the NAA, owing to contributions entering into the reservoir zone from upstream annually which are then resuspended and transported downstream during drawdowns to streambed each fall.

Operations of Big Cliff, Foster and Dexter Reservoirs under the action alternatives remain the same as under the NAA. These reservoirs provide for re-regulation of water discharged from upstream WVS dams. Therefore, they would not be further considered in the action alternatives except regarding their effects on sediment delivery in the system from upstream WVS dams.

Alternatives 2A, 2B, 4 and 5 – Under these alternatives, reservoir operations would occur similar to the NAA at Lookout Point, Hills Creek, Fall Creek, Blue River, Green Peter, and Detroit Dams, and therefore effects on lamprey would be as described for these dams under the NAA. In addition, gravel augmentation is included as a measure in all action alternatives below WVS dams in the North Santiam, South Santiam, and McKenzie Rivers. Gravel augmentation would help maintain and improve spawning and incubation habitat availability for lamprey below these dams.

At Cougar Dam under Alternative 2B, a deeper drawn to the diversion tunnel would result in significant delivery of sediments in the first few years after implementation of this measure. The drawdown would occur down to 25 feet over the top of the diversion tunnel. In this case, there would still be a small residual reservoir pool present which would initially affect coarse grained sediment delivery from reservoir erosion and upstream watershed sources from passing the dam. The. all residual pool would likely fill with sediment eroded from the reservoir and increase the ability of the dam to pass coarser grained sediments. Reductions in quantity would then likely occur, similar to that which occurred below Fall Creek Dam after initiation of drawdowns to streambed in 2011.

During the first few years below Cougar Dam, it is likely that finer sediments would negatively impact areas used by larval lamprey for rearing, covering these areas with finer silt and clay sediments. Areas used for spawning and incubation in the South Fork McKenzie and mainstem McKenzie Rivers also would be negatively affected by finer sediments filling interstitial spaces in gravel substrate, reducing the value of the habitat for spawning and incubation. These effects are however expected to be temporary and finer sediments, particularly in the spawning gravel areas within main channels would be flushed out with subsequent winter high flows and as declines in sediment delivery occur after the first few years (e.g. see Zymonas et al. 2010). Deposition of fines in low energy and backwater areas is expected to be persistent.

Below Green Peter Dam under alternatives 2A and 2B, deeper reservoir drawdowns to the regulating outlets would result in silts and clay sediments being discharged below the dam. Some of this sediment would settle in downstream Foster Reservoir, and some would be transported downstream of Foster Reservoir. It is highly uncertain if the levels passing downstream of Foster Reservoir would result in impacts to rearing or spawning/incubation areas. Conservatively, it is assumed these effects would be similar but lesser to those described above for Alternative 2B below Cougar Dam, and that repeated deeper drawdowns would lead to decreases in these effects over a few years following initiation of this measure.

Alternatives 3A and 3B – Deeper drawdowns are included in these alternatives at Lookout Point, Hills Creek, Fall Creek, Cougar, Blue River, Green Peter and Detroit reservoirs. With the exception of Cougar under Alternative 3B, large residual pools would remain. Effects downstream for lamprey are expected to be the same as described for Green Peter Reservoir for Alternatives 2A and 2B. For Cougar Reservoir under Alternative 3B, the deep drawdown is down to 25 feet over the top of the diversion tunnel. In this case, there would still be a small residual reservoir pool present which would affect sediment delivery from upstream in the watershed, however large releases of sediment are possible in the first few years, with effects as described for lamprey under Cougar Alternative 2B for Cougar Dam.

Under Alternative 3A, deeper drawdowns occur twice per year (in spring and fall) at Lookout Point and at Detroit reservoirs. Total annual sediment delivery is expected to be higher in the first couple of years, but also decline in magnitude to lower levels within fewer years, than in cases where deep drawdowns occur only once per year.

8.4.5 Habitat Access

Due to the lack of Pacific Lamprey spawning habitat information available, habitat for spring Chinook spawning was applied, as reported by Bond et al. (2017), to assess the availability of Pacific lamprey spawning habitat (Table 8 [Spawning redd capacity estimates]). We assumed habitat was available if effective fish passage to the reach exists. As previously described, we assumed Pacific lamprey passage at WVS dams would only occur at Fall Creek Dam under the NAA and under each action alternatives. Therefore, accessibility of habitat above WVS dams only occurs above Fall Creek under the NAA and under all action alternatives.

Based on the redd capacity information for spring Chinook salmon applied as a surrogate for lamprey, 43% of the existing spawning habitat in tributaries affected by WVS dams is accessible for Pacific lamprey under the NAA and under each action alternative. At the basin wide scale, Clemens et al. (2023) estimates there is 68% accessible Pacific lamprey habitat downstream of federal and non-federal dams.

Table 8-8. Spawning redd capacity estimates for spring Chinook salmon in the Upper Willamette River Basin applied for assessing Pacific lamprey habitat availability reproduced from Bond et al. (2017).

Basin and Range	Redd Capacity Estimates*	Accessible**
North Santiam Below Detroit	22,693	Y
North Santiam Above Detroit	15,602	
North Santiam Total	38,295	
South Santiam Below Foster	8,787	Y
South Santiam Above Foster	4,504	Y
South Santiam Above Green Peter	1,508	
South Santiam Total	14,799	
McKenzie Below Cougar and Trail Bridge dams	44,480	Y
McKenzie Above Cougar Dam	5,423	
McKenzie Total	49,903	

Middle Fork Below Fall Cr/Dexter/Lookout Point dams	8,813	Y
Middle Fork Above Fall Creek Dam	3,419	Y
Middle Fork Above Dexter/Lookout Point dams	72,937	
Middle Fork Above Hills Creek Dam	27,532	
Middle Fork Total	112,701	
Total available	215,698	
Total accessible	92,696	
Percent of total accessible	43%	
* under 1993-2011 avg temperatures		
**Fish Passage provided under NAA or Action Alternatives		

Y= yes

8.5 SUMMARY

NAA – Habitat access for Pacific lamprey spawning would be constrained to approximately 40% of that existing in tributaries where WVS dams are located, due to the lack of effective fish passage conditions at these dams. At Fall Creek Dam, an adult fish collection facility allows for collection of upstream migrating adults and trucking above the dam, and downstream passage is provided annually via a drawdown of the reservoir to streambed. Due to constrained habitat access above most WVS dams, abundance and production of lamprey would also be substantially constrained to existing levels. WVS water management would support spawning and rearing below WVS dams, with temperatures nearly always below stressful levels within tributaries. WVS reservoir releases during spring to fall would increase (supplement) river flows downstream, helping to reduce mainstem water temperature maximums, water temperatures in the mainstem, particularly in dry hot years would rise above stressful levels in summer. Flood management in winter however would reduce peak flows and associated river channel forming processes to that help maintain and create habitat. Sediment transport from upper watershed areas to areas below WVS dams would continue to be reduced by operation and maintenance of dams, which would reduce habitat quality and quantity for rearing and spawning slowly over time in these areas.

Alternative 1 and 2A – Spawning habitat access (constrained to approximately 40% of available), and effects of water management on habitat below WVS dams is similar to the NAA for Pacific lamprey with the following notable exceptions. Spawning habitat available at the 90% MWUA flow levels below WVS dams are provided nearly throughout the spawning and incubation season, except for below Dexter Dam. Alternative 1 also includes gravel augmentation which would improve spawning habitat quality and availability below WVS dams in major Willamette River tributaries affected by the WVS. Fish passage improvements at the Monroe Drop structure would provide access upstream in the Long Tom River, providing a minor increase in potential spawning and rearing habitat availability.

Alternative 2B and 5 – Habitat access, and effects of water management on habitat below WVS dams would be similar to Alternative 1, except below Cougar Dam. A deep drawdown of Cougar Reservoir to 25 feet over the diversion tunnel would reduce water storage for summer flow supplementation downstream annually, and change sediment discharge rates. Spawning habitat availability below Cougar Dam at the 90% MWUA flow level would range from approximately 51% to 66% annually depending on water year type. Substantial sediment releases in the first few years after deep reservoir drawdowns commence would reduce the quality and quantity of spawning and rearing habitat downstream in this timeframe. The levels of sediment are then expected to decline to natural levels of sediment transport similar to that entering Cougar Reservoir from the upstream watershed.

Alternative 3A– Deep drawdown of Detroit, Green Peter, Cougar, Hills Creek, Lookout and Fall Creek Reservoirs occur under this alternative. Under Alternative 3A, combined spring and fall drawdowns at Detroit and Cougar reservoirs would reduce water storage for summer flow supplementation annually downstream, reducing spawning habitat availability. Conversely, a deep reservoir drawdown in fall at Green Peter and Hills Creek Reservoir would increase flows below Foster and Dexter dams, respectively, increasing incubation habitat available in this reach. Sediment releases below Detroit, Green Peter and Lookout Point dams as a result of the deeper reservoir drawdowns to the regulating outlets would result in silts and clay sediments being discharged below the dams. Some of this sediment would settle in downstream reservoirs (Big Cliff Reservoir, Foster and Dexter), and some would be transported further downstream, impacting rearing and spawning/incubation areas. The highest levels of silt and clay releases would be temporary, occurring in the first few years of operations, and then sediment release levels would decline to approximately ambient levels delivered from upstream of Detroit Dam. Sediment releases from Hills Creek Dam are not expected to affect conditions downstream of Dexter Dam due to the presence of two downstream reservoirs (Lookout Point and Dexter Reservoirs) which would cause much or all of the suspended sediment to settle. Aside from the effect of deeper reservoir drawdowns at Detroit, Cougar and Lookout Point dams, effects are as described for Alternative 1.

Alternative 3B - Deep reservoir drawdowns also occur at the dams listed for Alternative 3A, however combined spring and fall drawdowns shift to occur at Green Peter, Cougar (to the diversion tunnel) and Hills Creek Reservoirs. The combined spring and fall drawdowns at Green Peter Reservoir would reduce water storage for summer flow supplementation annually downstream, reducing spawning habitat availability. Conversely, deep reservoir drawdowns in fall at Lookout Point would increase flows below Dexter dams, respectively, increasing incubation habitat available in this reach. Deep drawdown of Cougar Reservoir to the diversion tunnel would reduce water storage for summer flow supplementation downstream annually, and change sediment discharge rates, with effects are described for Alternative 2b. Other effects would occur as described for Alternative 1.

Alternative 4 – Structural improvements for downstream fish passage are included at Detroit, Cougar, Lookout Point and Hills Creek Dams. Although minimum flow targets are different, reservoir operations and the flow releases estimated to occur below each dam are similar to those occurring under Alternative 1. Therefore, effects are the same as those described for Alternative 1.

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