FINAL
Deschutes Basin
Habitat Conservation Plan

Volume II: Appendices

Submitted by:

Arnold Irrigation District
Central Oregon Irrigation District
Lone Pine Irrigation District
North Unit Irrigation District
Ochoco Irrigation District
Swalley Irrigation District
Three Sisters Irrigation District
Tumalo Irrigation District
City of Prineville, Oregon

October 2020

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Habitat Conservation Plan

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Submitted to: US Fish and Wildlife Service – *Portland, OR*
National Marine Fisheries Service – *Portland, OR*

Submitted by: Arnold Irrigation District – *Bend, OR*
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Three Sisters Irrigation District – *Sisters, OR*
Tumalo Irrigation District – *Bend, OR*
City of Prineville, Oregon

In Support of: Applications for ESA Section 10(a)(1)(B)
Incidental Take Permits

OCTOBER 2020

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FINAL

DESCHUTES BASIN HABITAT CONSERVATION PLAN

Appendix A – Supporting Technical Reports

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APPENDIX A-1

MOUNT HOOD ENVIRONMENTAL

Fisheries and Aquatic Toxicology Research

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TECHNICAL MEMORANDUM

Subject: Juvenile *Oncorhynchus mykiss* Rearing Capacity in the Crooked River, Oregon

Date: August 21, 2020

Prepared by: Mount Hood Environmental

Prepared for: Biota Pacific Environmental Sciences, Inc. and the Deschutes Basin Board of Control

Suggested Citation: Blackman, T.E. 2019. Juvenile *Oncorhynchus mykiss* rearing capacity in the Crooked River, Oregon. Technical Memorandum prepared for Biota Pacific Environmental Sciences, Inc. and the Deschutes Basin Board of Control. Mount Hood Environmental, Boring, OR. 17 pp.

PURPOSE

In preparation of the Deschutes Basin Habitat Conservation Plan (DBHCP), the effects of flow management scenarios being considered for the Crooked River on juvenile *Oncorhynchus mykiss* were assessed by comparing estimated fish carrying capacity across 9 scenarios and under three different hydrologic conditions. Estimates of juvenile fish were made by (1) surveying juvenile fish density and distribution in the mainstem Crooked River, (2) relating observed fish densities to habitat attributes (e.g. depth, substrate, water temperature, etc.) using a Bayesian N-mixture model, (3) estimating the changes in habitat attributes (e.g. depth, width, total area and temperature) under the potential flow management scenarios using predictive models for hydraulic area calculations and temperature changes, (4) estimating fish density under flow scenarios by applying modeled habitat coefficients to predicted changes in habitat area and temperature, and (5) expanding those predicted densities to the total available habitat quantified by the Aquatic Inventory Project (AIP) to estimate fish production potential (weekly expected number of fish) in each river reach (Figure 1). The 10 flow scenarios represent four potential phases of implementation of the DBHCP and six alternatives to the DBHCP (including no-action) being evaluated in the Draft Environmental Impact Statement for the DBHCP. The three hydrologic conditions represent a wet year (1993), an average year (2005) and a dry year (2001) from the historical record, where the year is defined according to available volume of storage in Prineville Reservoir at the beginning of the irrigation season. A schematic of the Crooked River rearing capacity calculations is shown in Figure 2.

FISH DENSITY & HABITAT SURVEY SUMMARY

In-stream habitat and fish densities were surveyed (via snorkeling) in several targeted locations in the Crooked Basin with the goal of sampling both summer conditions, when water temperatures are >7°C and <22°C, and winter conditions, when temperatures are <7 °C. Since juvenile salmonids use slow water habitats in much greater proportions at temperatures below 7°C, pool and run habitat was the primary focus of winter surveys. Moreover, because fish are most active at night during winter (Grunbaum 1996), wintertime surveys were conducted after sundown. Although all age classes of fish were recorded, this analysis focused on juveniles that have spent at least one winter rearing (age 1+) rather than young of year fish (age 0+), that experience significant mortality. Additionally, two life-history variants (i.e. resident red band vs. anadromous steelhead) of juvenile *O. mykiss* were not visually distinguishable, and therefore are treated as a single population in this analysis.

A total of 96 mesohabitat units (27 pools, 37 runs, and 32 riffles) were snorkeled during the summer from August 7-31, 2018 (Table 1). Water clarity significantly diminished in the uppermost reach (C-5) during the last week of August, constraining the majority of summer surveys to lower reaches. Winter surveys occurred from December 4-20, 2018, when temperatures fell below 7 °C and included only slow water habitat units (Table 1). Temperature sensors were placed throughout the Crooked River watershed to continuously monitor temperatures from August through December 2018 (Figure 3). Mean temperatures were relatively cool in reach C-1, which historically do not fall below 7 °C in the winter months as a result of year-round ground water inputs. Mean daily temperatures in reach C-2 were notably high during August, while C-5 remained quite cool during the summer months.

Steelhead

We observed *O. mykiss* across a variety of habitats (Figure 4). Estimated mean densities of age 1+ *O. mykiss* varied between reaches in the summer, with C-1 (the most downstream reach) having the highest observed densities. All fish density values were slightly lower than those used in the 2014 DBHCP capacity assessment (Courter et al. 2014). Moreover, observations of yearling *O. mykiss* were rare in reaches C-2 and C-3 during both summer and winter. Pool habitat was the least preferred habitat unit type in the summer, and the most preferred in the winter. This observation is consistent with Grunbaum (1996) who found age 1+ steelhead in inland streams preferred faster-water habitats during summer. Moreover, Reeves et al. (1983) indicated that preferred pool habitat for 1+ *O. mykiss* includes the upstream end of pools that are >1 m deep or pools close to higher velocity habitat. During our surveys, pools were seldom close to higher velocity unit types in the C-4, C-3, and C-2 reaches. This is an artifact of long stretches of homogenous habitat in these reaches, most of which are composed of slow-moving water (i.e. runs and pools). Density surveys conducted in the Crooked River by Torgersen et al. (2007) reported a similar pattern of declining *O. mykiss* abundance as they moved upstream from reach C-1 to reach C-2 and surmised this trend was related to temperature and turbidity. Interestingly, our surveys extended into reaches that were not surveyed by Torgersen (C-3, C-4 and C-5) and we observed very low densities of fish in those reaches during our summer sampling, despite optimal temperatures for juvenile salmonids.

Other Salmonids

Observations of Chinook salmon were rare (Figure 4), with only 15 individuals observed during the entire sampling effort almost exclusively in the C-1 reach. Further, only three age 1+ juveniles were detected from ~RM 10 to Bowman Dam, all downstream of Smith Rocks. This was likely an artifact of ODFW not planting fry in 2018 and only eight adult Chinook having passed above Opal Springs in 2017 (Burchell 2018). Additionally, we observed 15 Redband Trout adults in the C-1 reach and a single individual in the C-4 reach during the summer surveys. During winter surveys, 19 Redband Trout adults were identified in the C-1 reach and a single individual in the C-5 reach. 37 Mountain Whitefish were observed across the C-2 and C-3 reaches during the summer and none were observed during the winter surveys.

Density Modeling

Using a modified N-mixture model design from Som et al. (2017), we developed summer and winter models that used the reach-specific, replicated point counts (double observer snorkel surveys) to estimate both detection probability and fish abundance in the Crooked River as a function of habitat attributes (Equations 1 & 2).

Equation 1: Mixed effects Poisson binomial mixture model for summer habitat coefficients:

$$[N_i|\lambda_i,\omega_i] = \alpha \text{ Intercept} + \alpha \text{ Depth} + \alpha \text{ MWAT} + \text{offset(Area)} + \theta$$

Where Ni follow a Poisson distribution with mean λ_i, replicated counts follow a binomial distribution (with detection probability accounting for individual diver and pass) conditional on the local abundance. α's indicates vectors of regression parameter values: unit depth and maximum weekly average temperature (MWAT). ω_i is the zero inflation (Bernoulli trial) component of the model and includes random effects for reach. The model also includes an offset to account for variation in the size of areas sampled and θ for overdispersion. Random effects distributions are logit-normal on the response scale of the zero-inflation.

Equation 2: Mixed effects Poisson binomial mixture model for winter habitat coefficients:

$$[N_i|\lambda_i] = \alpha \text{ Intercept} + \alpha \text{ Depth} + \alpha \text{ MWAT} + \alpha \text{ Cobble} + \text{offset(Area)} + \theta$$

Where Ni follow a Poisson distribution with mean λi, replicated counts follow a binomial distribution (with detection probability accounting for individual diver) conditional on the local abundance. α's indicates vectors of regression parameter values: unit depth, maximum weekly average temperature (MWAT), and percent cobble substrate. The model also includes an offset to account for variation in the size of areas sampled and θ for overdispersion.

Changes in Habitat Attributes

Predicted MWAT values (Table 2) were summarized from estimated temperatures calculated by the CE-QUAL-W2 River Basin Model (Berger et al. 2019). The change in channel unit measurements (width and depth) were estimated by applying the predicted CE-QUAL-W2 flows to HEC-RAS hydraulic model equations (Table 3) and applying those estimates to all AIP units.

Summer Capacity Calculation

$$\text{Fish/ft}^2_{ij} = \alpha_0 + \alpha_{depth}*\text{Depth}_{ij} + \alpha_{mwat}*\text{MWAT}_{ij}$$

Where:

i = *ith* AIP unit

j = *jth* flow scenario

α_0 = N-mixture model summer intercept

α_{depth} = N-mixture model summer depth coefficient

$Depth_{ij}$ = predicted depth for *ith* AIP unit for the *jth* flow scenario and scaled to modeled data

α_{mwat} = N-mixture model summer mwat coefficient

$MWAT_{ij}$ = modeled MWAT for *ith* AIP unit for the *jth* flow scenario and scaled to modeled data

Unit $Capacity_{ij}$ for 95th quantile of poisson distribution = $Fish/ft^2_{ij}$ * area $(ft^2)_{ij}$

Reach $Capacity_r = \Sigma(Capacity_{ij})$

r = AIP reach (C-1, C-2, …)

Summer Capacity Predictions

Summer capacity was summarized on a weekly time scale (roughly mid-May – early October) and the week with the lowest total capacity for each scenario is shown in Figure 5. Reach C-5 had the highest overall capacity for juvenile *O. mykiss* as a result of consistently low summer temperatures. For water year 1993 (wet year), the HCP 400 cfs scenario yielded more than twice the capacity in the C-3 and C-4 reaches than the No Action (current) scenario, however, this was negligible compared to number of fish predicted in reach C-5 under any given scenario. In the 2001 water year (dry year), all scenarios were relatively comparable across all reaches, though C-5 shows some variability in the Alternative 4 (400 cfs) scenario. The 2005 water year (average year) had significant variability among scenarios. The HCP 100 cfs scenario yielded the highest capacity in reaches C-2, C-3, and C-4. This increase in capacity was driven by the lower MWAT values observed for that scenario relative to the other scenarios (Table 2). All summer capacity results are shown in Table 4.

Summer Model Assumptions

Mesohabitats with depths less than 6 inches do not provide adequate habitat and were outside the range of observational data and HEC-RAS predictions. Therefore, we assumed these depths would have a strong negative effect and were assigned a depth value of 4 feet, which would result in a large negative effect (Figure 7).

MWATs in C-5 during the 2005 water-year were always below the lowest MWAT under which we observed fish and were thus considered outside the range of the model's ability to predict abundance; the effect of MWAT was removed from 2005 scenarios in C-5 since presumably temperature was not a limiting factor.

Winter Capacity Calculation

$Fish/ft^2_{ij} = \alpha_0 + \alpha_{depth}*Depth_{ij} + \alpha_{boulder}*Boulder_i + \alpha_{mwat}*MWAT_{ij}$

Where:

i = *ith* AIP unit

j = *jth* flow scenario

α_0 = N-mixture model winter intercept

α_{depth} = N-mixture model winter depth coefficient

$Depth_{ij}$ = predicted depth for *ith* AIP unit for the *jth* flow scenario and scaled to modeled data

$\alpha_{boulder}$ = N-mixture model winter boulder coefficient

$Boulder_{ij}$ = Percent of unit with boulder substrate in *ith* AIP unit and scaled to modeled data

α_{mwat} = N-mixture model winter mwat coefficient

$MWAT_{ij}$ = modeled MWAT for *ith* AIP unit for the *jth* flow scenario and scaled to modeled data

$Unit\ Capacity_{ij}$ for 95^{th} quantile of poisson distribution = $Fish/ft^2_{ij} * area\ (ft^2)_{ij}$

$Reach\ Capacity_r = \Sigma(Capacity_{ij})$

r = AIP reach (C-1, C-2, …)

Winter Capacity Predictions

Winter capacity was summarized on a weekly time scale (roughly mid-November through December 31) and the week with the lowest total capacity for each scenario is shown in (Figure 6). In water year 1993, capacity was highest under the HCP 400 cfs scenario for all reaches with the exception of C-5. The 2001 water year had similar capacities under all scenarios. Similar to the summer capacities, HCP 100 cfs yielded higher capacities in the 2005 water year in all reaches except C-5. All winter capacity results are shown in Table 5.

Winter Model Assumptions

Depth ranges are capped at 3 feet to stay within the predictive range of the model (i.e. the effect all depths > 3 feet on abundance were the same as the effect of 3 feet of water in the model).

Based on Deschutes River steelhead data that documented the majority of smolt emigration at age 1+ (Olsen et al. 1992), all observations of juvenile *O. mykiss* were pooled (age 0 – 1+) since these fish would likely represent the following year's out-migrants.

Sensitivity Analysis

Summer and winter models were run with set flow and temperature values (Figure 9) to assess the validity of predictions. Summer fish estimates were highest at Crooked River flows between 50 and 200 cfs and were inversely related to flow; reflecting the negative relationship between depth and abundance in the summer N-mixture model. The magnitude of this relationship was highly dependent on temperature scenario, where warmer MWAT values (e.g. 24-25°C) resulted in very little change in the number of fish as flows increased. It should be noted that predicted MWAT values (CE-QUAL-W2 results) regularly exceeded 25°C under various scenarios whereas this analysis modeled temperatures from 20-25°C. For the winter model, the relationship between flow and the estimated number of fish was positively related to flow. In the context of the DBHCP, this sensitivity analysis highlights several key components of the seasonal capacity models:

1. When water in the Crooked River experiences high MWATs in the summer, increasing flow does not substantially change the number of fish the habitat can support. At lower MWAT values, increasing flows reduces the number of fish due to increasing water depth.
2. Increasing flow in the winter can substantially increase the number of fish a habitat can support.

Conclusions

Flow is limiting to both winter and summer rearing conditions in the Crooked River. In the summer, flow may negatively influence capacity if it falls below 50 cfs or rises high enough to inundate foraging habitat (>450 cfs). On the other hand, increasing flow in the summer could potentially increase summer capacity by lowering water temperature, which is most limiting factor to summer capacity. However, the amount of flow required to reduce summertime water temperatures would depend on climatic conditions and travel time through the system. Flow has a more direct effect on wintertime capacity, though it should be acknowledged that capacity of rearing fish in the winter is wholly dependent on those that survive the summer. Increasing flow in the winter will likely result in increased capacity, and the magnitude of the increase will be much greater when summertime thermal maximums are < 23°C.

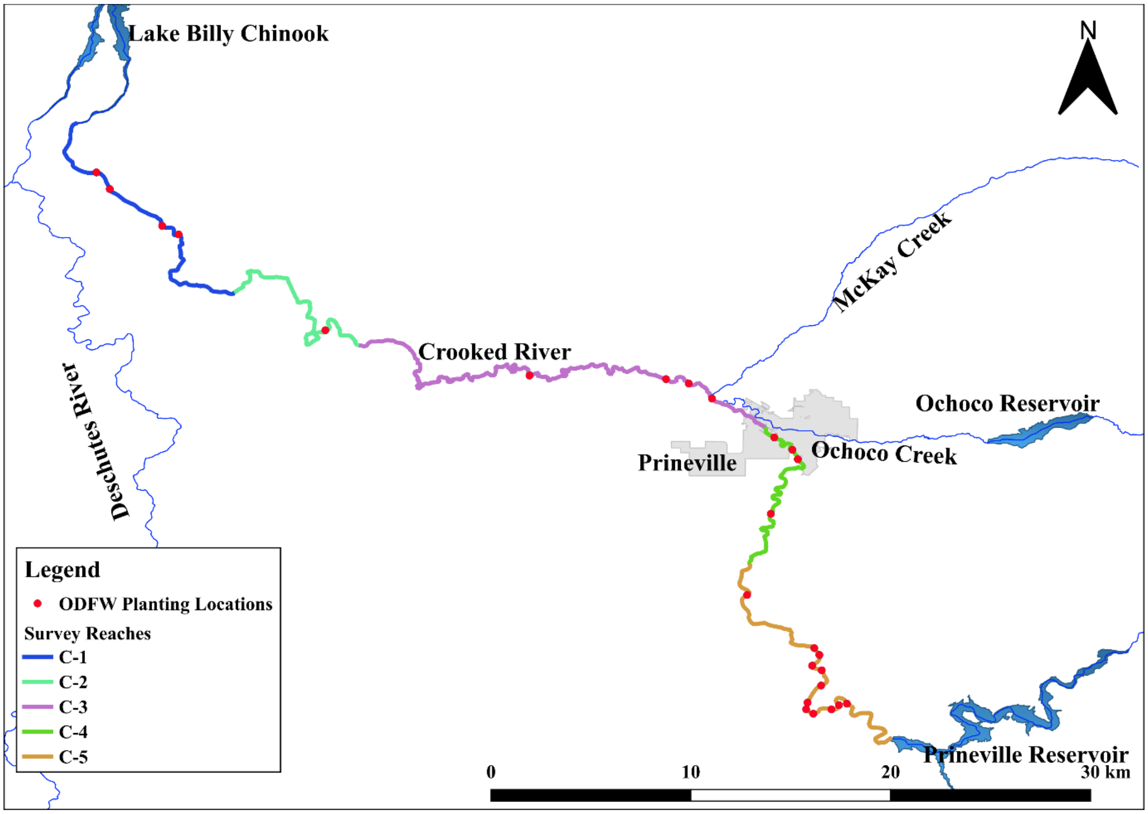

Figure 1. Crooked River, Oregon study reaches as defined in the Aquatic Inventory Project.

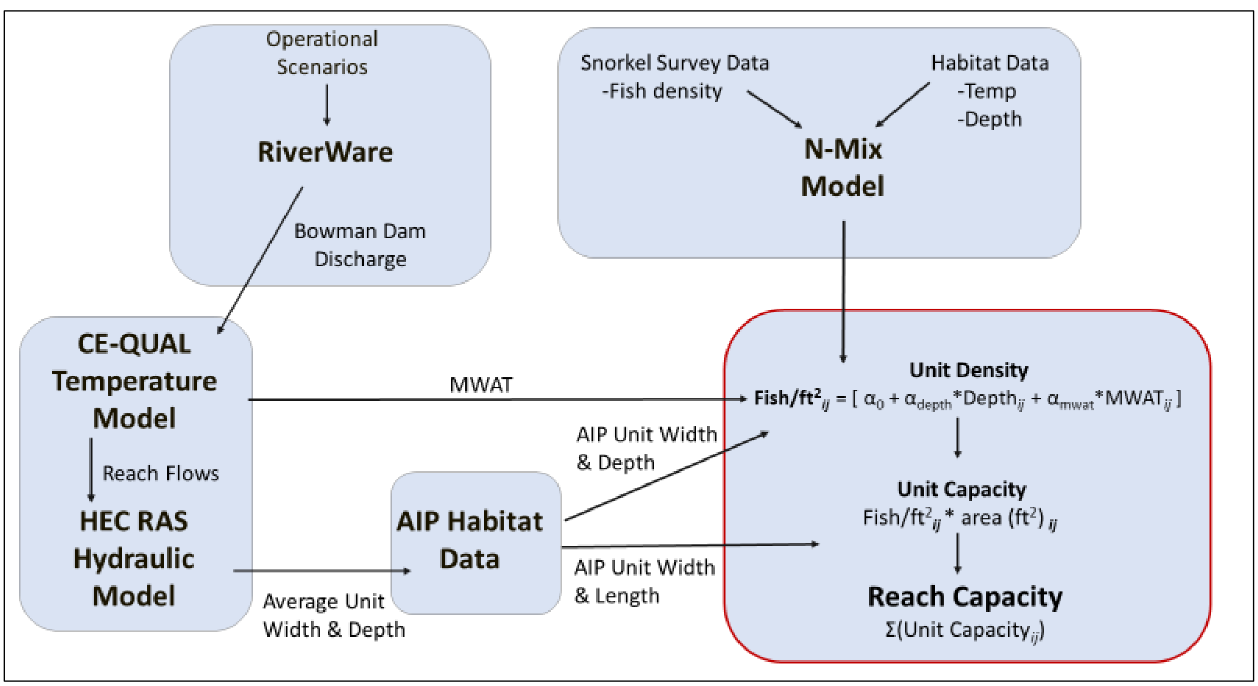

Figure 2. Schematic of capacity calculation

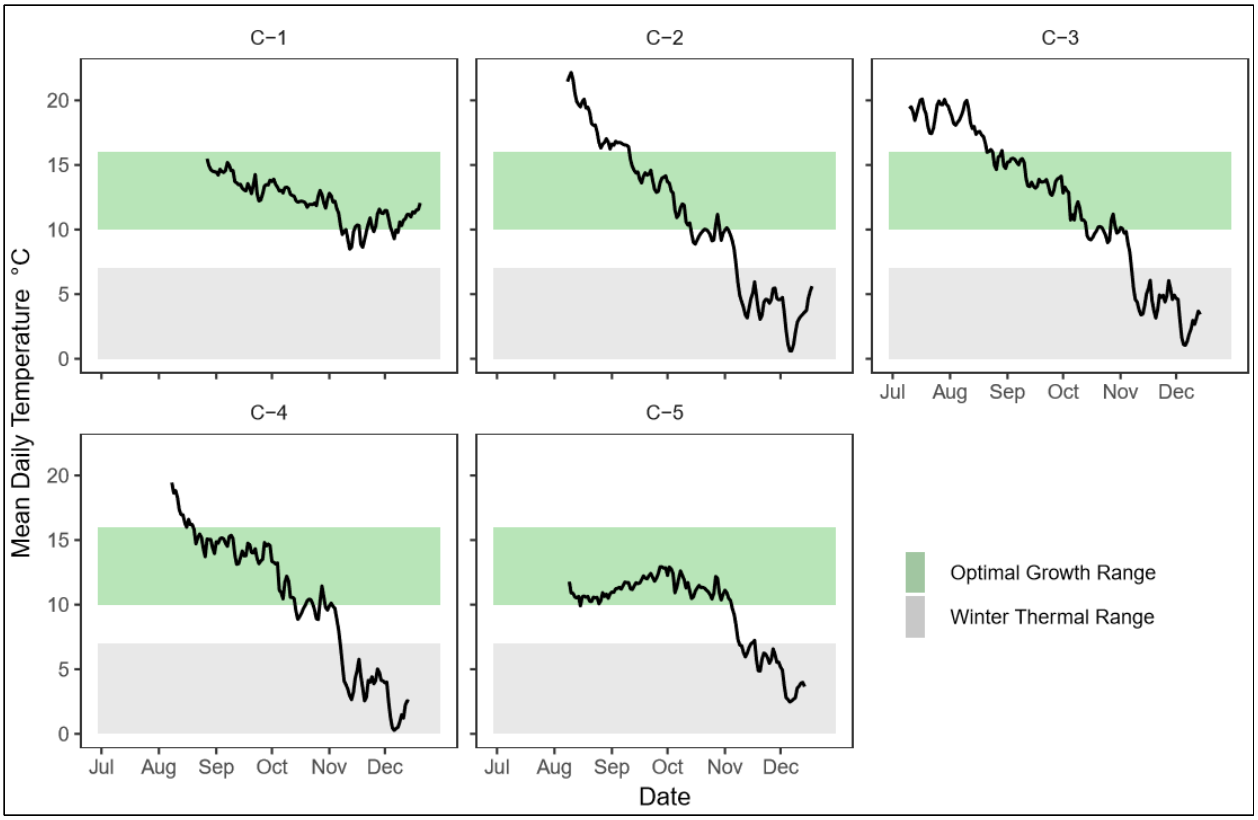

Figure 3. Mean daily temperatures in the mainstem Crooked River, Oregon in 2018. Green rectangles indicate generalized optimal thermal ranges for growth in rearing salmonids in inland rivers. Grey rectangles indicate winter temperatures range where behavioral shifts occur. Data for July in reach C-3 was acquired from USGS.

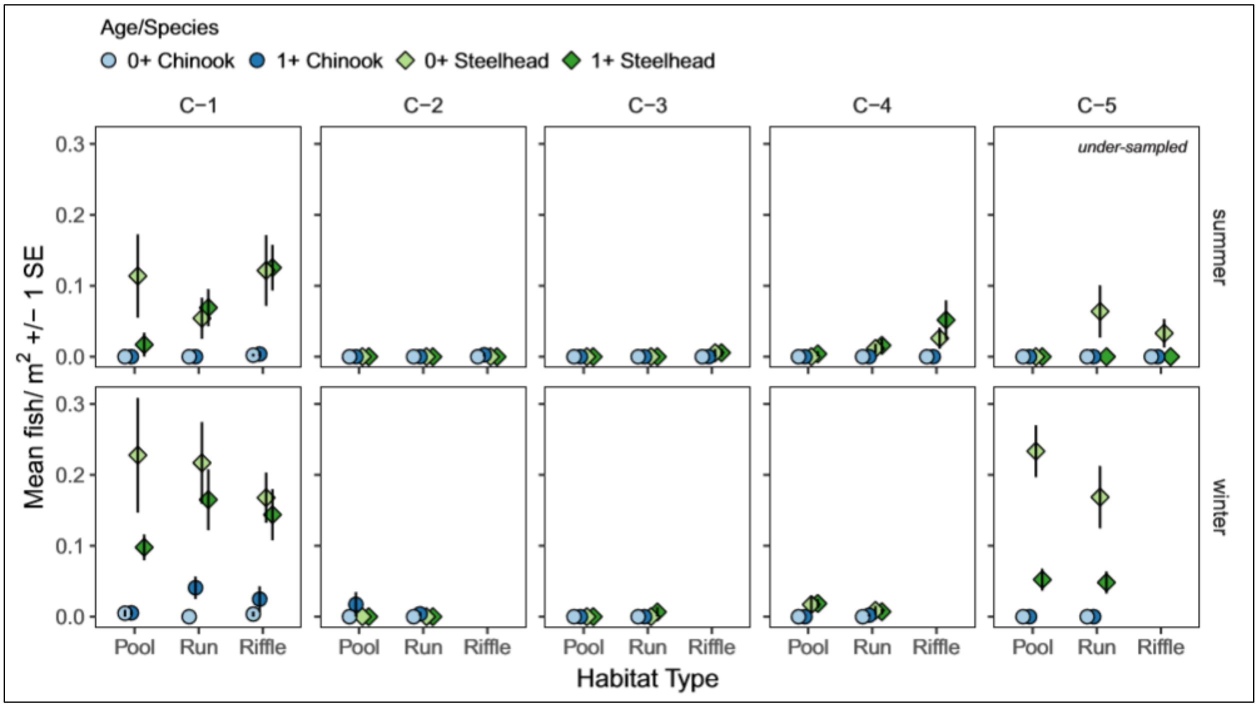

Figure 4. Seasonal fish densities in different habitat unit types within 5 reaches of the Crooked River, Oregon. Reach C-1 was surveyed in the winter but did not undergo winter temperatures (< 7 °C).

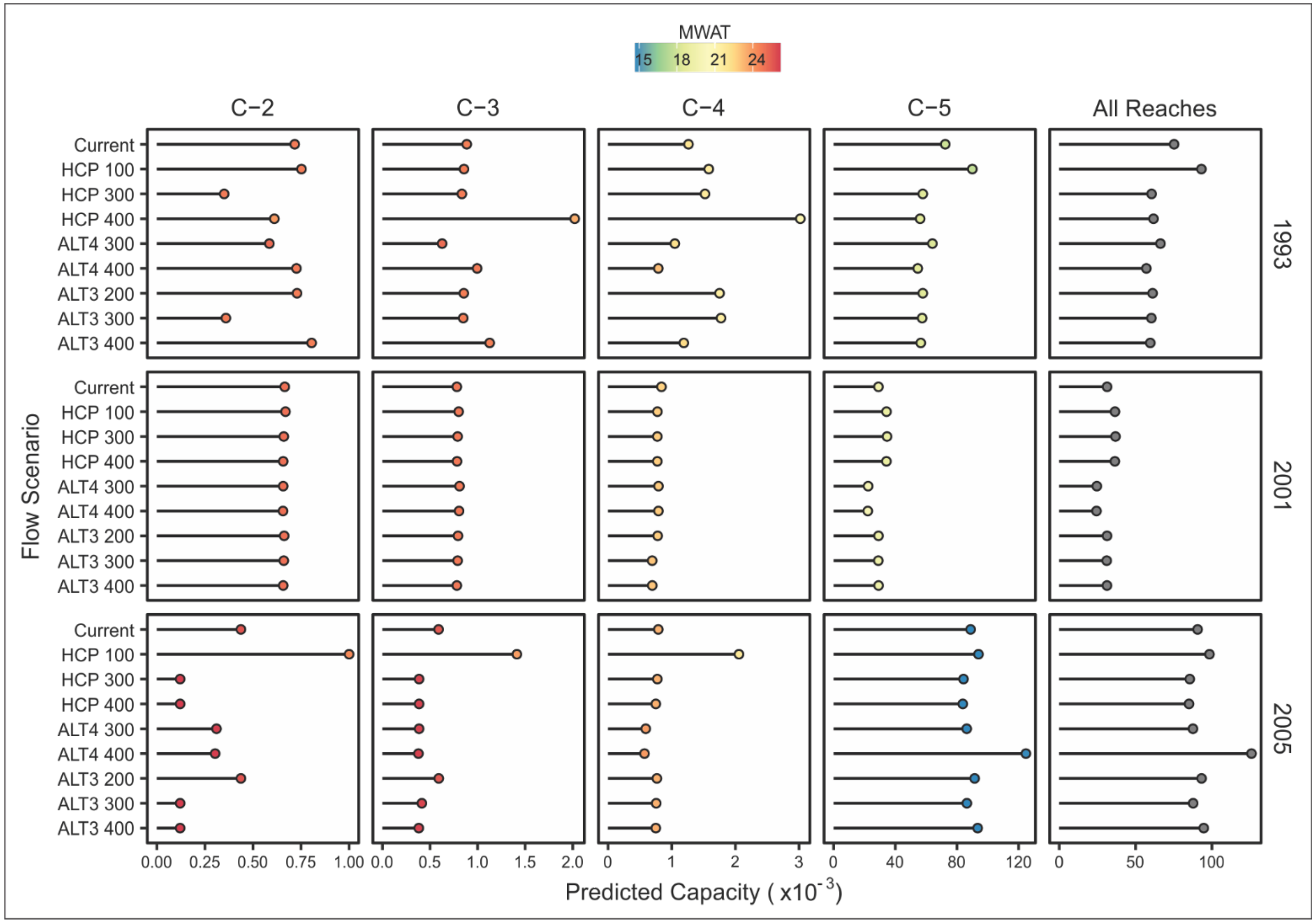

Figure 5. Summer capacity predictions (95th quantile of Poisson distribution) for three water years in the Crooked River reaches C-2, C-3, C-4, C-5, and all reaches combined. Reaches displayed in columns and water years displayed in rows. Colors indicate the predicted MWAT under each scenario. Capacities for all reaches are shown in grey.

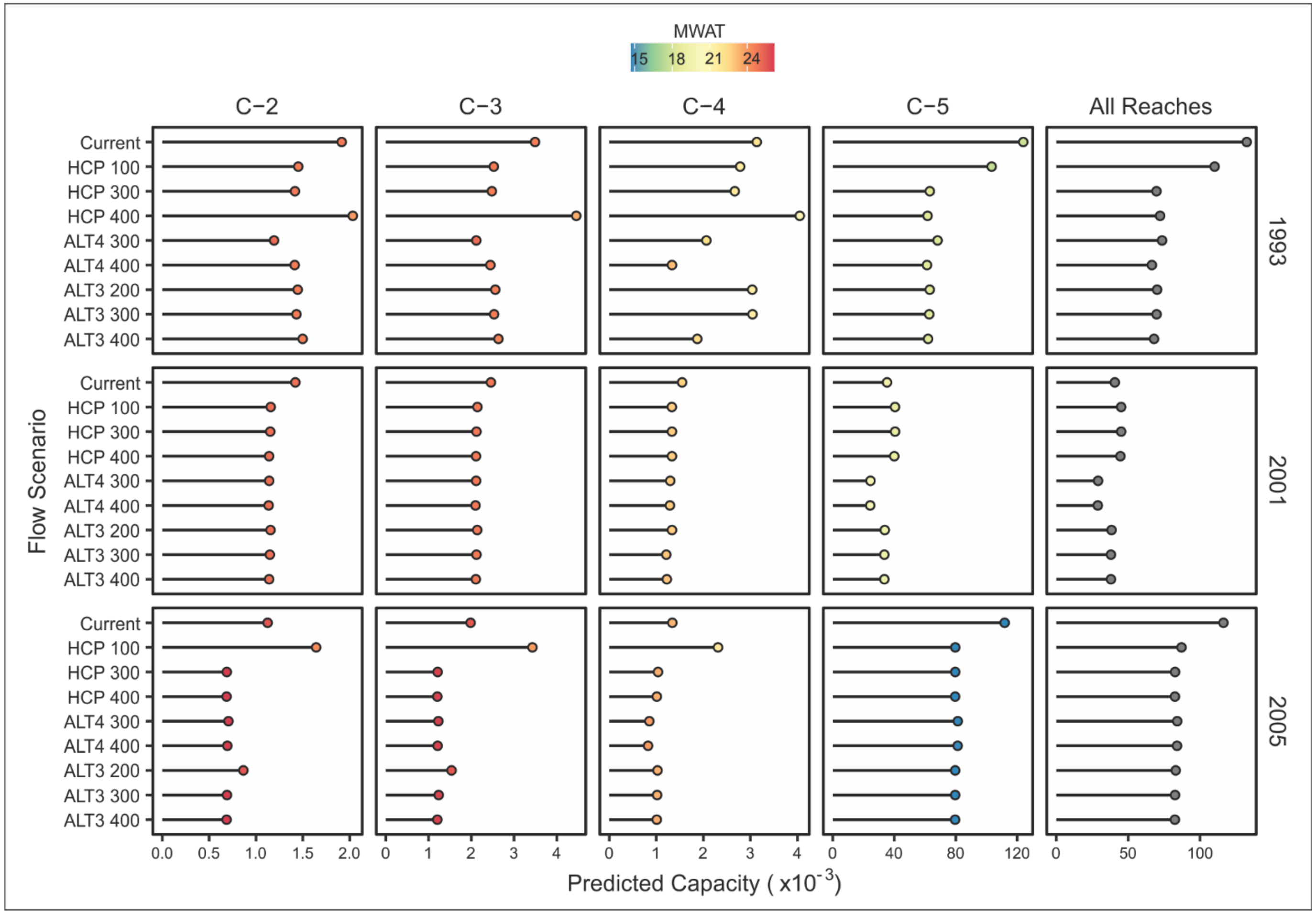

Figure 6. Winter capacity predictions for three water years in the Crooked River reaches C-2, C-3, C-4, C-5, and all reaches combined. Reaches displayed in columns and water years displayed in rows. Colors indicate predicted MWAT under each flow scenario. Capacities for all reaches are shown in grey.

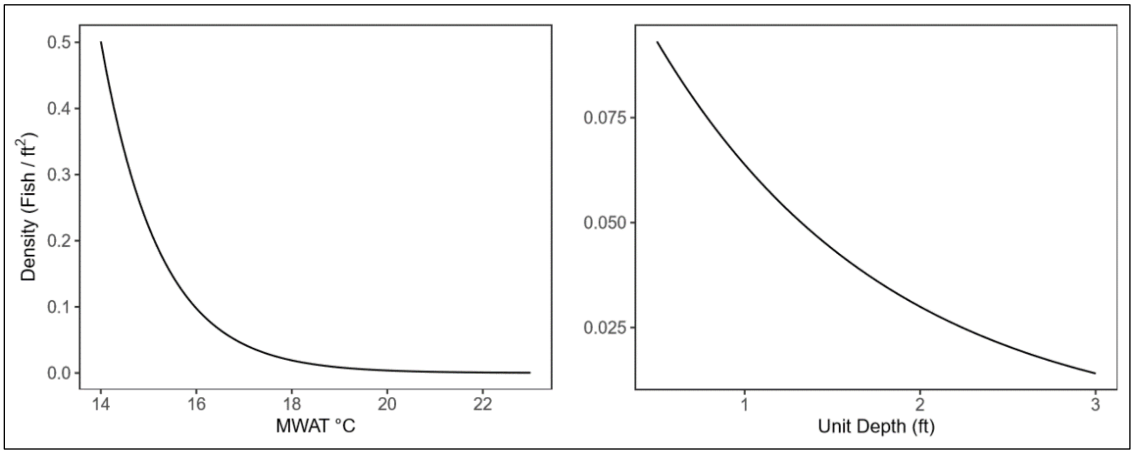

Figure 7. Main effects plots for summer n-mixture model coefficients: MWAT (maximum weekly average temperature, and habitat unit depth.

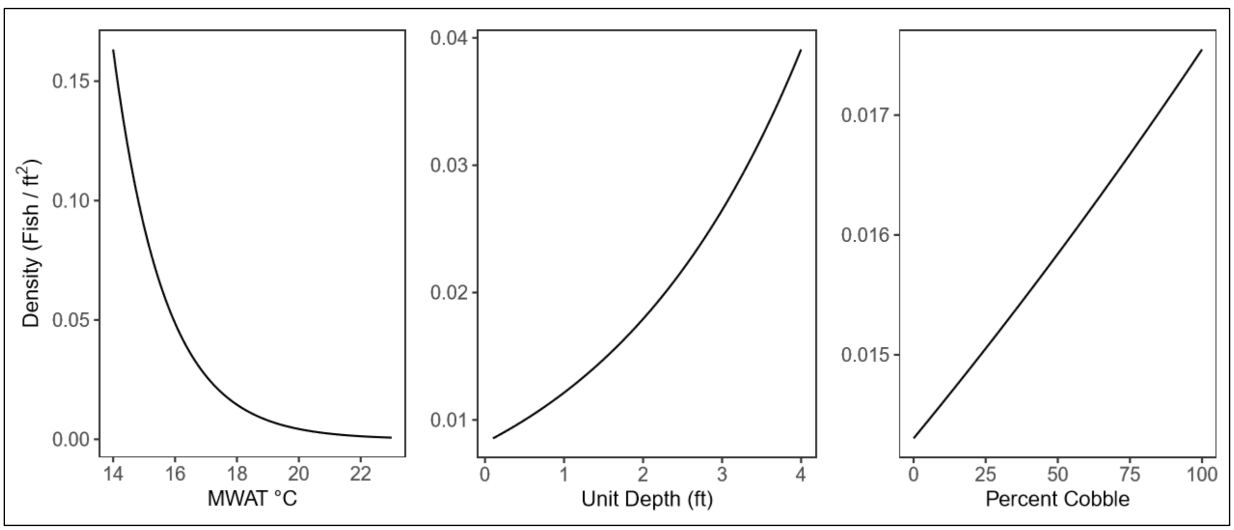

Figure 8. Main effects plots for winter n-mixture model coefficients: MWAT (maximum weekly average temperature, habitat unit depth, and percent of substrate comprised of cobbles.

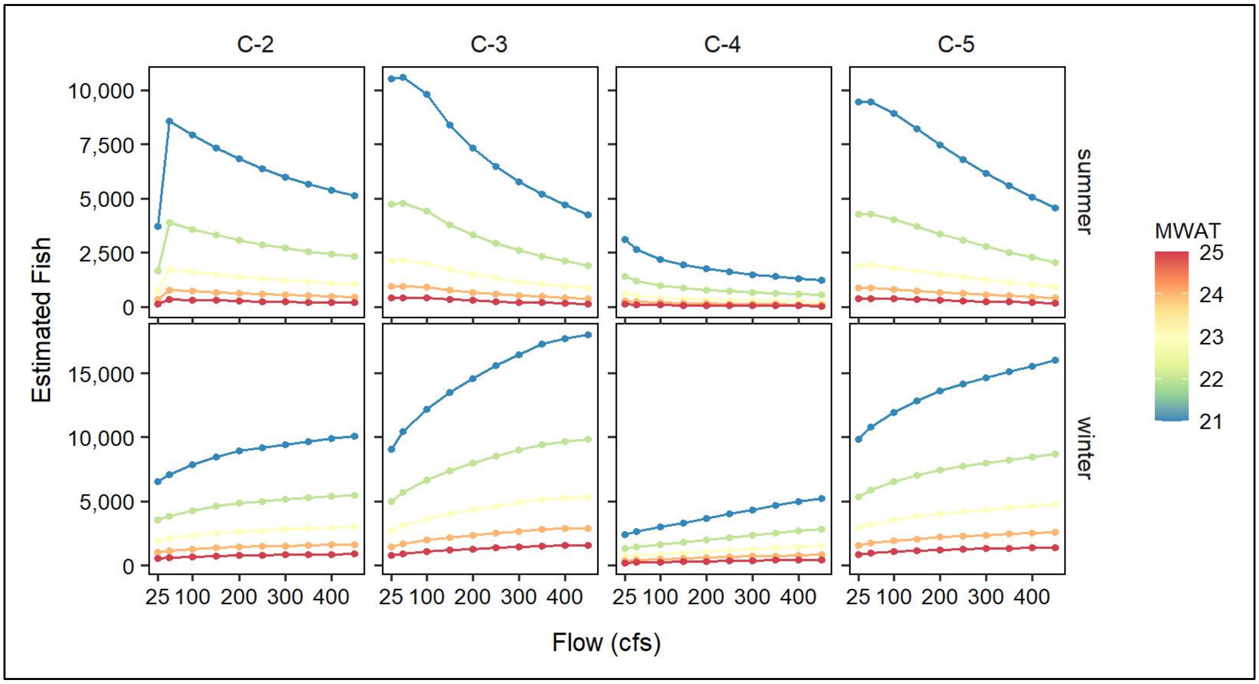

Figure 9. Model sensitivity for winter and summer models. Capacity was calculated for flow range 25 to 450 cfs across five MWAT scenarios. Fish estimates are the sum of median estimates for all habitat units within a reach.

Table 1. Number of habitat units snorkeled in the mainstem Crooked River in 2018.

	Habitat Unit Type (summer/winter)		
Reach	**Riffle**	**Pool**	**Run**
C-1	8/7	8/7	9/7
C-2	7/na	6/4	7/16
C-3	4/na	3/7	7/13
C-4	10/na	8/11	10/9
C-5	3/na	2/10	4/10

Table 2. Predicted MWAT values (°C) for 1993, 2001, and 2005 water years (WY). *Temperatures were outside the lower thermal range in model and assigned the maximum observed temperature, 14.7°C.

Reach	WY	Predicted MWAT (°C) by Flow Scenario								
		HCP 400	HCP 300	HCP 100	Alt4 400	Alt4 300	Alt3 400	Alt3 200	Alt3 300	No Action
C-2	1993	24.0	24.8	24.7	24.8	25.2	24.6	24.7	24.7	24.8
	2001	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
	2005	26.2	26.2	24.3	26.2	26.2	26.2	25.7	26.2	25.7
C-3	1993	23.5	24.7	24.7	24.8	25.1	24.6	24.7	24.7	24.6
	2001	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8
	2005	26.1	26.1	23.9	26.1	26.1	26.1	25.6	26.1	25.6
C-4	1993	21.0	21.8	21.7	23.2	22.3	22.4	21.5	21.5	22.0
	2001	22.8	22.8	22.8	22.9	22.9	23.0	22.8	23.0	22.7
	2005	23.5	23.4	21.8	24.0	23.9	23.5	23.5	23.5	23.4
C-5	1993	18.5	18.4	17.6	18.5	18.3	18.5	18.4	18.4	17.9
	2001	19.0	19.0	19.0	19.9	19.8	19.3	19.3	19.3	19.5
	2005	14.7*	14.7*	14.7*	14.8	14.7*	14.7*	14.7*	14.7*	14.7*

Table 3. HEC-RAS hydraulic equations for predicted depth (d) and width (w) for flow (x). Depths and widths are in feet and flows in cfs.

Reach	Unit Type	Depth equation	Width equation
C-2	RIFFLE	$d = 0.2221x^{0.2736}$	$w = 6.8531\ln(x) + 56.53$
	RUN	$d = 0.0049x + 0.9089$	$w = 6.7863\ln(x) + 52.303$
	POOL	$d = 0.0061x + 1.8933$	$w = 5.9361\ln(x) + 52.245$
C-3	RIFFLE	$d = 0.0037x + 0.3882$	$w = 20.433x^{0.217}$
	RUN	$d = 0.1135x^{0.5047}$	$w = 42.109x^{0.1173}$
	POOL	$d = 0.315x^{0.3832}$	$w = 5.9081\ln(x) + 35.398$
C-4	RIFFLE	$d = 0.5868\ln(x) - 1.5463$	$w = 0.1025x + 37.588$
	RUN	$d = 0.2528x^{0.3878}$	$w = 0.0808x + 64.696$
	POOL	$d = 0.4053x^{0.3412}$	$w = 0.0495x + 49.033$
C-5	RIFFLE	$d = 0.0034x + 0.6936$	$w = 10.436\ln(x) + 30.761$
	RUN	$d = 0.7364x^{0.2254}$	$w = 3.8708\ln(x) + 74.155$
	POOL	$d = 0.0034x + 2.3043$	$w = 61.407x^{0.0742}$

Table 4. Juvenile O. mykiss summer capacity estimates for 4 reaches in the mainstem Crooked River, Oregon.

Water Year	Flow Scenario	C-2	C-3	C-4	C-5	Total Capacity
	ALT3 400	805	1,127	1,190	56,522	59,644
	ALT3 300	359	849	1,774	57,411	60,393
	ALT3 200	729	855	1,751	57,829	61,164
	ALT4 400	726	995	789	54,573	57,083
1993	ALT4 300	585	627	1,049	64,069	66,330
	HCP 400	611	2,021	3,020	56,108	61,760
	HCP 300	350	835	1,523	57,822	60,530
	HCP 100	752	857	1,582	89,957	93,148
	NO ACTION	717	886	1,263	72,391	75,257
	ALT3 400	657	782	694	29,139	31,272
	ALT3 300	660	790	693	28,959	31,102
	ALT3 200	662	794	779	29,089	31,324
	ALT4 400	656	805	791	22,144	24,396
2001	ALT4 300	657	810	792	22,365	24,624
	HCP 400	657	784	774	34,235	36,450
	HCP 300	660	790	774	34,631	36,855
	HCP 100	669	801	775	34,282	36,527
	NO ACTION	665	782	839	29,058	31,344
	ALT3 400	121	382	750	93,423	94,676
	ALT3 300	121	414	756	86,426	87,717
	ALT3 200	437	592	767	91,449	93,245
	ALT4 400	303	378	572	124,719	125,972
2005	ALT4 300	310	385	592	86,318	87,605
	HCP 400	121	385	750	83,772	85,028
	HCP 300	121	385	774	84,237	85,517
	HCP 100	1,000	1,413	2,056	93,956	98,425
	NO ACTION	437	590	789	88,846	90,662

Table 5. Juvenile O. mykiss winter capacity estimates for 4 reaches in the mainstem Crooked River, Oregon.

Water Year	Flow Scenario	C-2	C-3	C-4	C-5	Total Capacity
1993	ALT3 400	1,498	2,634	1,871	61,987	67,990
	ALT3 300	1,432	2,533	3,045	62,754	69,764
	ALT3 200	1,445	2,561	3,039	63,072	70,117
	ALT4 400	1,413	2,446	1,333	61,280	66,472
	ALT4 300	1,193	2,117	2,064	68,184	73,558
	HCP 400	2,033	4,455	4,050	61,656	72,194
	HCP 300	1,416	2,481	2,668	63,111	69,676
	HCP 100	1,451	2,526	2,783	103,363	110,123
	NO ACTION	1,915	3,491	3,136	123,925	132,467
2001	ALT3 400	1,140	2,106	1,223	33,539	38,008
	ALT3 300	1,148	2,121	1,212	33,539	38,020
	ALT3 200	1,155	2,138	1,333	33,811	38,437
	ALT4 400	1,135	2,099	1,289	24,346	28,869
	ALT4 300	1,141	2,113	1,296	24,524	29,074
	HCP 400	1,140	2,111	1,332	40,013	44,596
	HCP 300	1,152	2,121	1,332	40,529	45,134
	HCP 100	1,157	2,143	1,330	40,484	45,114
	NO ACTION	1,420	2,458	1,548	35,290	40,716
2005	ALT3 400	686	1,205	1,009	79,582	82,482
	ALT3 300	690	1,237	1,017	79,626	82,570
	ALT3 200	865	1,538	1,025	79,636	83,064
	ALT4 400	694	1,212	824	81,244	83,974
	ALT4 300	706	1,229	852	81,317	84,104
	HCP 400	686	1,205	1,010	79,621	82,522
	HCP 300	688	1,212	1,036	79,672	82,608
	HCP 100	1,642	3,429	2,312	79,700	87,083
	NO ACTION	1,124	1,983	1,340	111,809	116,256

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APPENDIX A-2

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TECHNICAL MEMORANDUM

Subject: Effects of the Deschutes Basin Habitat Conservation Plan on juvenile summer steelhead trout (*Oncorhynchus mykiss*) rearing habitat availability in the Lower Deschutes River, Oregon.

Date: August 21, 2020

Prepared by: Mount Hood Environmental

Prepared for: Biota Pacific Environmental Sciences, Inc. and the Deschutes Basin Board of Control

Suggested Citation: Carpenter, F. 2019. Effects of the Deschutes Basin Habitat Conservation Plan on juvenile summer steelhead trout (*Oncorhynchus mykiss*) rearing habitat availability in the Lower Deschutes River, Oregon. Technical Memorandum prepared for Biota Pacific Environmental Sciences, Inc. and the Deschutes Basin Board of Control. Mount Hood Environmental, Boring, OR. 20 pp.

BACKGROUND

Juvenile steelhead trout (*O. mykiss*) avoid rearing areas where water velocities exceed 0.4 m/s (Bjornn and Reiser 1991). Flow conditions (Figure 1) and channel geomorphology in the Lower Deschutes River confine juvenile steelhead rearing habitat to the river's edge, where velocity and predator refugia exists.

To meet Federal Energy Regulation Commission requirements for the relicensing of the Pelton Round Butte Project (PRB), Portland General Electric (PGE) examined how changes in flow (discharge) would affect the wetted perimeter of the Lower Deschutes River in 2001, based on data collected by Fassnacht (1997). This study monitored the lower river between the PRB Reregulation Dam (RM 100) and the confluence with Trout Creek (RM 87) to assess the effects of hydro project operation on downstream bedload transport. Geomorphology, substrate compositions, and transport frequency were monitored along 24 transects across a range of flow conditions (3,500 – 8,000 cfs). These data were used to calculate the amount of edge habitat available at each transect location for the same range of flows (Duke 2001). In 2005, the National Marine Fisheries Service (NMFS) used the wetted perimeter data compiled by PGE to assess the impact of Deschutes River Basin Project water management scenarios proposed by the Bureau of Reclamation (Reclamation) on juvenile summer steelhead rearing habitat availability in the Lower Deschutes River.

In preparation of the Deschutes Basin Habitat Conservation Plan (DBHCP) and the accompanying Draft Environmental Impact Statement (DEIS), the effects of proposed water management scenarios on juvenile steelhead rearing habitat availability in the Lower Deschutes River were assessed using a similar approach. Specifically, predictions of wetted perimeter under historical conditions were compared to predictions calculated for each future alternative to demonstrate how the management action would change the availability of habitat for juvenile steelhead. A reduction in habitat relative to historical conditions is assumed to negatively impact rearing juvenile steelhead.

METHODS

Using data from Fassanacht (1997) and PGE (Duke 2001) we developed linear regression models, specific to each of the 24 monitoring transects, that related discharge to total wetted perimeter. An average model was calculated using the mean of all the transect model coefficients and corresponding intercepts. The average model was used to predict total wetted perimeter values for the flow conditions included in Duke (2001) at each of the 24 transects. Model fit was determined by regressing the predicted wetted perimeter against the observed wetted perimeter to calculate R^2 values.

Finally, we used the mean regression model to predict wetted perimeter values for monthly 10%, 50%, and 90% exceedance flows based on modeled flow output at Madras, Oregon (USGS Gauge 14092500). Modeled flows were generated by Reclamation (2020) using the RiverWare hydrologic model and exceedance values were consistent with the NMFS (2005) analysis. Predictions were made for each of the three final DBHCP flow management scenarios, five EIS flow scenarios, and historical conditions. These estimates were expanded to the section of river monitored by Duke (2001) and Fassnacht (1997) by multiplying wetted perimeter estimates by the total channel length (7.8 mi. or 41,184 ft.). The difference in predicted wetted perimeter values for each scenario relative to historical conditions was used to evaluate the impact each scenario would have on juvenile steelhead rearing habitat.

RESULTS

Variability in total wetted perimeter at all sites was low (Table 1) and for most sites wetted perimeter increased linearly with flow (Figure 2). Sites D-1, D-2, and D-4 were the exception. However, linear model fits still accounted for more than 70% ($R^2 > 0.7$) of the observed variation (Figure 2; Table 2). For some transect locations, the mean model overestimated or underestimated total wetted perimeter habitat. However, across all 24 sites the mean model overestimated total wetted perimeter by only 0.3% (190.73 ft.), indicating that the model was a strong fit to the data, regardless of station location (Figure 2).

Monthly exceedance flows increased as a result of the three DBHCP flow management scenarios, slight reductions were noted for the No Action scenario (Table 3). Predicted flows under the DBHCP increased most notably in the spring (March and April) whereas flows in the summer and fall remained similar to historical conditions (increasing less than 10%)(Table 4).

Similarly, monthly exceedance flows generally increased under all EIS alternatives (Table 6 and Table 7). Slight reductions (<0.05%) at 10% exceedance were noted for all EIS alternatives in February. The largest predicted increases in flow occurred in April between 4% and 12% (Table 7).

Due to the small magnitude of change in modeled flow conditions for each DBHCP scenario and EIS alternative relative to historical conditions, total wetted perimeter was minimally affected (Table 5 and Table 8). The proportional change in wetted perimeter never exceeded 1.5% for any of the three DBHCP scenarios or for the five EIS alternatives (Table 5 and Table 8). Total wetted perimeter was predicted to increase under both the DBHCP and the EIS alternatives. Therefore, it is unlikely that juvenile steelhead rearing habitat in the Lower Deschutes River will be altered by either the DBHCP flow management scenarios or any of the EIS alternatives since flow conditions and wetted perimeter are not predicted to deviate from historical conditions.

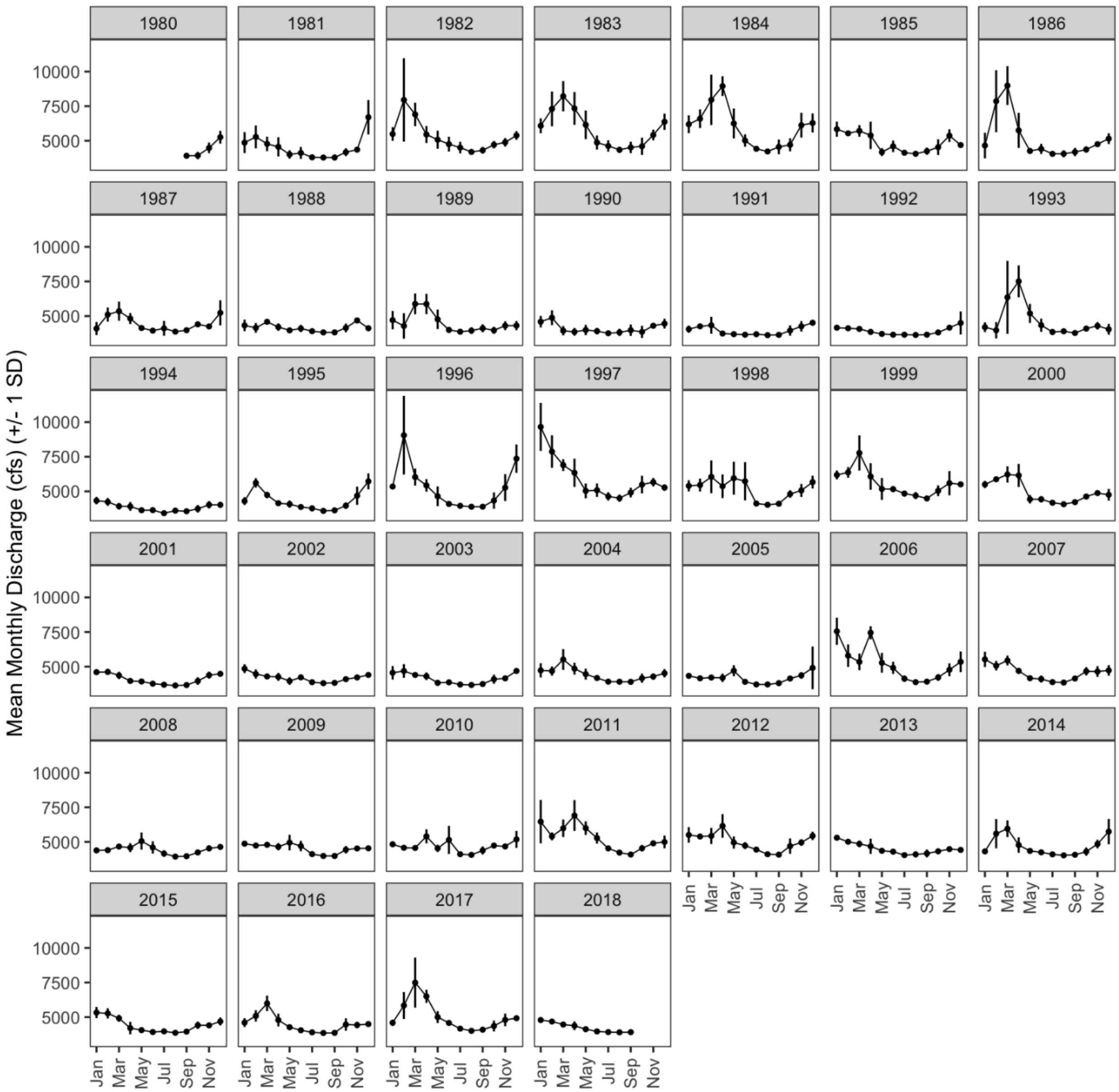

Figure 1. Modeled historical mean monthly discharge (cfs) at USGS gauge 14092500 on the Lower Deschutes River near Madras, Oregon 1980 – 2018 (Source: Reclamation 2020).

Table 1. Observed range of the total wetted perimeter (ft) for each of the river transects monitored in the Lower Deschutes River by Fassnacht (1997) and Portland General Electric (Duke 2001).

		Total Wetted Perimeter (ft)	
Station	**RM**	**Range**	**Mean (*SD*)**
B-1	98	193.99 − 209.23	202.79 (*4.98*)
B-2	98	178.72 − 193.66	188.06 (*4.33*)
B-3	98	187.36 − 200.25	194.21 (*4.11*)
B-4	98	203.23 − 214.95	209.47 (*3.78*)
D-1	96.1	199.14 − 225.18	208.69 (*6.9*)
D-2	96.1	185.57 − 229.99	197.79 (*14.61*)
D-3	96.1	186.75 − 252.03	219.03 (*21.79*)
D-4	96.1	187.26 − 256.16	237.28 (*23.79*)
E-1	94	244.66 − 259.88	250.95 (*5.23*)
E-2	94	260.48 − 274.03	266.77 (*4.81*)
E-3	94	329.69 − 347.15	338.57 (*5.63*)
E-4	94	491.75 − 499.35	495.74 (*2.48*)
E-5	94	487.23 − 494.38	490.85 (*2.33*)
E-6	94	465.92 − 472.92	469.39 (*2.28*)
H-1	90.4	264.02- − 278.77	271.01 (*4.62*)
H-2	90.4	278.98 − 287.84	283.09 (*2.94*)
H-3	90.4	276 − 283.88	280.7 (*2.38*)
H-4	90.4	271.36 − 278.44	274.99 (*2.31*)
I-1	90.2	194.52 − 211.07	203 (*5.36*)
I-2	90.2	133.48 − 167.18	151.6 (*10.77*)
I-3	90.2	130.39 − 151.81	142.53 (*6.73*)
I-4	90.2	154.42 − 204.49	181.78 (*16.44*)
I-5	90.2	180.59 − 229.33	209.53 (*16.41*)
I-6	90.2	237.38 − 257.81	245.82 (*6.71*)

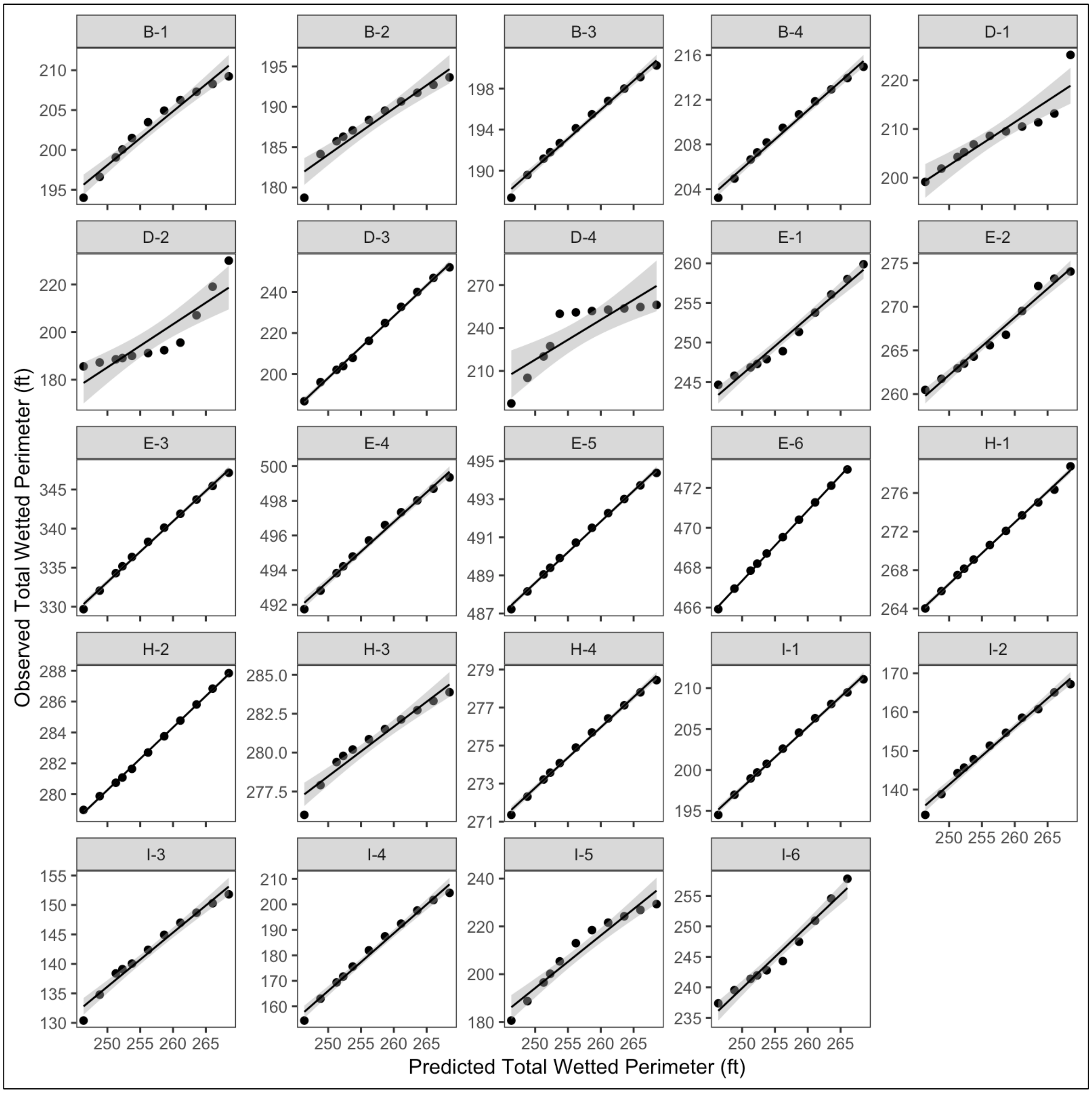

Figure 2. Comparison of total wetted perimeter predictions and observed values.

Table 2. Parameters for linear regression models developed to relate total wetted perimeter (W.P.) at each monitored transect in the Lower Deschutes River to flows (Q) near Madras, OR (USGS Gauge – 14092500).

Station	Model Formula	Intercept (β)	Coefficient (m)	R^2	*p-value*
B-1	W.P. = (Q*m) + β	184	0.003322	0.963	0.000000096121562
B-2	W.P. = (Q*m) + β	172.1	0.002821	0.916	0.000003894497413
B-3	W.P. = (Q*m) + β	178.5	0.002783	0.991	0.000000000136442
B-4	W.P. = (Q*m) + β	195	0.002558	0.989	0.000000000334398
D-1	W.P. = (Q*m) + β	184.2	0.004338	0.856	0.000045635092312
D-2	W.P. = (Q*m) + β	147.5	0.008895	0.801	0.000196755021135
D-3	W.P. = (Q*m) + β	135.3	0.0148	0.997	0.000000000000673
D-4	W.P. = (Q*m) + β	159.8	0.01371	0.718	0.000987355935104
E-1	W.P. = (Q*m) + β	231.1	0.003513	0.976	0.000000014569880
E-2	W.P. = (Q*m) + β	248.5	0.003238	0.981	0.000000004284567
E-3	W.P. = (Q*m) + β	316.9	0.003823	0.997	0.000000000001233
E-4	W.P. = (Q*m) + β	486.2	0.001681	0.992	0.000000000083001
E-5	W.P. = (Q*m) + β	481.9	0.001585	0.998	0.000000000000385
E-6	W.P. = (Q*m) + β	460	0.001731	0.999	0.000000000000078
H-1	W.P. = (Q*m) + β	253.3	0.003137	0.998	0.000000000000413
H-2	W.P. = (Q*m) + β	271.8	0.001998	0.999	0.000000000000014
H-3	W.P. = (Q*m) + β	271.8	0.00157	0.943	0.000000668742564
H-4	W.P. = (Q*m) + β	266.1	0.001565	0.996	0.000000000004024
I-1	W.P. = (Q*m) + β	182.4	0.003636	0.997	0.000000000001913
I-2	W.P. = (Q*m) + β	110.4	0.007282	0.988	0.000000000554554
I-3	W.P. = (Q*m) + β	117	0.004516	0.975	0.000000017566857
I-4	W.P. = (Q*m) + β	118.9	0.01111	0.987	0.000000000744431
I-5	W.P. = (Q*m) + β	148.2	0.01084	0.945	0.000000588199464
I-6	W.P. = (Q*m) + β	218.6	0.00503	0.972	0.000000176305458
Mean Model	W.P. = (Q*m) + β	229.164	0.00491	NA	NA

Table 3. Monthly discharge by exceedance probability for historical conditions and three DBHCP flow scenarios at USGS gauge 14092500 on the Lower Deschutes River near Madras, Oregon (1980-2018).

Exceedance Probability	Historical (cfs)	No Action (cfs)	HCP 100 (cfs)	HCP 300 (cfs)	HCP 400 (cfs)
			January		
10%	6,353	6,399	6,420	6,485	6,556
50%	4,870	5,005	5,028	5,041	5,113
90%	4,140	4,233	4,265	4,432	4,524
			February		
10%	7,044	7,028	7,069	7,107	7,096
50%	5,020	5,157	5,177	5,207	5,246
90%	4,170	4,303	4,312	4,493	4,586
			March		
10%	7,896	7,962	7,946	7,966	7,995
50%	5,100	5,563	5,546	5,606	5,673
90%	4,167	4,493	4,471	4,657	4,750
			April		
10%	7,313	7,663	7,643	7,632	7,617
50%	4,825	5,433	5,416	5,405	5,398
90%	3,840	4,360	4,305	4,284	4,281
			May		
10%	5,780	5,835	5,823	5,808	5,783
50%	4,360	4,505	4,507	4,466	4,454
90%	3,727	3,922	3,910	3,864	3,848
			June		
10%	5,161	5,266	5,257	5,242	5,201
50%	4,210	4,360	4,364	4,355	4,333
90%	3,700	3,885	3,880	3,851	3,817
			July		
10%	4,513	4,634	4,634	4,630	4,604
50%	3,980	4,134	4,132	4,091	4,051
90%	3,670	3,852	3,850	3,781	3,759
			August		
10%	4,290	4,366	4,366	4,351	4,330
50%	3,920	4,052	4,054	4,033	3,999
90%	3,627	3,804	3,808	3,771	3,755
			September		
10%	4,460	4,488	4,569	4,556	4,549
50%	3,960	4,048	4,060	4,038	4,032
90%	3,650	3,765	3,780	3,770	3,779
			October		
10%	4,970	5,314	5,320	5,325	5,360
50%	4,310	4,423	4,473	4,531	4,603
90%	3,770	3,879	3,930	3,930	3,939
			November		
10%	5,451	5,903	5,862	5,863	5,837
50%	4,575	4,737	4,775	4,806	4,868
90%	4,120	4,113	4,137	4,308	4,398
			December		
10%	6,220	6,328	6,347	6,382	6,425
50%	4,780	4,949	4,966	5,022	5,085
90%	4,200	4,300	4,330	4,499	4,581

Table 4. Differences in modeled monthly exceedance flow probabilities for DBHCP flow scenarios relative to historic conditions at USGS gauge 14092500 on the Lower Deschutes River near Madras, Oregon (1980 – 2018). Reductions in flow are highlighted in red.

Exceedance Probability	No Action Flow Diff. (cfs) (% Change)	HCP 100 Flow Diff. (cfs) *(% Change)*	HCP 300 Flow Diff. (cfs) *(% Change)*	HCP 400 Flow Diff. (cfs) *(% Change)*
		January		
10%	46.02 (0.72)	66.52 (*1.05*)	132.32 (*2.08*)	203.39 (*3.2*)
50%	134.73 (2.77)	158.07 (*3.25*)	171.43 (*3.52*)	243.03 (*4.99*)
90%	92.6 (2.24)	125.02 (*3.02*)	292.05 (*7.05*)	383.94 (*9.27*)
		February		
10%	-15.88 (-0.23)	24.97 (*0.35*)	63.39 (*0.9*)	52.04 (*0.74*)
50%	137.27 (2.73)	156.95 (*3.13*)	187.27 (*3.73*)	226.32 (*4.51*)
90%	132.78 (3.18)	141.53 (*3.39*)	322.63 (*7.74*)	416.15 (*9.98*)
		March		
10%	66.26 (0.84)	49.7 (*0.63*)	69.83 (*0.88*)	98.89 (*1.25*)
50%	463.39 (9.09)	445.68 (*8.74*)	506.02 (*9.92*)	573.01 (*11.24*)
90%	325.6 (7.81)	304.47 (*7.31*)	489.51 (*11.75*)	582.94 (*13.99*)
		April		
10%	350.09 (4.79)	330.42 (*4.52*)	319.3 (*4.37*)	303.62 (*4.15*)
50%	607.71 (12.6)	591.17 (*12.25*)	579.94 (*12.02*)	572.94 (*11.87*)
90%	519.52 (13.53)	465.26 (*12.12*)	443.7 (*11.55*)	440.72 (*11.48*)
		May		
10%	54.59 (0.94)	43.48 (*0.75*)	28.23 (*0.49*)	2.63 (*0.05*)
50%	145.02 (3.33)	146.58 (*3.36*)	106.45 (*2.44*)	94 (*2.16*)
90%	195.44 (5.24)	183.25 (*4.92*)	136.51 (*3.66*)	121.3 (*3.25*)
		June		
10%	104.65 (2.03)	95.86 (*1.86*)	81.44 (*1.58*)	40.13 (*0.78*)
50%	149.77 (3.56)	153.83 (*3.65*)	144.5 (*3.43*)	122.63 (*2.91*)
90%	184.79 (4.99)	179.73 (*4.86*)	151.45 (*4.09*)	116.81 (*3.16*)
		July		
10%	121.2 (2.69)	121.04 (*2.68*)	117.12 (*2.6*)	91.33 (*2.02*)
50%	154.41 (3.88)	151.98 (*3.82*)	110.75 (*2.78*)	71.15 (*1.79*)
90%	181.96 (4.96)	179.52 (*4.89*)	110.83 (*3.02*)	89 (*2.43*)
		August		
10%	76.49 (1.78)	75.59 (*1.76*)	61.17 (*1.43*)	39.52 (*0.92*)
50%	132.25 (3.37)	134.33 (*3.43*)	112.55 (*2.87*)	78.73 (*2.01*)
90%	176.77 (4.87)	180.79 (*4.98*)	144.02 (*3.97*)	127.93 (*3.53*)
		September		
10%	27.84 (0.62)	109.46 (*2.45*)	96.1 (*2.15*)	88.76 (*1.99*)
50%	88.17 (2.23)	99.82 (*2.52*)	78.22 (*1.98*)	71.81 (*1.81*)
90%	114.81 (3.15)	130.44 (*3.57*)	119.53 (*3.27*)	128.66 (*3.53*)
		October		
10%	344.01 (6.92)	350.34 (*7.05*)	354.77 (*7.14*)	389.86 (*7.84*)
50%	113.04 (2.62)	163.06 (*3.78*)	221.43 (*5.14*)	292.53 (*6.79*)
90%	108.89 (2.89)	160.22 (*4.25*)	159.76 (*4.24*)	169.47 (*4.5*)
		November		
10%	452.27 (8.3)	411.16 (*7.54*)	412.23 (*7.56*)	385.86 (*7.08*)
50%	161.59 (3.53)	200.37 (*4.38*)	231.32 (*5.06*)	292.82 (*6.4*)
90%	-6.52 (-0.16)	16.54 (*0.4*)	188.14 (*4.57*)	277.85 (*6.74*)
		December		
10%	108.04 (1.74)	127.46 (*2.05*)	161.94 (*2.6*)	204.94 (*3.29*)
50%	168.71 (3.53)	185.64 (*3.88*)	242.08 (*5.06*)	304.86 (*6.38*)
90%	100.35 (2.39)	129.68 (*3.09*)	298.6 (*7.11*)	380.76 (*9.07*)

Table 5. Change in predicted total wetted perimeter (ft^2) for DBHCP flow scenarios relative to historical conditions for 7.8 miles between the Reregulating Dam and Trout Creek. Reductions in total wetted perimeter (ft^2) are highlighted in red.

Exceedance Probability	No Action W.P. Diff. (ft^2) (% Change)	HCP 100 W.P. Diff. (ft^2) (% Change)	HCP 300 W.P. Diff. (ft^2) (% Change)	HCP 400 W.P. Diff. (ft^2) (% Change)
January				
10%	9,419 (0.09)	13,615 (0.13)	27,084 (0.25)	41,630 (0.39)
50%	27,577 (0.26)	32,354 (0.31)	35,089 (0.33)	49,745 (0.47)
90%	18,954 (0.18)	25,590 (0.25)	59,778 (0.58)	78,586 (0.76)
February				
10%	-3251 (-0.03)	5,110 (0.05)	12,975 (0.12)	10,653 (0.1)
50%	28,096 (0.27)	32,125 (0.3)	38,332 (0.36)	46,323 (0.44)
90%	27,178 (0.26)	28,969 (0.28)	66,037 (0.64)	85,179 (0.82)
March				
10%	13,562 (0.12)	10,172 (0.09)	14,294 (0.13)	20,241 (0.18)
50%	94,848 (0.9)	91,223 (0.86)	103,574 (0.98)	11,7286 (1.11)
90%	66,644 (0.64)	6,2321 (0.6)	100,196 (0.97)	119,320 (1.15)
April				
10%	71,657 (0.65)	67,631 (0.61)	65,356 (0.59)	62,145 (0.56)
50%	124,390 (1.19)	121,003 (1.15)	118,705 (1.13)	117,272 (1.12)
90%	106,337 (1.03)	95,231 (0.93)	90,818 (0.88)	90,208 (0.88)
May				
10%	11,173 (0.1)	8,899 (0.08)	5,778 (0.05)	538 (0.01)
50%	29,683 (0.29)	30,003 (0.29)	21,788 (0.21)	19,241 (0.19)
90%	40,003 (0.39)	37,508 (0.37)	27,942 (0.27)	24,827 (0.24)
June				
10%	21,420 (0.2)	19,621 (0.19)	16,669 (0.16)	8,214 (0.08)
50%	30,656 (0.3)	31,486 (0.3)	29,578 (0.29)	25101 (0.24)
90%	37,823 (0.37)	36,788 (0.36)	30,999 (0.3)	23,909 (0.23)
July				
10%	24,808 (0.24)	24,776 (0.24)	23,972 (0.23)	18,693 (0.18)
50%	31,606 (0.31)	31,109 (0.3)	22,669 (0.22)	14,563 (0.14)
90%	37,245 (0.36)	36,745 (0.36)	22,685 (0.22)	18,217 (0.18)
August				
10%	15,656 (0.15)	15,472 (0.15)	12,520 (0.12)	8,090 (0.08)
50%	27,071 (0.26)	27,495 (0.27)	23,036 (0.22)	16,114 (0.16)
90%	36,181 (0.35)	37,004 (0.36)	29,478 (0.29)	26,185 (0.26)
September				
10%	5,699 (0.05)	22,405 (0.22)	19,670 (0.19)	18,168 (0.17)
50%	18,047 (0.17)	20,431 (0.2)	16,011 (0.16)	14,698 (0.14)
90%	23,501 (0.23)	26,698 (0.26)	24,466 (0.24)	26,335 (0.26)
October				
10%	70,414 (0.67)	71,708 (0.68)	72,616 (0.69)	79,798 (0.76)
50%	23,138 (0.22)	33,376 (0.32)	45,323 (0.44)	59,877 (0.58)
90%	22,288 (0.22)	32,795 (0.32)	32,701 (0.32)	34,687 (0.34)
November				
10%	92,573 (0.87)	84,158 (0.79)	84,377 (0.79)	78,979 (0.74)
50%	33,076 (0.32)	41,013 (0.39)	47,348 (0.45)	59,936 (0.57)
90%	-1,334 (-0.01)	3,386 (0.03)	38,508 (0.37)	56,871 (0.55)
December				
10%	22,114 (0.21)	26,090 (0.24)	33,146 (0.31)	41,948 (0.39)
50%	34,532 (0.33)	37,998 (0.36)	49,551 (0.47)	6,2401 (0.6)
90%	20,540 (0.2)	26,544 (0.26)	61,118 (0.59)	77,936 (0.75)

Table 6. Monthly discharge by exceedance probability for historical conditions and five DEIS alternatives at USGS gauge 14092500 on the Lower Deschutes River near Madras, Oregon (1980-2018).

Exceedance Probability	Historical	Alternative 3.200	Alternative 3.300	Alternative 3.400	Alternative 4.300	Alternative 4.400
			January			
10%	6,353	6,449	6,509	6,524	6,509	6,558
50%	4,870	5,034	5,095	5,122	5,095	5,135
90%	4,140	4,351	4,439	4,515	4,439	4,517
			February			
10%	7,044	7,025	7,025	7,039	7,025	7,041
50%	5,020	5,179	5,233	5,241	5,233	5,264
90%	4,170	4,415	4,499	4,581	4,499	4,580
			March			
10%	7,896	7,967	8,010	7,997	8,010	8,037
50%	5,100	5,591	5,653	5,686	5,653	5,702
90%	4,167	4,578	4,670	4,759	4,670	4,758
			April			
10%	7,313	7,635	7,630	7,625	7,630	7,625
50%	4,825	5,407	5,399	5,385	5,399	5,381
90%	3,840	4,282	4,280	4,299	4,280	4,304
			May			
10%	5,780	5,814	5,801	5,761	5,801	5,760
50%	4,360	4,496	4,453	4,434	4,453	4,412
90%	3,727	3,896	3,852	3,846	3,852	3,839
			June			
10%	5,161	5,223	5,202	5,160	5,202	5,159
50%	4,210	4,365	4,348	4,323	4,348	4,325
90%	3,700	3,871	3,843	3,824	3,843	3,821
			July			
10%	4,513	4,655	4,644	4,626	4,644	4,624
50%	3,980	4,133	4,098	4,075	4,098	4,070
90%	3,670	3,801	3,778	3,760	3,778	3,757
			August			
10%	4,290	4,390	4,380	4,361	4,380	4,361
50%	3,920	4,063	4,024	4,006	4,024	3,999
90%	3,627	3,776	3,751	3,750	3,751	3,740
			September			
10%	4,460	4,584	4,548	4,553	4,548	4,543
50%	3,960	4,058	4,034	4,018	4,034	4,018
90%	3,650	3,748	3,738	3,732	3,738	3,731
			October			
10%	4,970	5,301	5,305	5,348	5,305	5,355
50%	4,310	4,461	4,508	4,576	4,508	4,579
90%	3,770	3,906	3,908	3,914	3,908	3,912
			November			
10%	5,451	5,808	5,789	5,817	5,789	5,804
50%	4,575	4,724	4,781	4,862	4,781	4,858
90%	4,120	4,201	4,289	4,378	4,289	4,377
			December			
10%	6,220	6,296	6,368	6,402	6,368	6,417
50%	4,780	5,003	5,065	5,104	5,065	5,138
90%	4,200	4,404	4,492	4,567	4,492	4,568

Table 7. Differences in modeled monthly exceedance flow probabilities for each EIS alternative relative to historical conditions at USGS gauge 14092500 on the Lower Deschutes River near Madras, Oregon (1980 – 2018). Reductions in flow are highlighted in red.

Exceedance Probability	Alternative 3.200	Alternative 3.300	Alternative 3.400	Alternative 4.300	Alternative 4.400
			January		
10%	96.46 (1.52)	156.09 (2.46)	170.8 (2.69)	156.09 (2.46)	205.02 (3.23)
50%	163.88 (3.37)	224.79 (4.62)	252.49 (5.18)	224.79 (4.62)	264.61 (5.43)
90%	210.69 (5.09)	298.54 (7.21)	374.91 (9.06)	298.54 (7.21)	376.78 (9.1)
			February		
10%	-19.3 (-0.27)	-19.17 (-0.27)	-5.43 (-0.08)	-19.17 (-0.27)	-2.93 (-0.04)
50%	159.33 (3.17)	213.25 (4.25)	221.44 (4.41)	213.25 (4.25)	243.59 (4.85)
90%	245.1 (5.88)	328.76 (7.88)	411.11 (9.86)	328.76 (7.88)	409.83 (9.83)
			March		
10%	71.16 (0.9)	113.95 (1.44)	100.51 (1.27)	113.95 (1.44)	140.86 (1.78)
50%	491.38 (9.63)	553.25 (10.85)	586.23 (11.49)	553.25 (10.85)	601.52 (11.79)
90%	411.31 (9.87)	502.57 (12.06)	592.48 (14.22)	502.57 (12.06)	591.29 (14.19)
			April		
10%	322.41 (4.41)	316.92 (4.33)	312.47 (4.27)	316.92 (4.33)	311.55 (4.26)
50%	581.52 (12.05)	574.17 (11.9)	560.26 (11.61)	574.17 (11.9)	555.97 (11.52)
90%	442.19 (11.52)	440.28 (11.47)	458.54 (11.94)	440.28 (11.47)	464.05 (12.08)
			May		
10%	33.53 (0.58)	21.09 (0.36)	-18.65 (-0.32)	21.09 (0.36)	-20.44 (-0.35)
50%	136.05 (3.12)	92.9 (2.13)	73.52 (1.69)	92.9 (2.13)	52.13 (1.2)
90%	168.66 (4.53)	124.66 (3.34)	119.07 (3.19)	124.66 (3.34)	112.44 (3.02)
			June		
10%	61.61 (1.19)	41.22 (0.8)	-0.92 (-0.02)	41.22 (0.8)	-1.66 (-0.03)
50%	154.73 (3.68)	138.27 (3.28)	112.78 (2.68)	138.27 (3.28)	115.22 (2.74)
90%	170.89 (4.62)	143.3 (3.87)	124.15 (3.36)	143.3 (3.87)	120.55 (3.26)
			July		
10%	142.03 (3.15)	131.31 (2.91)	113.3 (2.51)	131.31 (2.91)	111.09 (2.46)
50%	153.35 (3.85)	117.52 (2.95)	95.47 (2.4)	117.52 (2.95)	89.72 (2.25)
90%	130.69 (3.56)	107.72 (2.94)	89.8 (2.45)	107.72 (2.94)	86.86 (2.37)
			August		
10%	100.37 (2.34)	90.45 (2.11)	70.82 (1.65)	90.45 (2.11)	70.57 (1.65)
50%	143.18 (3.65)	103.53 (2.64)	85.52 (2.18)	103.53 (2.64)	78.83 (2.01)
90%	148.8 (4.1)	124.12 (3.42)	122.56 (3.38)	124.12 (3.42)	113.03 (3.12)
			September		
10%	123.63 (2.77)	88.44 (1.98)	92.9 (2.08)	88.44 (1.98)	83.03 (1.86)
50%	97.82 (2.47)	73.7 (1.86)	58.32 (1.47)	73.7 (1.86)	58.18 (1.47)
90%	97.5 (2.67)	88.01 (2.41)	81.56 (2.23)	88.01 (2.41)	81.37 (2.23)
			October		
10%	330.67 (6.65)	334.5 (6.73)	378.39 (7.61)	334.5 (6.73)	384.96 (7.75)
50%	151.02 (3.5)	197.59 (4.58)	266.31 (6.18)	197.59 (4.58)	268.86 (6.24)
90%	135.73 (3.6)	138.41 (3.67)	143.82 (3.81)	138.41 (3.67)	142.35 (3.78)
			November		
10%	357.23 (6.55)	338.25 (6.21)	365.52 (6.71)	338.25 (6.21)	353.11 (6.48)
50%	149.12 (3.26)	206.47 (4.51)	286.82 (6.27)	206.47 (4.51)	282.95 (6.18)
90%	81.14 (1.97)	169.04 (4.1)	258.3 (6.27)	169.04 (4.1)	257.32 (6.25)
			December		
10%	76.17 (1.22)	147.92 (2.38)	181.55 (2.92)	147.92 (2.38)	197.13 (3.17)
50%	222.82 (4.66)	285.32 (5.97)	323.7 (6.77)	285.32 (5.97)	357.73 (7.48)
90%	203.84 (4.85)	292.11 (6.96)	366.63 (8.73)	292.11 (6.96)	368.07 (8.76)

Table 8. Change in total wetted perimeter (ft^2) predicted for each EIS alternative relative to historical conditions for the 7.8 miles monitored by PGE, roughly between the Reregulating Dam and Trout Creek. Reductions in total wetted perimeter (ft^2) are highlighted in red.

Exceedance Probability	Alternative 3.200	Alternative 3.300	Alternative 3.400	Alternative 4.300	Alternative 4.400
			January		
10%	19,778 (0.18)	32,004 (0.3)	35,020 (0.32)	32,004 (0.3)	42,035 (0.39)
50%	33,601 (0.32)	46,089 (0.44)	51,767 (0.49)	46,089 (0.44)	54,252 (0.52)
90%	43,198 (0.42)	61,210 (0.59)	76,868 (0.74)	61,210 (0.59)	77,252 (0.75)
			February		
10%	-3,958 (-0.04)	-3,931 (-0.04)	-1,113 (-0.01)	-3,931 (-0.04)	-602 (-0.01)
50%	32,668 (0.31)	43,722 (0.42)	45,403 (0.43)	43,722 (0.41)	49,944 (0.47)
90%	50,253 (0.49)	67,405 (0.65)	84,290 (0.81)	67,405 (0.65)	84,028 (0.81)
			March		
10%	14,590 (0.13)	23,363 (0.21)	20,607 (0.19)	23,363 (0.21)	28,880 (0.26)
50%	100,748 (0.95)	113,434 (1.08)	120,196 (1.14)	113,434 (1.06)	123,330 (1.17)
90%	84,332 (0.81)	103,043 (0.99)	121,478 (1.17)	103,043 (0.99)	121,233 (1.17)
			April		
10%	66,103 (0.6)	64,979 (0.59)	64,066 (0.58)	64,979 (0.59)	63,877 (0.58)
50%	119,230 (1.14)	117,722 (1.12)	114,871 (1.09)	117,722 (1.11)	113,991 (1.09)
90%	90,663 (0.88)	90,270 (0.88)	94,015 (0.91)	90,270 (0.87)	95,145 (0.92)
			May		
10%	6,874 (0.06)	4,323 (0.04)	-3825 (-0.04)	4,323 (0.04)	-4191 (-0.04)
50%	27,895 (0.27)	19,048 (0.18)	15,075 (0.14)	19,048 (0.18)	10,688 (0.1)
90%	34,581 (0.34)	25,560 (0.25)	24,413 (0.24)	25,560 (0.25)	23,054 (0.22)
			June		
10%	12,633 (0.12)	8,451 (0.08)	-189 (0)	8,451 (0.08)	-341 (0)
50%	31,724 (0.31)	28,350 (0.27)	23,123 (0.22)	28,350 (0.27)	23,624 (0.23)
90%	35,038 (0.34)	29,380 (0.29)	25,455 (0.25)	29,380 (0.29)	24,717 (0.24)
			July		
10%	29,122 (0.28)	26,922 (0.26)	23,231 (0.22)	26,922 (0.26)	22,777 (0.22)
50%	31,442 (0.3)	24,096 (0.23)	19,574 (0.19)	24,096 (0.23)	18,394 (0.18)
90%	26,795 (0.26)	22,086 (0.22)	18,411 (0.18)	22,086 (0.21)	17,808 (0.17)
			August		
10%	20,579 (0.2)	18546 (0.18)	14520 (0.14)	18546 (0.18)	14470 (0.14)
50%	29,357 (0.28)	21226 (0.21)	17534 (0.17)	21226 (0.21)	16163 (0.16)
90%	30,510 (0.3)	25449 (0.25)	25129 (0.25)	25449 (0.25)	23175 (0.23)
			September		
10%	25,348 (0.24)	18,132 (0.17)	19,048 (0.18)	18,132 (0.17)	17,024 (0.16)
50%	20,055 (0.19)	15,112 (0.15)	11,958 (0.12)	15,112 (0.15)	11,929 (0.12)
90%	19,991 (0.19)	18,044 (0.18)	16,722 (0.16)	18,044 (0.18)	16,684 (0.16)
			October		
10%	67,798 (0.64)	68,583 (0.65)	77,583 (0.74)	68,583 (0.65)	78,929 (0.75)
50%	30,965 (0.3)	40,513 (0.39)	54,603 (0.53)	40,513 (0.39)	55,125 (0.53)
90%	27,829 (0.27)	28,378 (0.28)	29,488 (0.29)	28,378 (0.28)	29,187 (0.28)
			November		
10%	73,243 (0.69)	69,353 (0.65)	74,943 (0.71)	69353 (0.65)	72,398 (0.68)
50%	30,575 (0.29)	42,332 (0.41)	58,807 (0.56)	42,332 (0.4)	58,013 (0.56)
90%	16,637 (0.16)	34,658 (0.33)	52,960 (0.51)	34,658 (0.33)	52,759 (0.51)
			December		
10%	15,617 (0.14)	30,329 (0.28)	37,224 (0.35)	30,329 (0.28)	40,419 (0.37)
50%	45,685 (0.44)	58,500 (0.56)	66,368 (0.63)	58,500 (0.56)	73,345 (0.7)
90%	41,793 (0.4)	59,893 (0.58)	75,170 (0.73)	59,893 (0.58)	75,466 (0.73)

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APPENDIX A-3

MOUNT HOOD ENVIRONMENTAL
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TECHNICAL MEMORANDUM

Subject: Flow effects on steelhead (*Oncorhynchus mykiss)* smolt survival in the upper Deschutes River basin: Literature review and conceptual basis for evaluating effects of the Deschutes Basin Habitat Conservation Plan.

Date: August 21, 2020

Prepared by: Mount Hood Environmental

Prepared for: Biota Pacific Environmental Sciences, Inc. and the Deschutes Basin Board of Control

Suggested Citation: Courter, I. 2019. Flow effects on steelhead (*Oncorhynchus mykiss)* smolt survival in the upper Deschutes River basin: Literature review and conceptual basis for evaluating effects of the Deschutes Basin Habitat Conservation Plan. Technical Memorandum prepared for Biota Pacific Environmental Sciences, Inc. and the Deschutes Basin Board of Control. Mount Hood Environmental, Boring, OR. 4 pp.

LITERATURE REVIEW

For many anadromous salmonids, increased stream flow is often associated with faster migration rates. For example, subyearling fall Chinook salmon (*O. tshawytscha*) migration rates increased in free-flowing sections of the Snake River, Idaho compared with impounded sections (Tiffan *et al.*, 2009). Faster migration rates are in turn positively correlated to smolt survival. Perry *et al.* (2010) reported that survival of emigrating Chinook salmon in the Sacramento-San Joaquin River Delta, California doubled from 40% to 80% following a five-fold increase in flow from 3,500 to 16,600 cfs. Cavallo *et al.* (2013) and Kjelson and Brandes (1989) also found that increases in flow reduced travel time and increased smolt emigration survival in portions of the Sacramento-San Joaquin Delta, indicating that large changes in flow can alter smolt survival in that system.

Smolt survival analyses in the Yakima River, Washington provide some of the most compelling evidence that higher flows can increase survival of migrating juvenile salmon. Neeley (2002) and Pyper and Smith (2005) demonstrated that stream flow strongly influenced subyearling fall Chinook salmon survival and moderately influenced coho salmon smolt survival. Using a series of controlled flow releases from 2012 through 2014, Courter et al. (2016) quantified the relationship between flow and smolt survival from Roza Dam 18 km downstream to the confluence of the Naches and Yakima Rivers. This controlled field experiment in a highly managed river revealed a strong positive relationship between flow and smolt survival after accounting for the confounding effects of water temperature.

Despite evidence for a positive flow-survival relationship in some case studies, the effects of flow on smolt emigration survival appear to be context-dependent and difficult to quantify independent of other influential abiotic and biotic factors, including water temperature (Connor *et al.*, 2003; Beeman *et al.*, 2012; Haeseker *et al.*, 2012; Petrosky and Schaller, 2010), migration timing and fish size (Zabel and Williams, 2002), migration distance (Anderson *et al.*, 2005; Welch *et al.*, 2008), and predator density (Beamesderfer *et al.*, 1996; Anderson *et al.*, 2005;

Krueger *et al.*, 2011; Cavallo *et al.*, 2013). Moreover, some studies have challenged the positive relationship between flow and smolt survival. Romer *et al.* (2013) reported a negative relationship between stream flow and juvenile steelhead trout emigration survival in estuaries of the Nehalem and Alsea Rivers, Oregon. Effects of flow on survival of migrating juvenile steelhead and yearling Chinook salmon in the Snake River between lower Granite Dam and McNary Dam were also negligible, despite strong correlations between flow and travel time (Smith *et al.*, 2002). Similarly, juvenile fall Chinook survival correlated poorly with spring runoff in the Lewis River, a tributary to the lower Columbia River (Skalski, 1996). Theoretical predator-prey models have been used to explain some of these counterintuitive findings (Anderson *et al.*, 2005).

FLOW EFFECTS ON SMOLT SURVIVAL IN THE UPPER DESCHUTES BASIN

In the upper Deschutes Basin, the precise magnitude of flow influence on smolt migration survival is somewhat uncertain. However, local area fisheries biologists believe higher flows improve juvenile fish emigration conditions. Multiple regression analysis demonstrated that flow in the Crooked and Deschutes Rivers was positively associated with hatchery steelhead smolt survival after accounting for effects of the number of stocked fish (PGE and CTWSRO 2019). Therefore, we assumed smolt survival was linearly related to spring flow (March-June) when evaluating Deschutes Basin Habitat Conservation Plan (DBHCP) flow management alternatives. Although this approach was expected to overestimate the survival benefit of increased flows, particularly at high flows (Beeman et al. 2012, Courter et al. 2016), assuming a positive linear relationship between flow and survival provided a reasonable basis for making relative comparisons between flow management scenarios.

Comparison of modeled DBHCP flows to those expected to occur under the No Action scenario (current condition) did not reveal appreciable changes in the Crooked River, Whychus Creek, or Deschutes Rivers during the steelhead trout emigration periods, which typically occur from February through May and April through June, respectively. Therefore, flows under the DBHCP should not be expected to markedly change smolt survival conditions in the upper Deschutes Basin.

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APPENDIX A-4

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TECHNICAL MEMORANDUM

Subject: Flow effects on Sockeye Salmon and summer steelhead trout migration in the Upper Deschutes Basin.

Date: August 21, 2020

Prepared by: Mount Hood Environmental

Prepared for: Biota Pacific Environmental Sciences, Inc. and the Deschutes Basin Board of Control

Suggested Citation: Gibbs, S., F. Carpenter, and I. Courter. 2019. Flow effects on Sockeye Salmon and summer steelhead trout migration in the Upper Deschutes Basin. Technical Memorandum prepared for Biota Pacific Environmental Sciences, Inc. and the Deschutes Basin Board of Control. Mount Hood Environmental, Boring, OR. 35 pp.

Analysis Overview

To determine the impacts of stream flow on adult Sockeye Salmon and steelhead trout migration in the upper Deschutes Basin, we predicted changes in riffle depth across a series of synthetic flow scenarios generated using a river hydrology and water accounting model called RiverWare. In total, 9 scenarios representing three phases of implementation of the Deschutes Basin Habitat Conservation Plan (DBHCP) and six alternatives[1] to the DBHCP (including No Action) were analyzed. Each scenario was also modeled for different meteorological conditions included a wet year (1993), an average year (2005) and a dry year (2001) from the historical record. The effects of these flow scenarios were then evaluated independently for three reaches in the middle Deschutes River and four reaches in the Crooked River (Table 1). Flows required to meet minimum depth thresholds for adult salmon and steelhead trout migration in Whychus, Ochoco, and McKay Creeks were estimated. Finally, we examined thermal conditions present during the summer steelhead (October – March) migration periods in the middle Deschutes River.

Habitat Requirements

Adult salmon and steelhead upstream migration is influenced by numerous environmental factors including temperature and flow. Migration obstruction can occur when channel depth or water temperature conditions create physical or thermal barriers. Minimum depth requirements for adult salmon and steelhead are determined by body size, with larger species requiring deeper water. For adult summer steelhead, riffle depths less than 0.7 ft. likely impede upstream migration (CDFW 2017), whereas sockeye salmon only require depths of approximately 0.59 ft (Bjornn & Reiser 1991). Since both species are capable of migrating through depths of less than one foot, natural physical barriers are most likely to occur in shallow, fast-flowing areas such as riffles.

Salmonids that make long distance migrations during the summer and fall may encounter high water temperatures, and migration can be delayed when temperatures exceed 21°C. Water

[1] Six flow scenario alternatives to the DBHCP were generated to support an Environmental Impact Statement (EIS).

temperatures in excess of approximately 24ºC can be lethal (Table 2). At the lower end of their thermal tolerance, salmon and steelhead may avoid temperatures below 7.2ºC; however, this threshold was originally derived as the minimum optimal temperature for all adult pacific salmonid species in the Columbia River Basin (EPA & NMFS 1971). Therefore, it is unclear how temperatures below 7.2ºC would affect salmon and steelhead from river systems with cooler temperatures, such as the middle Deschutes Basin.

METHODS

Channel Depth

To determine the effects of each flow scenario on riffle depths in the middle Deschutes and Crooked Rivers, we applied a hydraulic model to predicted depths at specific riffle locations. In 2014, field data was collected throughout the Deschutes River basin to determine how channel unit-specific wetted area and average depth would change in response to the DBHCP. Detailed stream channel bottom profiles were collected along cross-sectional transects in mesohabitat units (e.g. riffle) in most study reaches (Courter et al. 2014). HEC-RAS, a widely used hydraulic model developed by the US Army Corps of Engineers, was then used to determine the relationship between flow and surface elevation (water depth) in each stream reach. We applied these HEC-RAS equations to modeled flows in order to predict average depth of each riffle identified in Oregon's Aquatic Inventories Project (AIP). The riffle depth estimates only incorporated the number and location of riffles identified in the AIP, and not specific measurements of each riffle observed during the survey (i.e. depth, width, etc.). Further, the HEC-RAS modeled equations provide an estimate of average depth. For these reasons, estimates of average riffle depths for a given reach do not incorporate the variation that occurs between riffles in each reach. Additionally, because channel depth is not uniform, it is quite possible that a riffle with a predicted average depth too shallow for upstream passage may actually have a portion of the channel with adequate depth. Therefore, our average depth predictions provide a conservative assessment of flows that could impede fish passage.

Flow models used to predict riffle depth varied between streams (Table 3). To utilize the known locations of specific riffles identified by Oregon's AIP in our riffle analysis, it was necessary that modeled stream flows include a longitudinal profile that accounted for water inputs and outputs. *CE-QUAL-W2* predicted flows for the Crooked River provided average daily discharge values at a 0.06 RM resolution for each reach of the river (Berger *et al.* 2019). However, RiverWare modeled flows produced discharge estimates for only a single location in the middle Deschutes River. To determine the longitudinal profile of discharge in the middle Deschutes River, we averaged the change in HeatSource modeled flows (ODFW 2014) during July through August 2001. Flows modeled in HeatSource included discharge estimates at 0.12 RM intervals from Lake Billy Chinook at RM 120 to RM 132.2. These incremental changes were the same for all DBHCP flow scenarios and were assumed to be the same over time since they are primarily the result of groundwater inputs (Gannett *et al*. 2001). The incremental changes in flow were then applied to RiverWare modeled discharge, which consisted of the summed average daily discharge for the Deschutes River (RM 164) and Tumalo Creek, for each flow scenario.

For Ochoco, Whychus, and McKay Creeks, modeled flow data were limited and we were unable to predict changes in average riffle depths. For these streams, we used the HEC-RAS modeled relationship developed by Courter *et al.* (2014) to describe how much flow is necessary to sustain upstream migration.

Water Temperature

Changes in water temperature were modeled to predict how each flow scenario would affect instream thermal conditions in the Crooked River. Water temperature predictions were generated using the *CE-QUAL-W2* model developed by Portland State University (Berger *et al.* 2019). We then determined if, when, and where average daily temperatures were expected to exceed thermal tolerances for migrating adult steelhead (Table 2). Modeled water temperatures were not available for the Deschutes River, Whychus, McKay, or Ochoco Creeks; however, water management changes under the DBHCP are not expected to significantly affect temperatures in these streams. Instead, recent thermal conditions and the expected effects on adult steelhead are described.

RESULTS: SUMMER STEELHEAD

Middle Deschutes River

Comparison of predicted average riffle depth revealed an increase under the DBHCP flow scenarios relative to Historical conditions in the middle Deschutes River for all water years and reaches during the adult steelhead migration period (Figure 1). During the wet (1993) and dry (2001) years, these increases under DBHCP flow scenarios resulted in 18 and 10 fewer days, respectively, where average riffle depth could be expected to impede upstream migration in the D-2b reach relative to Historical conditions (Table 3). While this represents a modest improvement in migration conditions, adult steelhead are not expected to encounter shallow riffle barriers often in the D-1, D-2a, and D-2b reaches under Historical, DBHCP, or EIS flow scenarios (Figure 1 and Figure 2; Table 3).

Recent historical temperatures in the middle Deschutes River are within the range preferred by steelhead in early and mid-October, but drop below the preferred threshold and remain there from late October through March (Figure 12 and Figure 13). It is unclear how cooler temperatures would adversely affect migration and holding conditions since most literature derives preferred temperature conditions from populations inhabiting warmer rivers. Nevertheless, temperature conditions in the middle Deschutes River are unlikely to change as a result of the DBHCP proposed actions and therefore should not further affect upstream adult steelhead migration.

Crooked River

Predicted average riffle depths under DBHCP and EIS flow scenarios generally experienced a small increase or no increase relative to the No Action scenario (Figure 5 and Figure 6). Increased depths were predicted to occur during January through February in 1993, and during October through December in 2001. Predicted average riffle depths fell below the required threshold in the C-2 and C-3 reaches and this occurred more often under the No Action scenario than the DBHCP and EIS scenarios, particularly in the wet and dry years (Table 3). As a result, increased flows under DBHCP and EIS scenarios can be expected to improve conditions for adult steelhead during their upstream migration in the Crooked River.

Comparison of predicted maximum daily temperature revealed no appreciable change under the DBHCP flow scenarios relative to No Action conditions for normal and dry years (Figure14 and Figure 15). In the wet year, DBHCP flows are expected to decrease maximum temperatures relative to No Action, particularly in the C-4 and C-5 reaches during early March (Figure 18).

Similarly, little difference is observed between EIS alternatives and No Action flows, except in the C-4 and C-5 reaches during early March (Figure 16 and Figure 17). Under DBHCP, EIS, and No Action flow scenarios, maximum predicted temperatures in the Crooked River are generally above the preferred threshold for steelhead migration in early and mid-October and below the threshold from early November through March. While warmer temperatures in October may have negative impacts on migrating steelhead, it is unclear how cooler temperatures would adversely affect migration and holding conditions. Nevertheless, the DBHCP and EIS alternatives are unlikely to further affect adult steelhead upstream migration.

Ochoco Creek

During the winter, conservation measures in Ochoco Creek mandate minimum flows of 3 and 5 cfs from Ochoco Dam to RM 6.3 and from RM 6.3 to the confluence with the Crooked River, respectively. HEC-RAS modeling results indicate that average riffle depth remains below the threshold for adult steelhead migration in Ochoco Creek when flows are at or below 26 cfs (Figure 10). As a result, adult summer steelhead will likely encounter physical barriers during upstream migration when winter flows are at their minimum.

Recent historical temperature data was available below Ochoco Reservoir (RM 11.0) and at RM 0.7. In early October, temperatures were typically above 13ºC and exceeded the preferred range of migrating steelhead (Figure 18 and Figure 19). These temperatures are not expected to delay adult steelhead migration in Ochoco Creek (Table 2). Thermal conditions in Ochoco Creek are unlikely to change as a result of the HCP proposed actions and therefore should not further impede or delay upstream adult steelhead migration.

Whychus Creek

Under the DBHCP, the instream water right is 31.18 cfs in Whychus Creek at the TSID diversion. However, if dry conditions prevent the instream water right from being met, the minimum flow in Whychus Creek at the TSID diversion is 20 cfs. Under these conditions, average predicted riffle depths do not meet the minimum depth requirement for adult steelhead migration (Figure 13). Flows would likely need to exceed 50, 30, 30, and 35 cfs in the W-1, W-2, W-3, and W-4 reaches of Whychus Creek, respectively, to provide adequate depths for adult steelhead migration.

Temperature data are not available for a large portion of the steelhead migration period (Figures 20-22). In October, temperatures are usually very cool in all reaches of Whychus Creek, and do not exceed 14ºC. In fact, temperatures drop below optimal conditions (7.2ºC), where they likely remain for much of the winter. These temperature conditions are unlikely to change as a result of the DBHCP.

McKay Creek

There is no irrigation storage on McKay Creek and no diversion during the winter. As a result, flow and temperature are not affected by the covered activities during October through March, when adult steelhead are expected to migrate upstream. Therefore, DBHCP measures are not expected to affect steelhead in McKay Creek during their upstream migration.

RESULTS: SOCKEYE SALMON

Middle Deschutes River

Predicted average riffle depths under DBHCP flow scenarios exceeded those under Historical conditions across all reaches and hydrologic conditions (Figure 5). However, predicted riffle depths differed little between DBHCP, EIS, and No Action scenarios (Figure 5 and Figure 6). Predicted average riffle depths met the minimum depth requirement for adult sockeye upstream migration across all reaches and hydrologic conditions for DBHCP, EIS, No Action scenarios (Table 3). As a result, sockeye are not expected to encounter physical barriers during migration in the middle Deschutes River.

Crooked River

Predicted average riffle depths were variable under DBHCP, EIS, and No Action flow scenarios and across hydrologic conditions, though the minimum required threshold for adult sockeye migration was generally met for all months (Figure 7 and Figure 8). Under Phases 3 and 4 of the DBHCP and EIS alternative scenarios 3-300 and 3-200, predicted riffle depths fell below the required threshold for a small number of days in the C-2 reach (Table 3). While sockeye are not expected to encounter physical barriers often in the Crooked River, the likelihood of this occurring increases slightly under DBHCP and EIS alternative flow scenarios, particularly in the lowest reach examined.

Whychus Creek

Under the DBHCP, the instream water right is 31.18 cfs in Whychus Creek at the TSID diversion. However, if dry conditions prevent the instream water right from being met, the minimum flow in Whychus Creek at the TSID diversion is 20 cfs. Flows would likely need to exceed 35, 20, 25, and 25 cfs in the W-1, W-2, W-3, and W-4 reaches of Whychus Creek, respectively, to provide adequate depth for adult sockeye migration (Figure 9).

Table 1. Stream reaches assessed for the DBHCP.

Stream	Reach	Reach Code	Upstream (RM)	Downstream (RM)	Length (miles)
Deschutes River	Big Falls to RM 130	D-2b	132.2	130.4	1.8
	RM 130 to Steelhead Falls	D-2a	130.4	127.7	2.7
	Steelhead Falls to Lake Billy Chinook	D-1	127.7	120	7.7
Whychus Creek	TSID Diversion to City of Sisters	W-4	24.2	22.2	2
	Within City of Sisters	W-3	22.2	20.2	2
	City of Sisters to Alder Springs	W-2	20.2	1.6	18.6
	Alder Springs to Mouth	W-1	1.6	0	1.6
Crooked River	Bowman Dam to Crooked River Diversion	C-5	70.6	56.5	14.1
	Crooked River Diversion to US Route 26	C-4	56.5	48	8.5
	US Route 26 to NUID Pumps	C-3	48	27.6	20.4
	NUID Pumps to US Route 97	C-2	27.6	18.4	9.2
Ochoco Creek	Ochoco Dam to Mouth	O-1	11.2	0	11.2
McKay Creek	Jones Dam to Dry Creek	MK-3	5.8	3.9	1.9
	Dry Creek to Reynolds Siphon	MK-2	3.9	3.2	0.7
	Reynolds Siphon to Mouth	MK-1	3.2	0	3.2

Table 2. Water temperature suitability for sockeye salmon and steelhead trout during adult upstream migration.

Species	Season	Water Temperature Suitability (°C)				Source
		Preference	Avoidance	Delay	Lethal	
Steelhead trout	Oct-Mar	10.0 – 12.8	< 7.2; > 14.4	> 21.0	> 23.9	McCullough *et al.* 2001
Sockeye salmon	Jul-Oct	7.2 – 15.5	-	18.0-22.8	23.5 – 24.8	Brett 1952; Brett 1971; Bell 1991; Fies et al. 1998 *in NPCC 2004*; McCullough et al. 2001; Hill et al. 2014; Burchell and Hill 2017

Table 3. Summary of days when predicted average riffle depth fell below the required thresholds for steelhead upstream migration. Values when the riffle depth thresholds were met for all flow scenarios are not shown.

Species	Reach	Year	No Action	Historic	HCP 100	HCP 300	HCP 400	ALT3 400	ALT3 300	ALT3 200	ALT4 400	ALT4 300
Steelhead	C-2	1993	63	-	0	0	0	0	0	0	1	1
		2005	2	-	2	2	2	2	2	2	0	0
	C-3	1993	67	-	0	0	0	0	0	0	0	0
		2001	91	-	14	14	14	14	14	14	14	14
		2005	16	-	15	15	15	15	15	15	15	15
	D-1	1993	0	18	0	0	0	0	0	0	0	0
		2001	1	11	1	1	1	1	1	1	1	1
	D-2a	1993	0	18	0	0	0	0	0	0	0	0
		2001	1	11	1	1	1	1	1	1	1	1
	D-2b	1993	0	18	0	0	0	0	0	0	0	0
		2001	1	11	1	1	1	1	1	1	1	1
Sockeye	C-2	1993	0	-	4	0	0	0	15	0	0	0
		2005	0	-	1	0	0	0	22	2	0	0
	D-1	1993	0	103	0	0	0	0	0	0	0	0
		2001	0	88	0	0	0	0	0	0	0	0
		2005	0	5	0	0	0	0	0	0	0	0
	D-2a	1993	0	103	0	0	0	0	0	0	0	0
		2001	0	88	0	0	0	0	0	0	0	0
		2005	0	5	0	0	0	0	0	0	0	0
	D-2b	1993	0	103	0	0	0	0	0	0	0	0
		2001	0	88	0	0	0	0	0	0	0	0
		2005	0	5	0	0	0	0	0	0	0	0

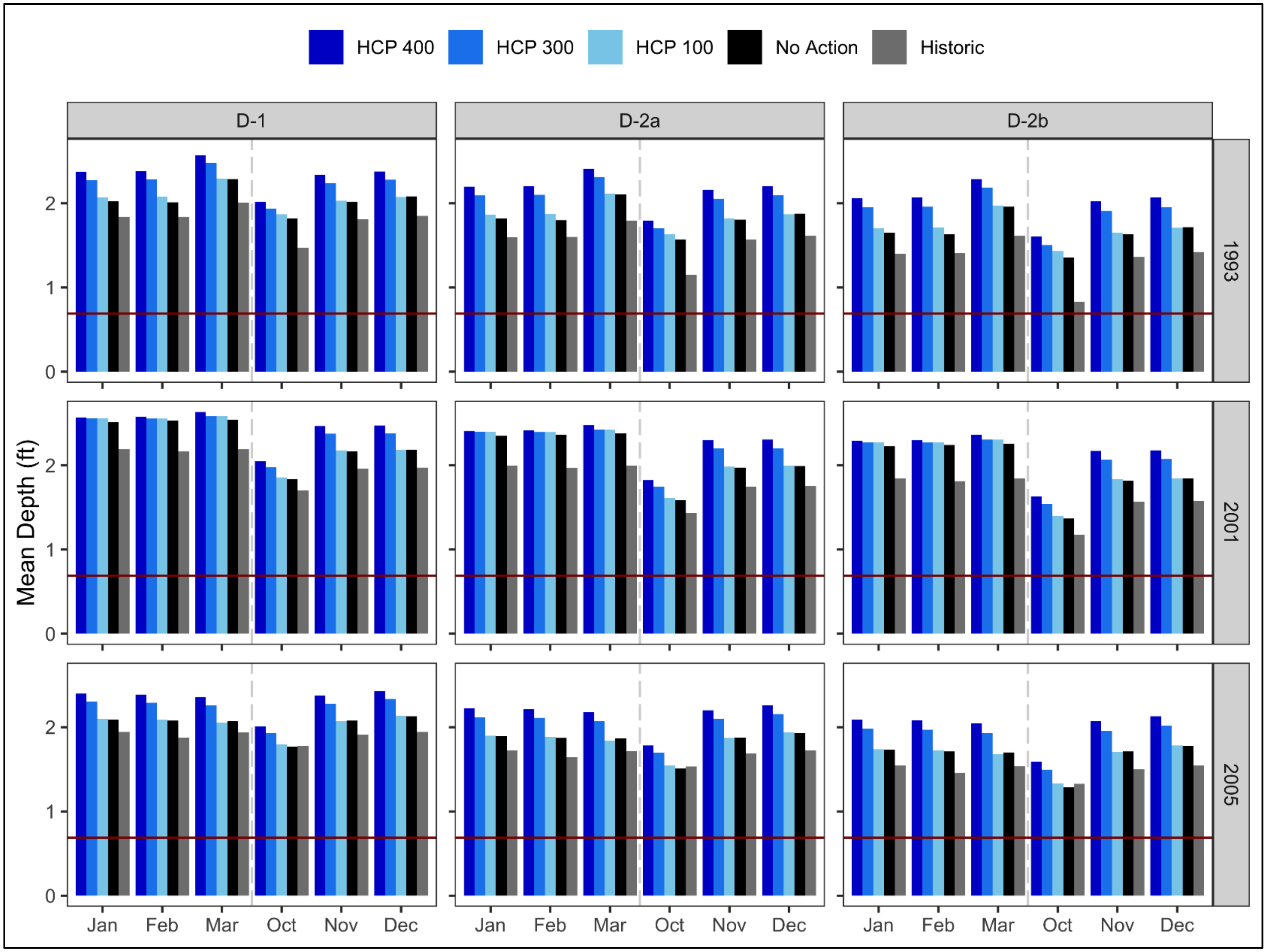

Figure 1. Estimated average riffle depth in the middle Deschutes River during the steelhead migration period. A horizontal red line indicates minimum depth required for passage.

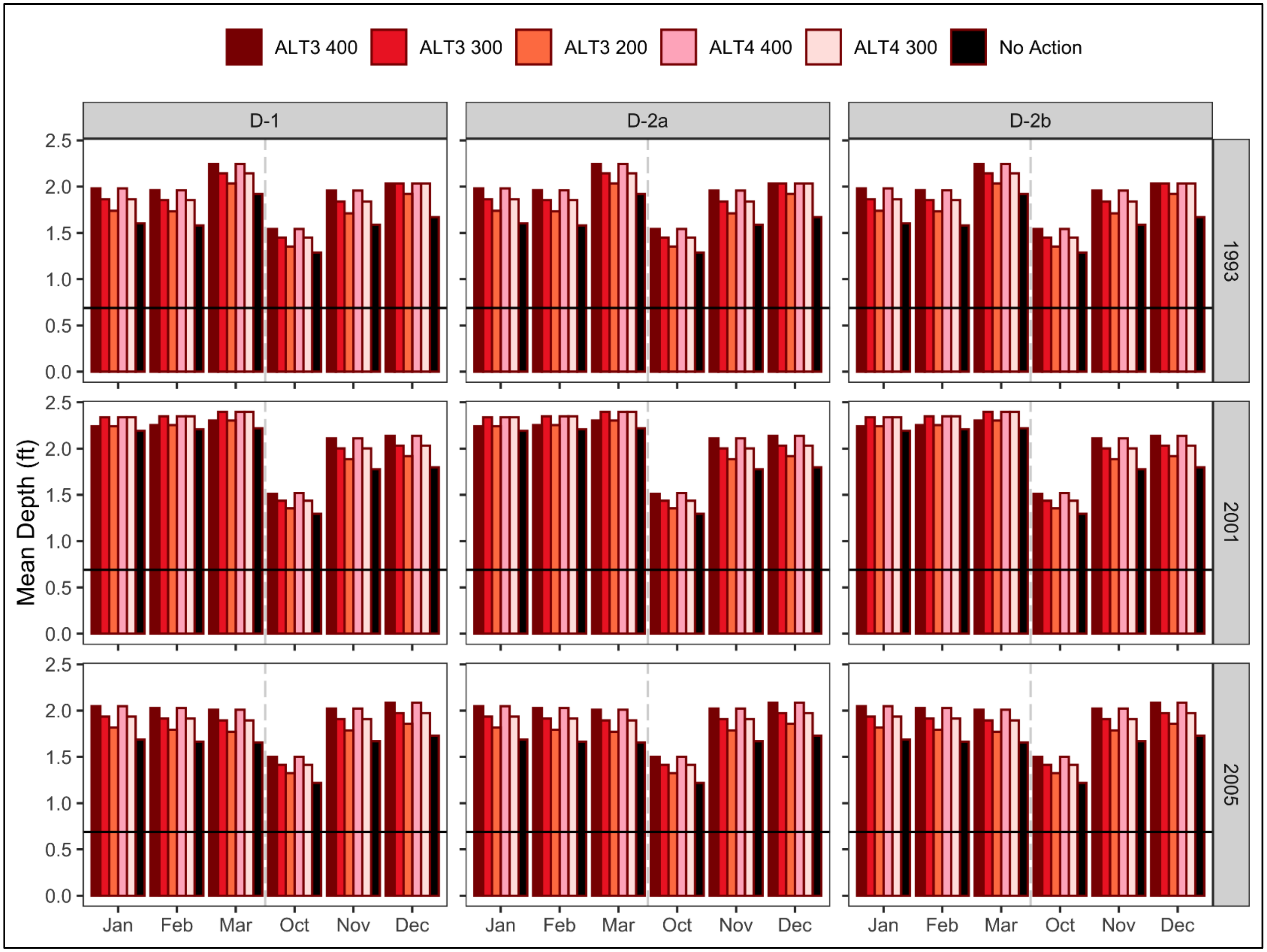

Figure 2. Estimated average riffle depth in the middle Deschutes River during the steelhead migration period. A horizontal black line indicates minimum depth required for passage.

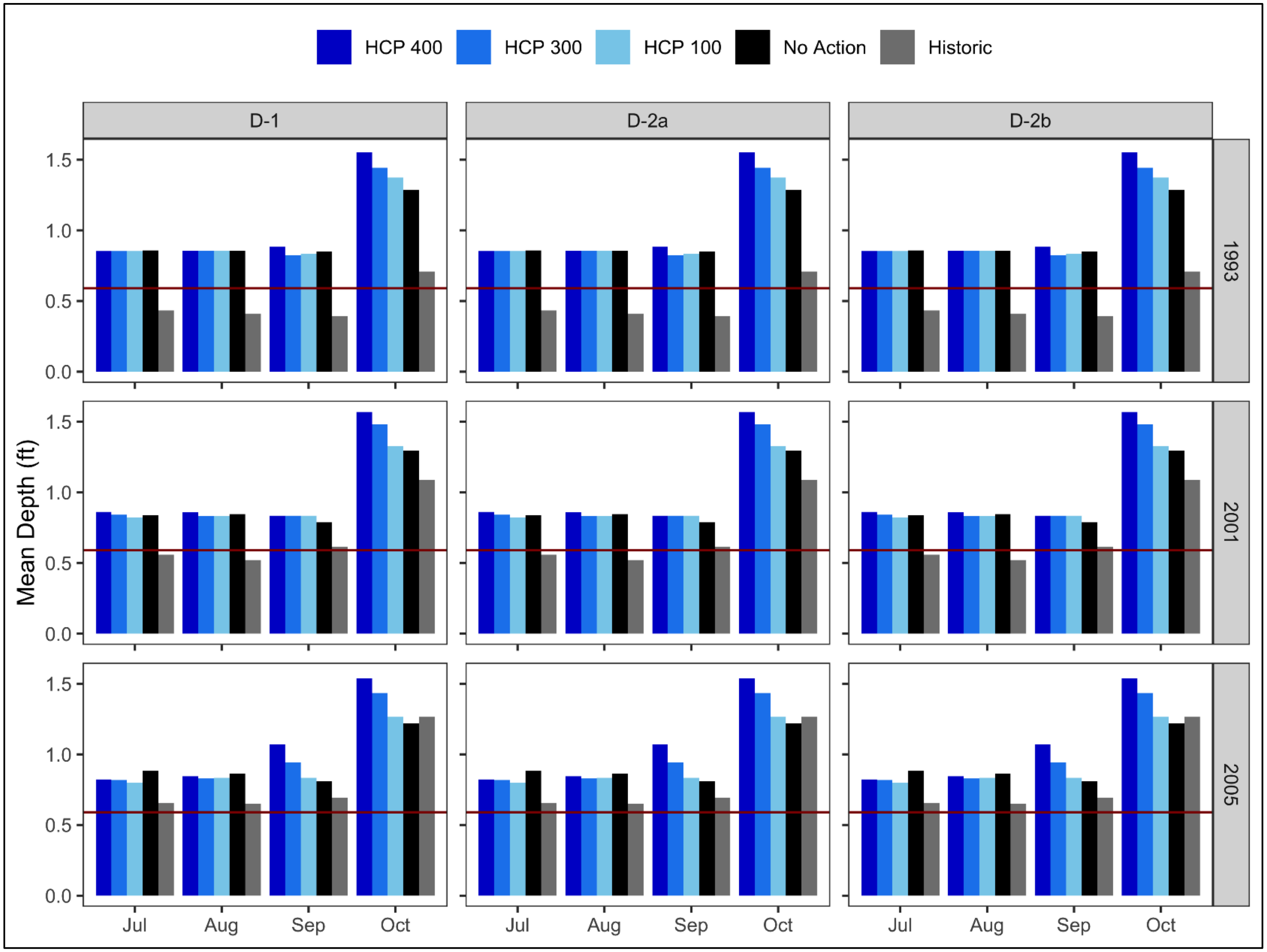

Figure 3. Estimated average riffle depth in the middle Deschutes River during the sockeye migration period. A horizontal red line indicates minimum depth required for passage.

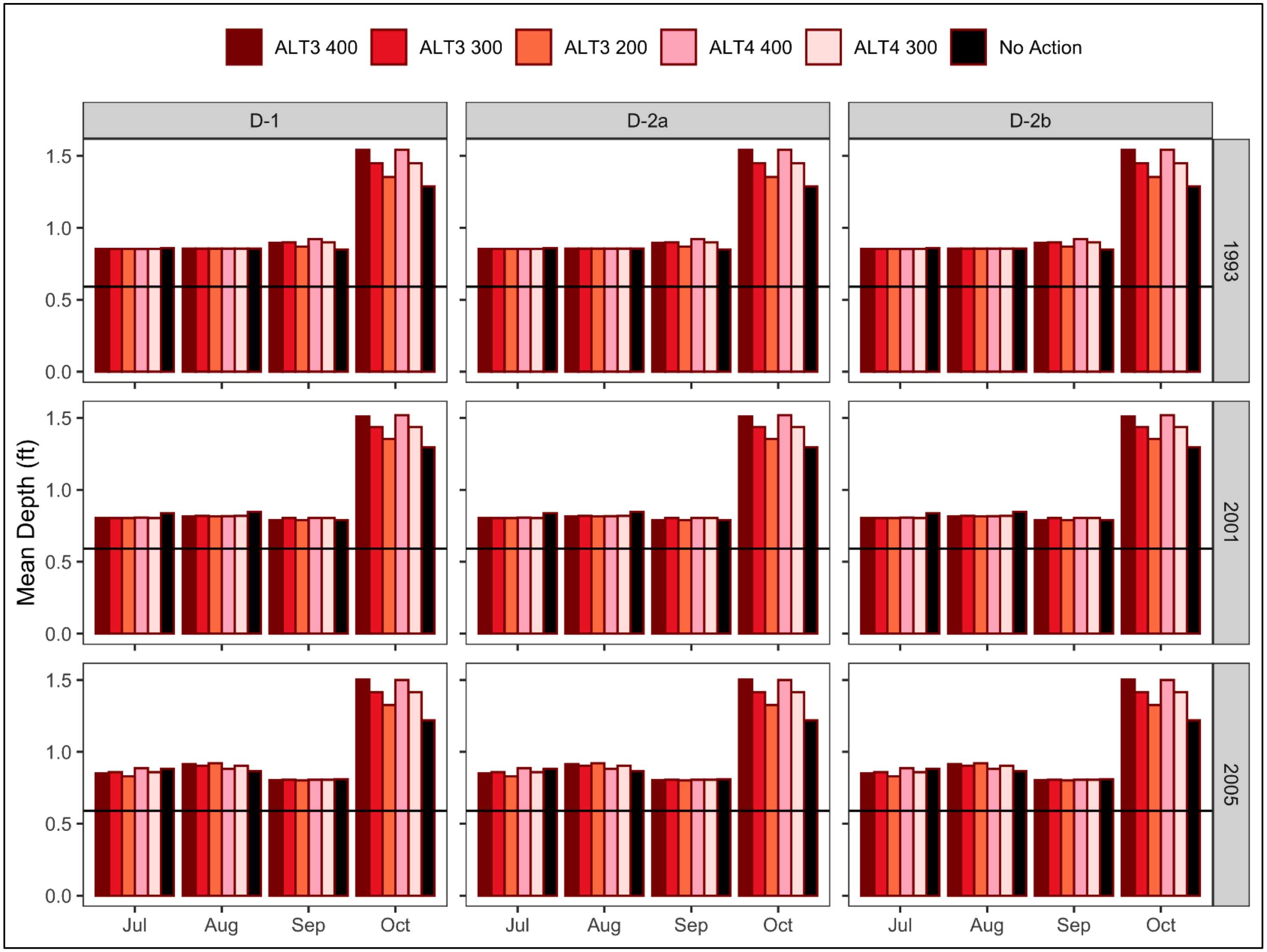

Figure 4. Estimated average riffle depth in the middle Deschutes River during the sockeye migration period. A horizontal red line indicates minimum depth required for passage.

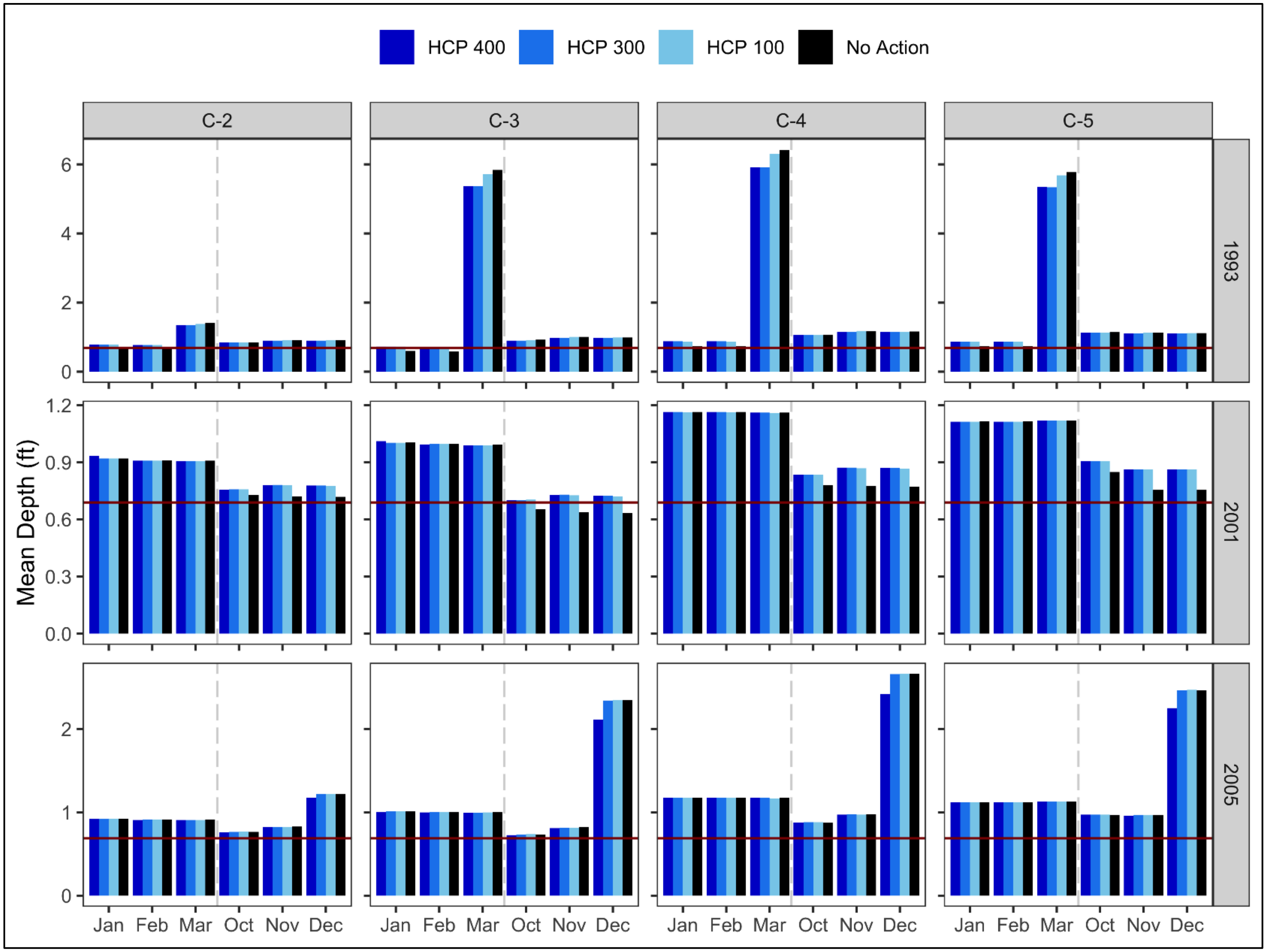

Figure 5. Estimated average riffle depth in the Crooked River during the summer steelhead migration period. A horizontal red line indicates minimum depth required for passage.

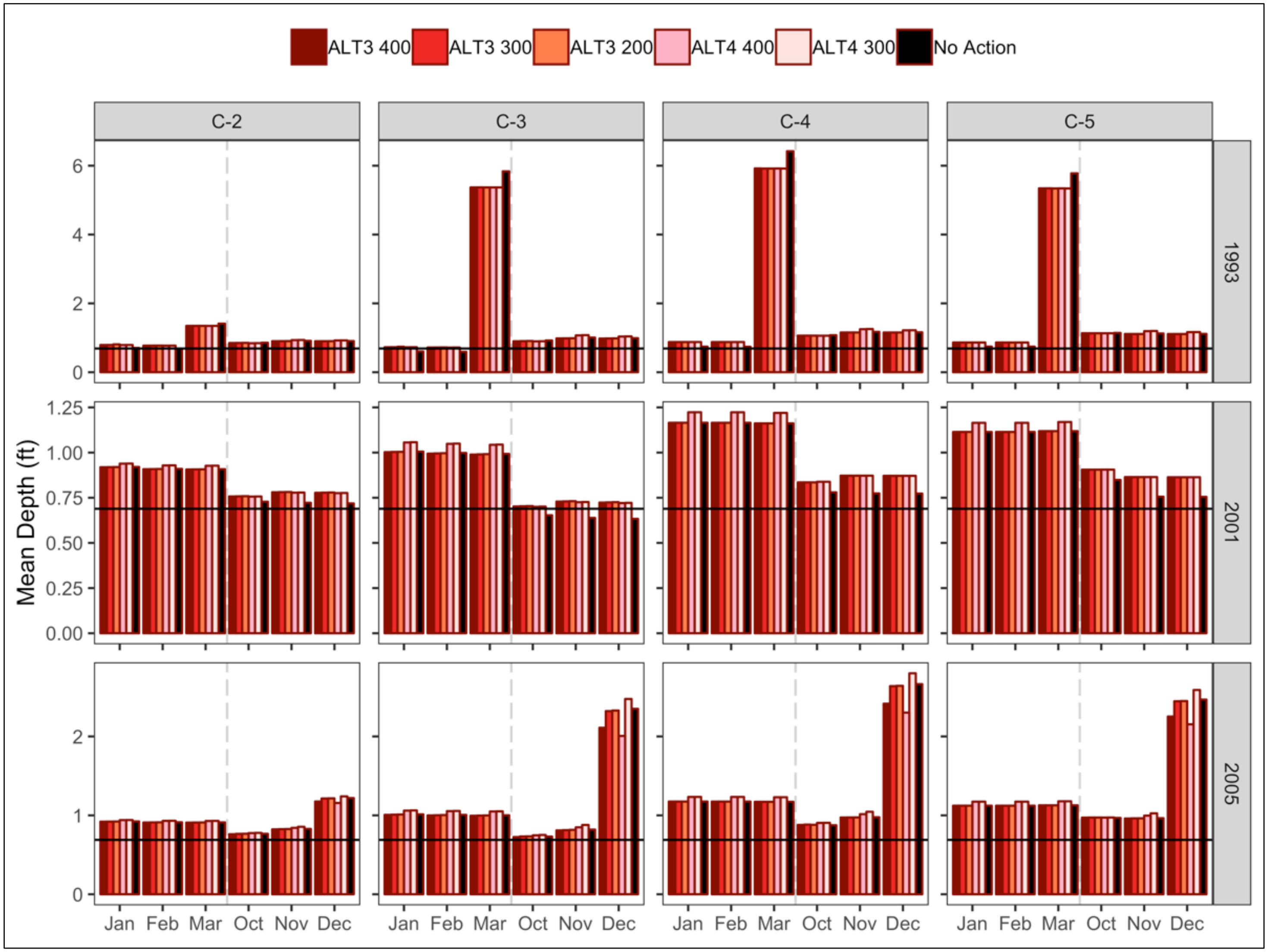

Figure 6. Estimated average riffle depth in the Crooked River during the summer steelhead migration period. A horizontal black line indicates minimum depth required for passage.

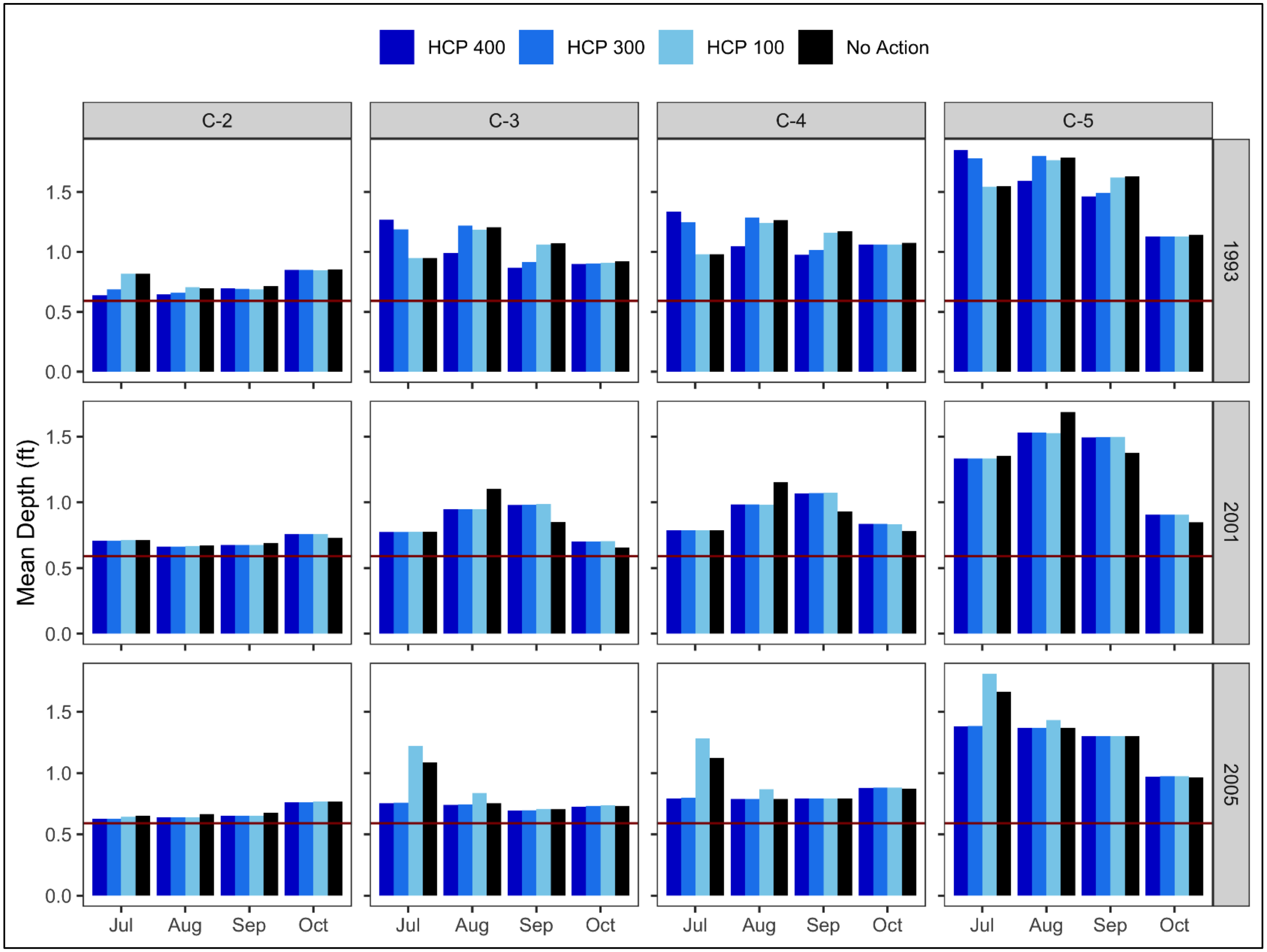

Figure 7. Estimated average riffle depth in the Crooked River during the sockeye migration period. A horizontal black line indicates minimum depth required for passage.

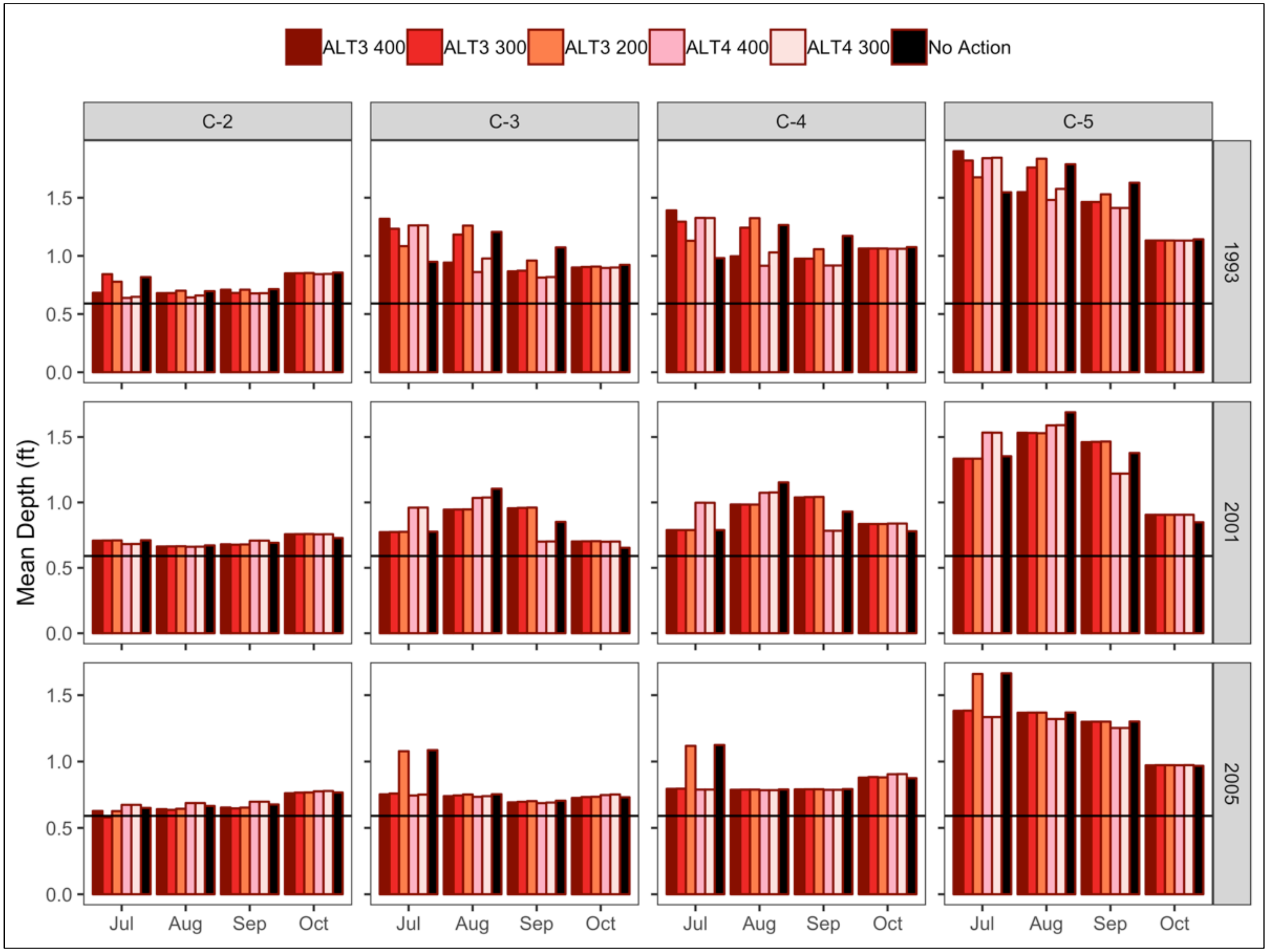

Figure 8. Estimated average riffle depth in the Crooked River during the sockeye migration period. A horizontal black line indicates minimum depth required for passage.

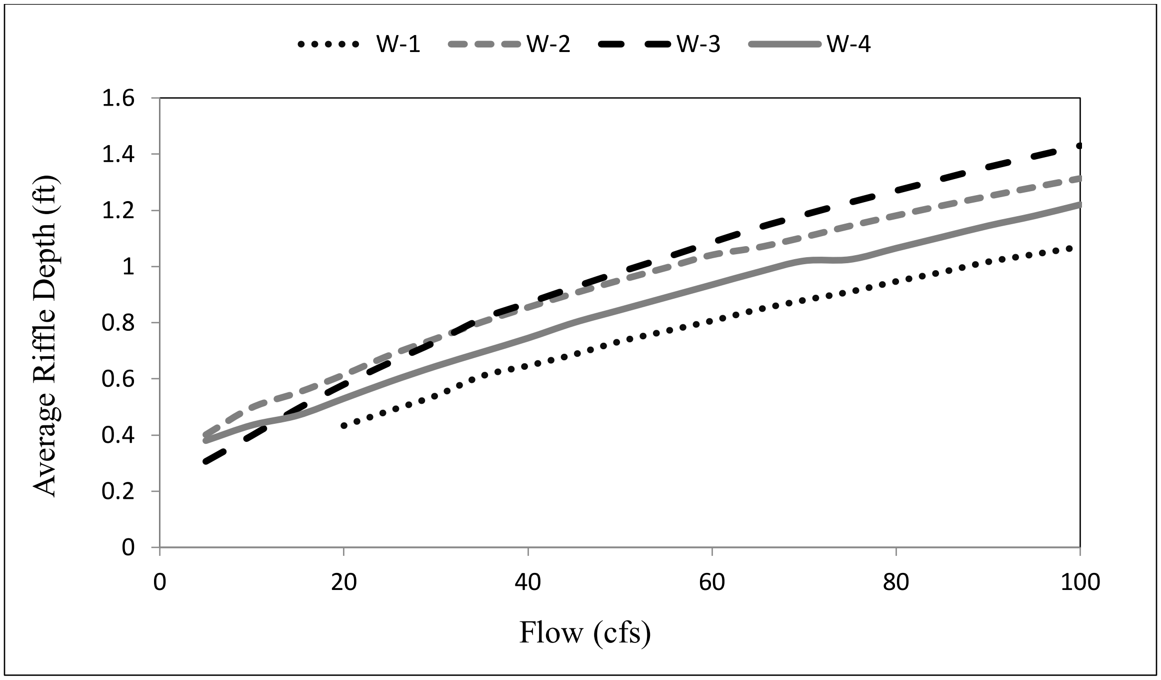

Figure 9. HEC-RAS modeled riffle depth for four reaches in Whychus Creek.

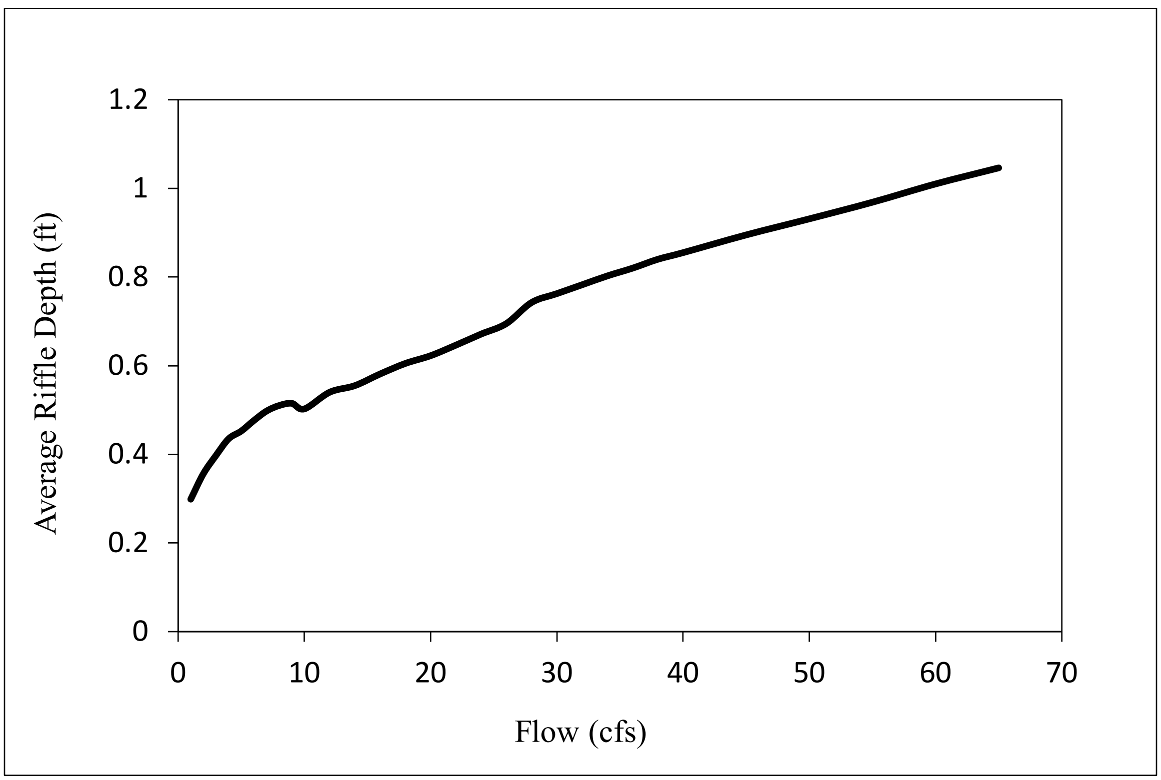

Figure 10. HEC-RAS modeled riffle depth for Ochoco Creek.

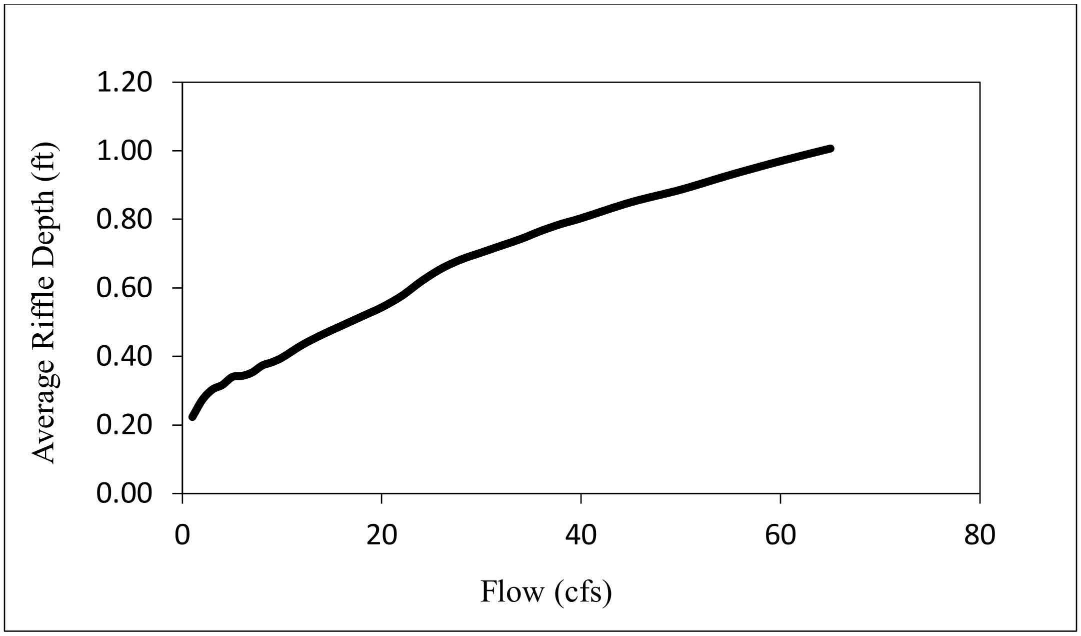

Figure 11. HEC-RAS modeled riffle depth for McKay Creek.

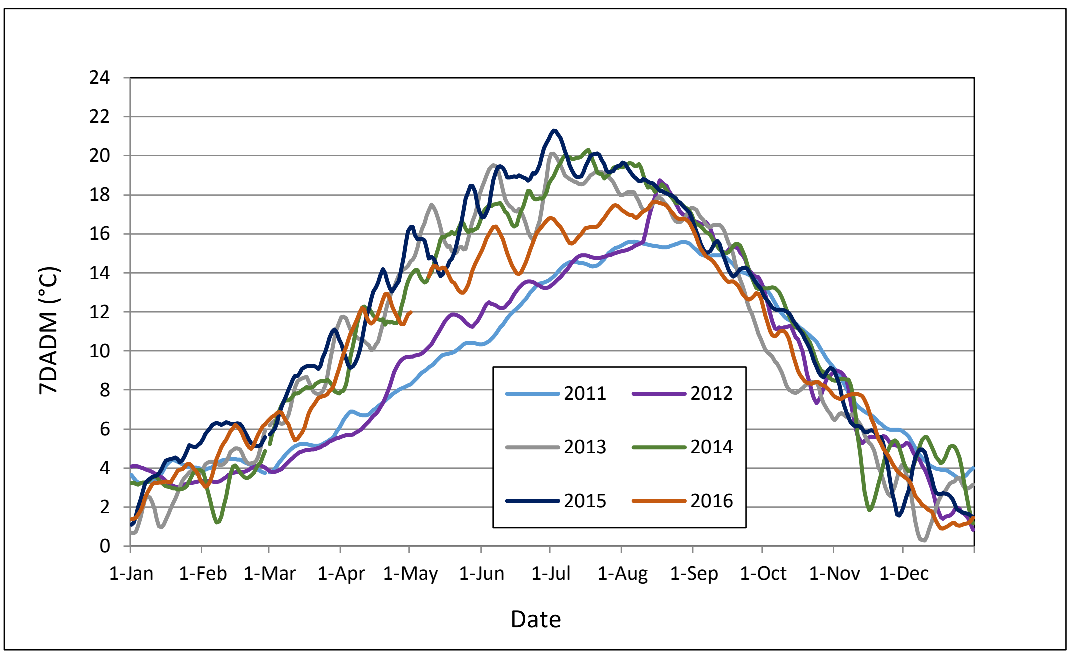

Figure 12. Seven-day averages of daily maximum water temperatures (7-DADM) in the Deschutes River below Bend (RM 164) from 2011 through 2016. Source: Reclamation 2017a.

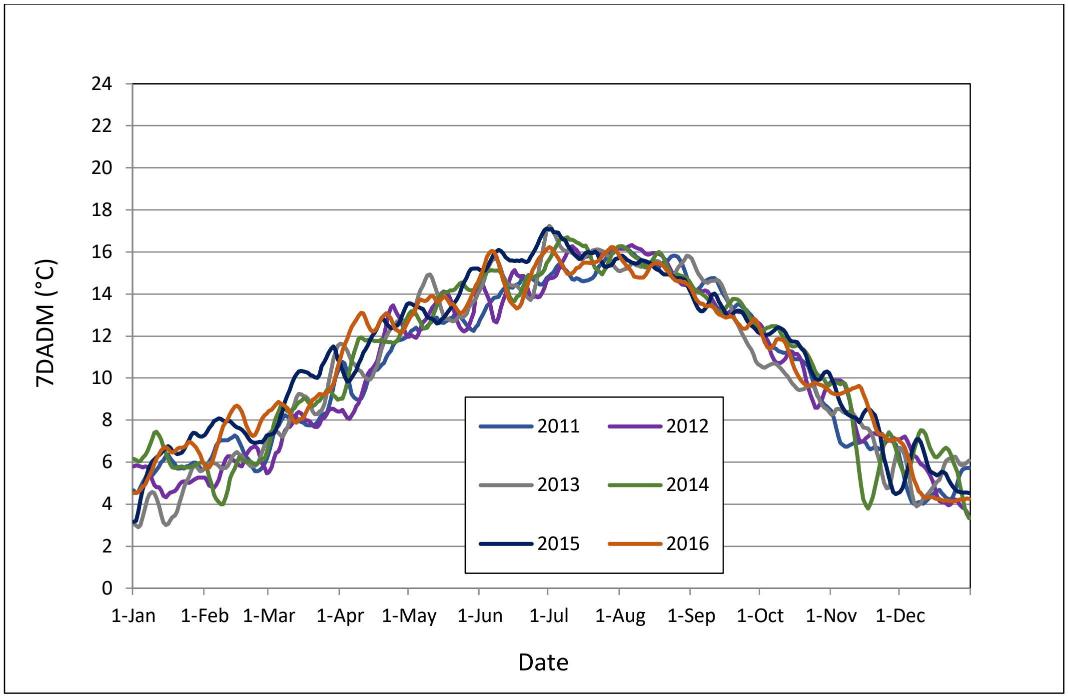

Figure 13. Seven-day averages of daily maximum water temperatures (7-DADM) in the Deschutes River near Culver (RM 120) from 2011 through 2016. Source: USGS 2019.

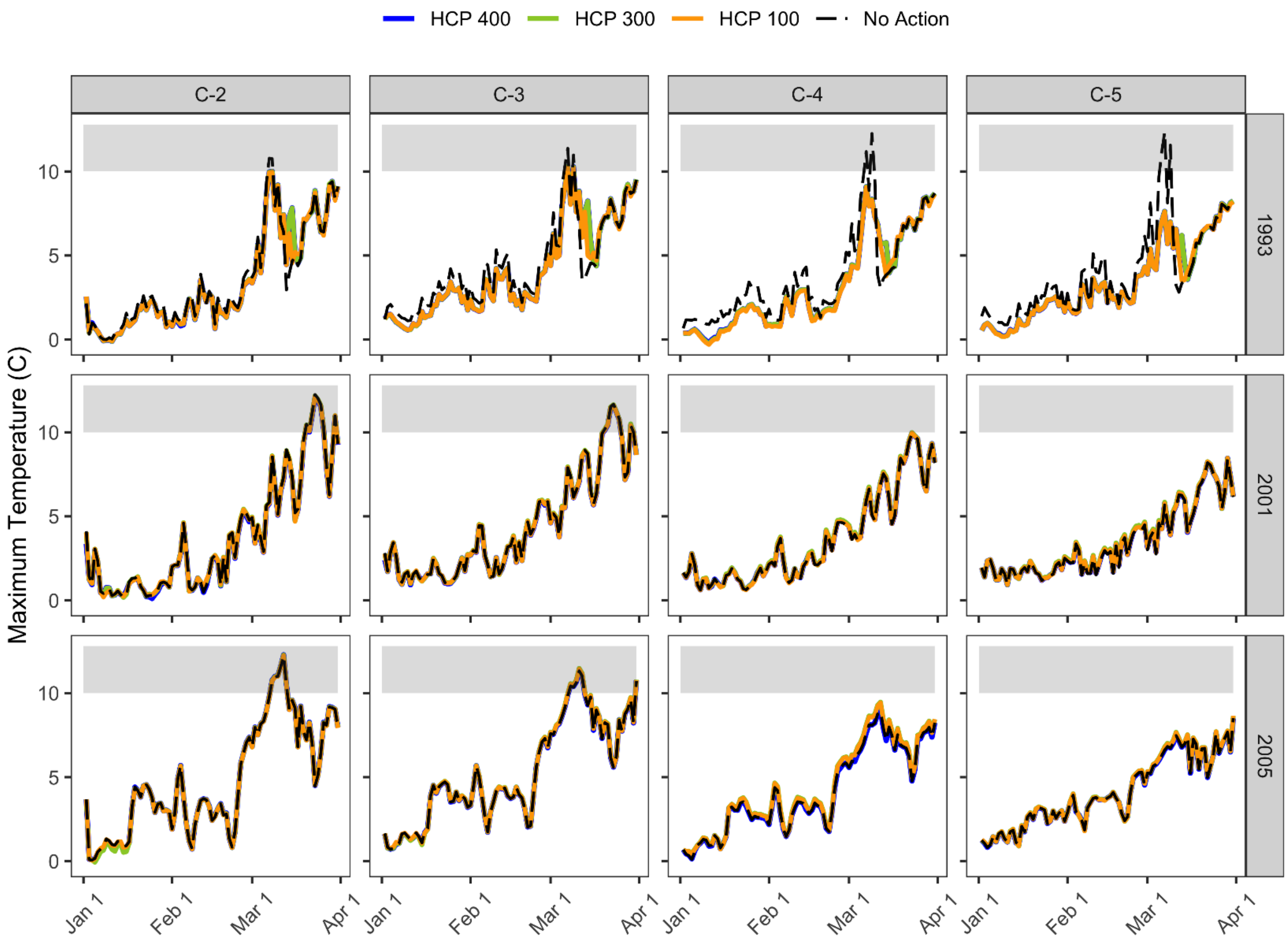

Figure 14. Maximum daily temperatures predicted under DBHCP flow scenarios in the Crooked River during January through March. A horizontal grey band indicates the temperatures preferred by steelhead during adult migration.

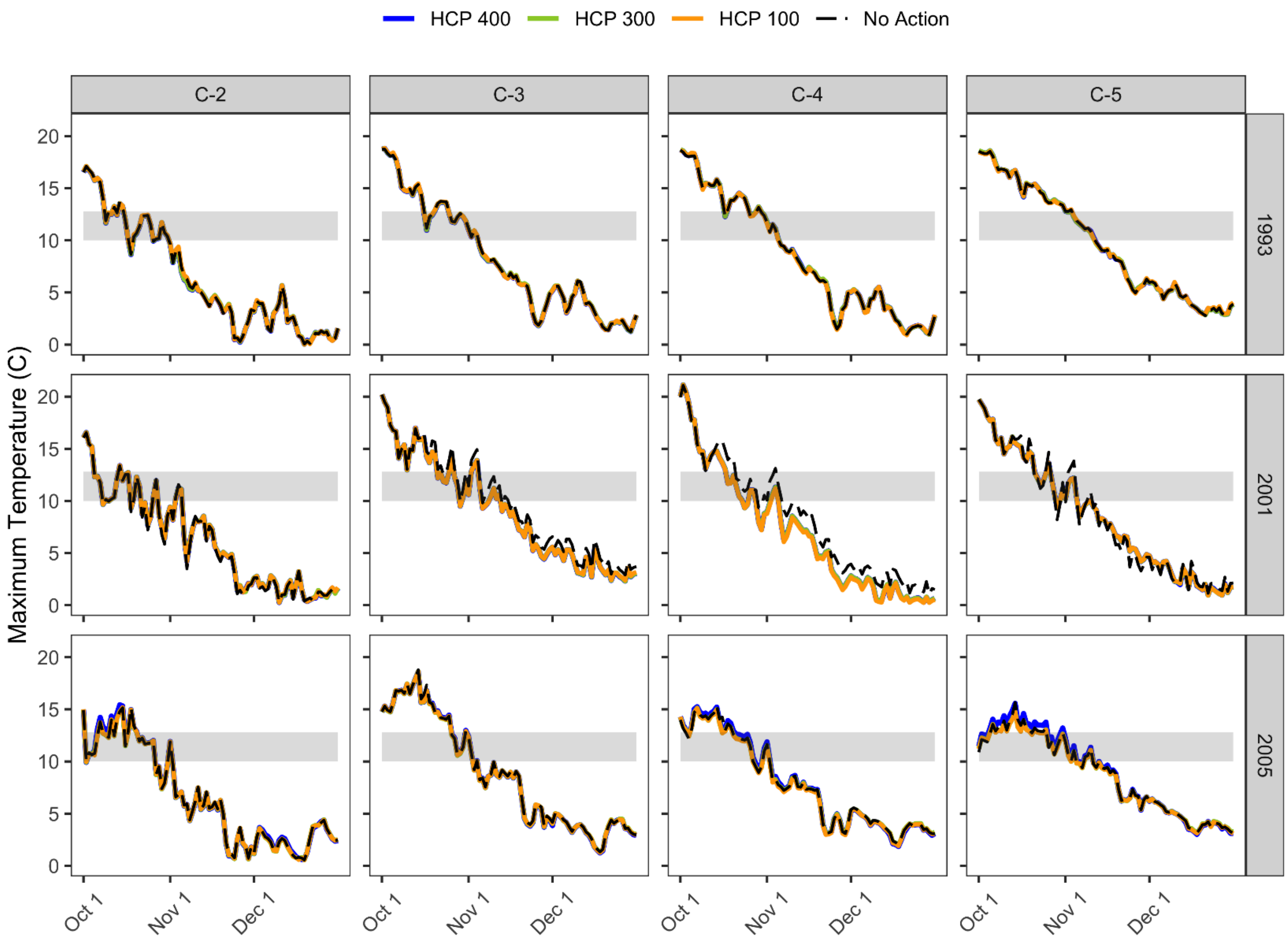

Figure 15. Maximum daily temperatures predicted under DBHCP flow scenarios in the Crooked River during October through December. A horizontal grey band indicates the temperatures preferred by steelhead during adult migration.

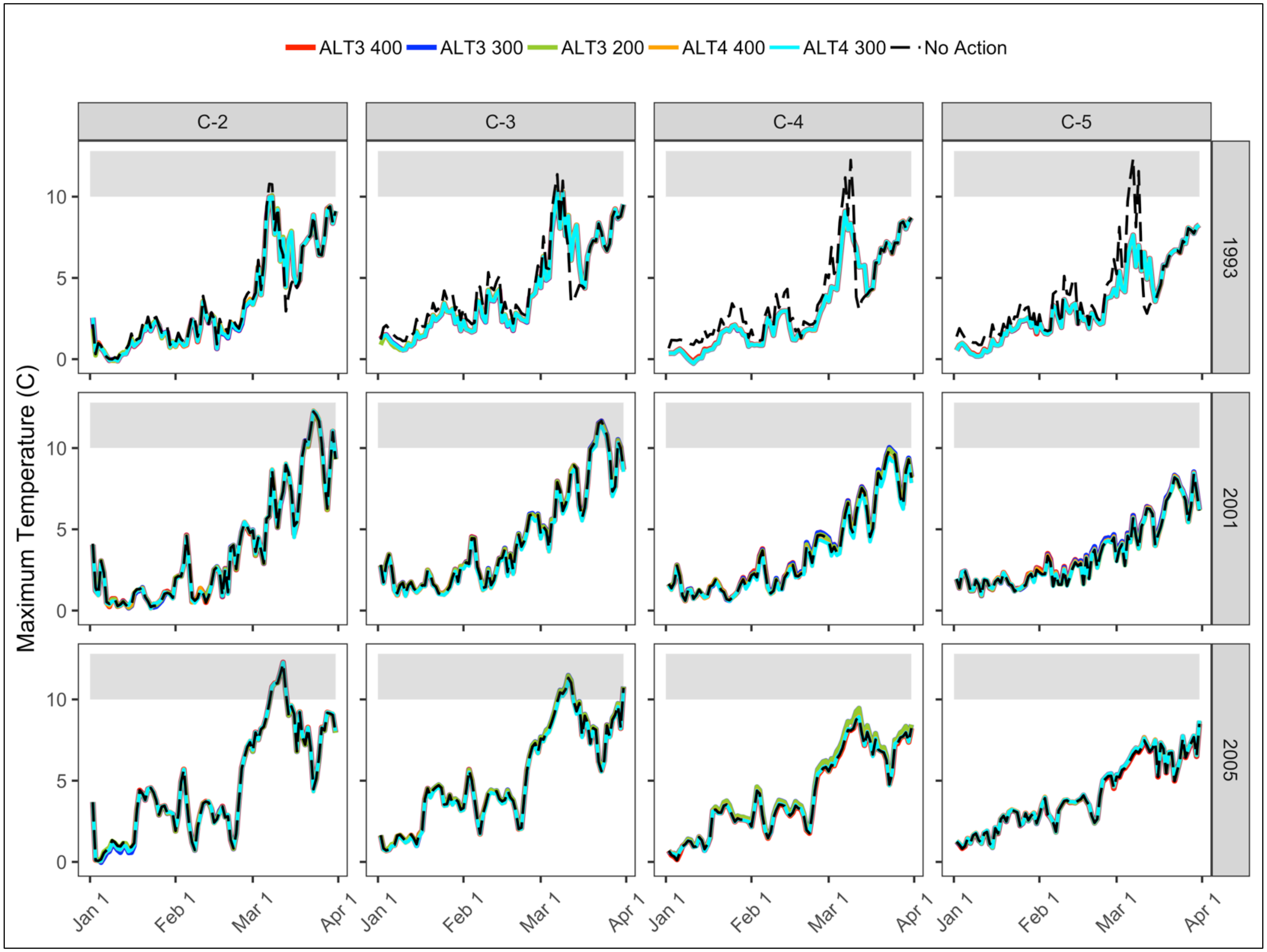

Figure 16. Maximum daily temperatures predicted under EIS alternative flow scenarios in the Crooked River during January through March. A horizontal grey band indicates the temperatures preferred by steelhead during adult migration.

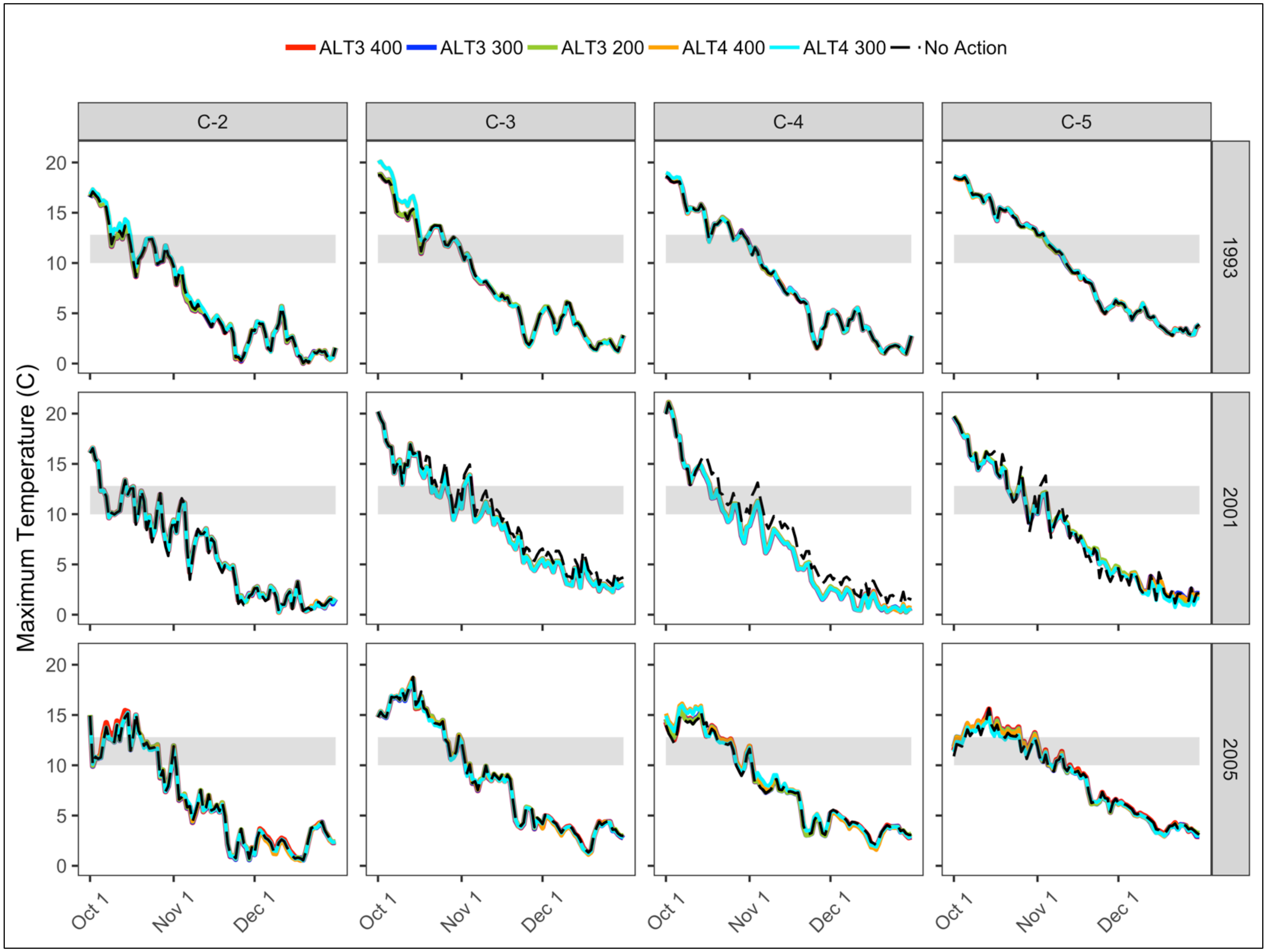

Figure 17**.** Maximum daily temperatures predicted under EIS alternative flow scenarios in the Crooked River during October through December. A horizontal grey band indicates the temperatures preferred by steelhead during adult migration.

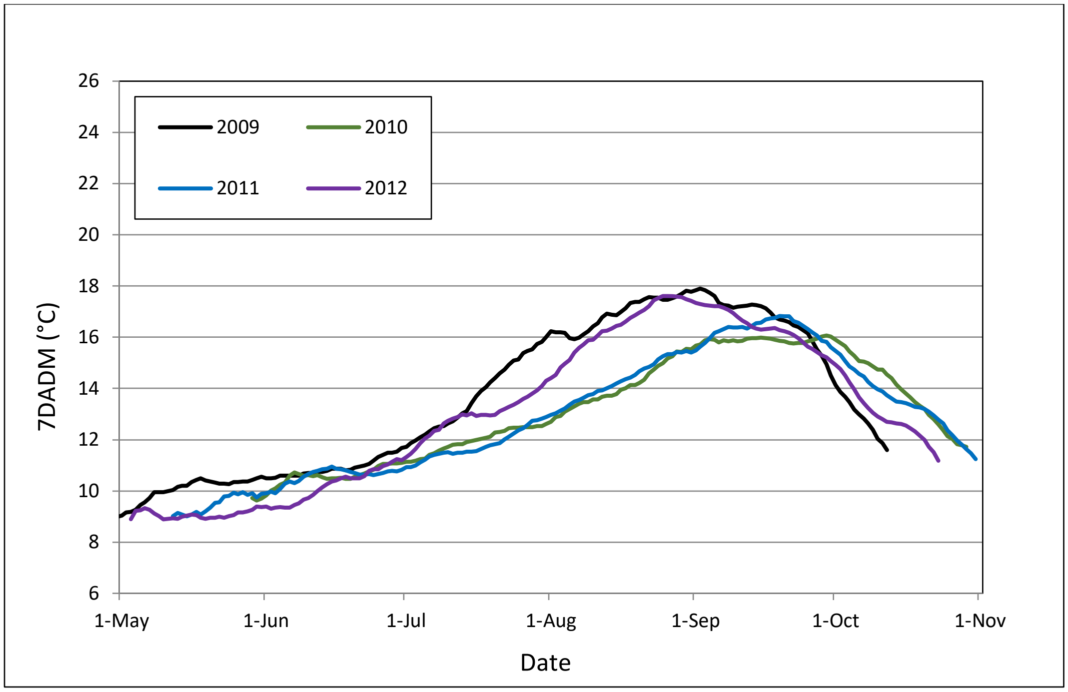

Figure 18. Seven-day averages of daily maximum water temperatures (7-DADM) in Ochoco Creek downstream of Ochoco Reservoir (RM 11.0) during the irrigation season. Source: CRWC 2014.

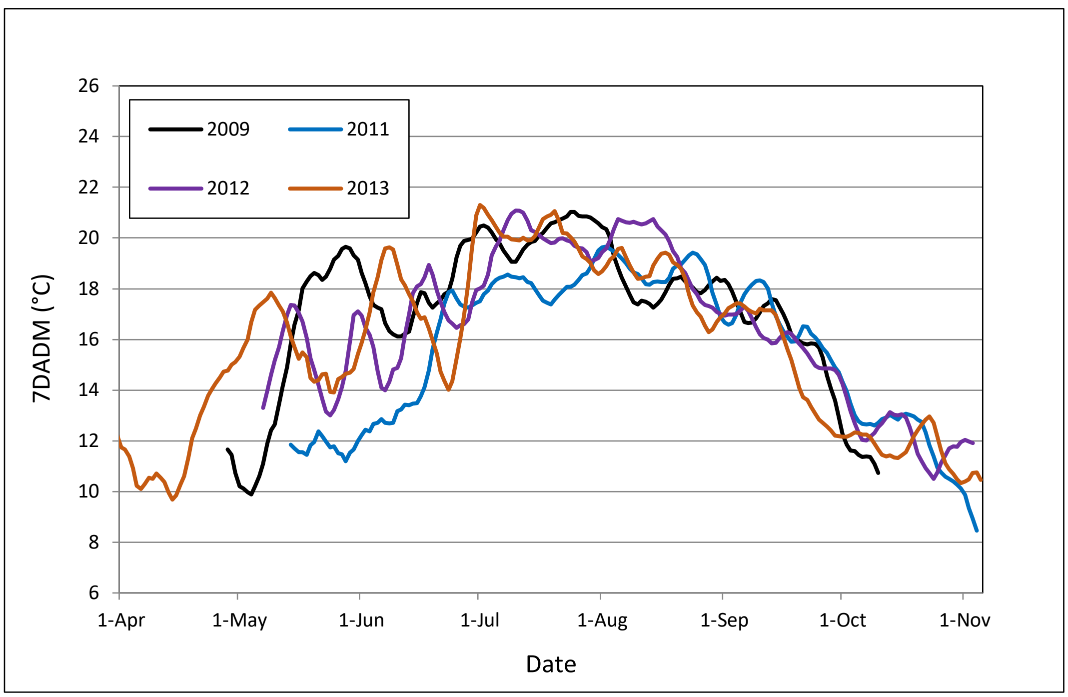

Figure 19. Seven-day averages of daily maximum water temperatures (7-DADM) in Ochoco Creek at RM 0.7 during the irrigation season. Source: CRWC 2014.

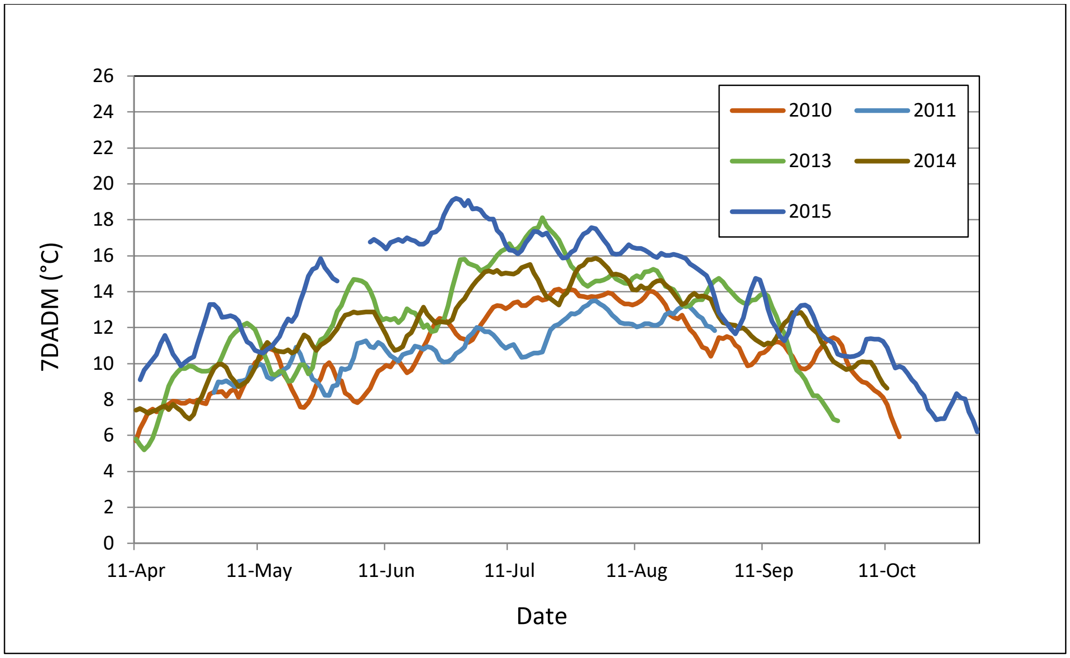

Figure 20. Seven-day averages of daily maximum water temperatures (7-DADM) in Whychus Creek downstream of Three Sisters irrigation District Diversion at Forest Road 4606 during the irrigation season. Source: UDWC 2016.

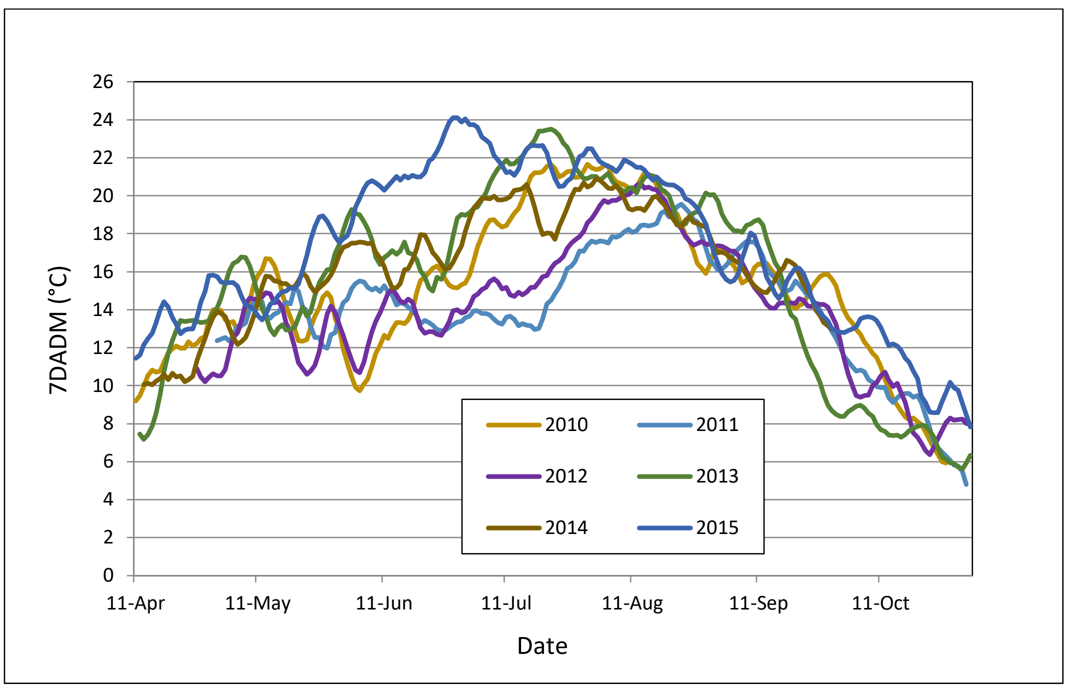

Figure 21. Seven-day averages of daily maximum water temperatures (7-DADM) in lower Whychus Creek at Forest Road 6360 (approximate RM 6.00) during the irrigation season. Source: UDWC 2016.

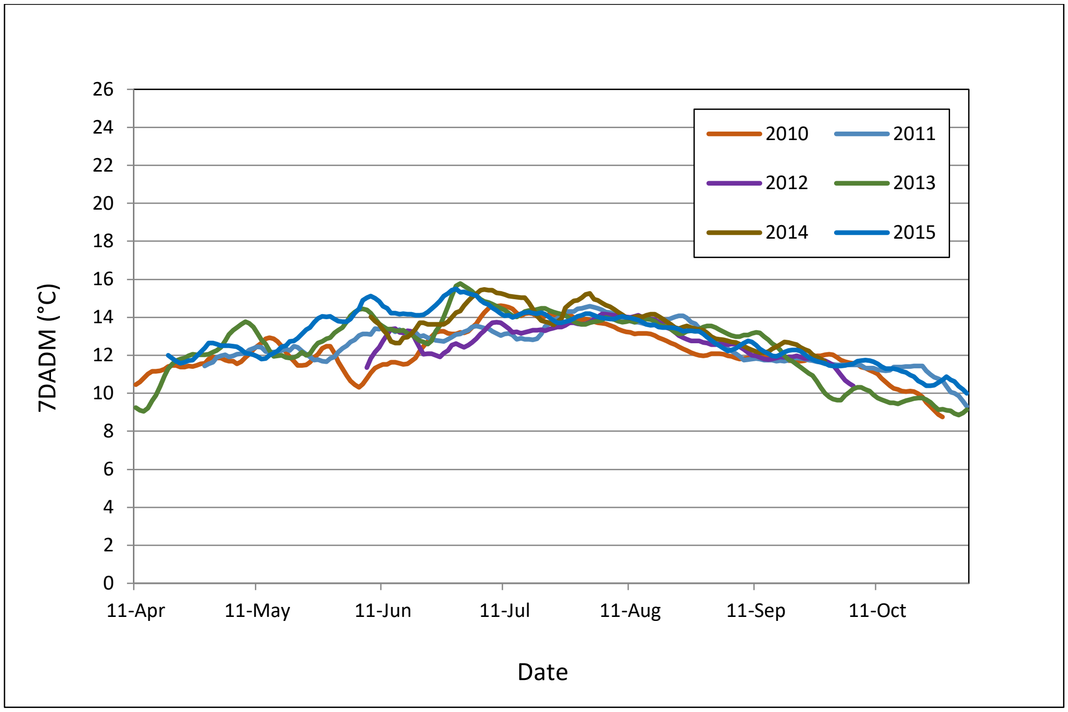

Figure 22. Seven-day averages of daily maximum water temperatures (7-DADM) in Whychus Creek near the mouth (RM 0.25) during the irrigation season. Source: UDWC 2016.

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FINAL

DESCHUTES BASIN
HABITAT CONSERVATION PLAN

Appendix B
Permittee Inter-District Agreements

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APPENDIX B-1

INTER-DISTRICT COORDINATION AGREEMENT

by and among

Arnold Irrigation District, Central Oregon Irrigation District, Lone Pine Irrigation District, North Unit Irrigation District, Ochoco Irrigation District, Swalley Irrigation District, Three Sisters Irrigation District, Tumalo Irrigation District, and The City of Prineville

to Implement the Deschutes Basin Habitat Conservation Plan

This Inter-District Coordination Agreement ("Agreement") is entered into by and among ARNOLD IRRIGATION DISTRICT, CENTRAL OREGON IRRIGATION DISTRICT, LONE PINE IRRIGATION DISTRICT, NORTH UNIT IRRIGATION DISTRICT, OCHOCO IRRIGATION DISTRICT, SWALLEY IRRIGATION DISTRICT, THREE SISTERS IRRIGATION DISTRICT, TUMALO IRRIGATION DISTRICT, and THE CITY OF PRINEVILLE (each individually a **"Permittee"** and collectively the **"Permittees"**).

RECITALS

The Permittees enter this Agreement based on the following facts:

A. Pursuant to the provisions of Section 10(a)(1)(B) of the Endangered Species Act ("ESA"), the Permittees have prepared a Habitat Conservation Plan (the "DBHCP") and submitted it to the United States Fish and Wildlife Service and National Marine Fisheries Service (the "Services") with a request that the Services each issue an incidental take permit (each individually a "Permit" and collectively the "Permits") to allow the incidental take of certain "Covered Species" on certain "Covered Lands and Waters" as the result of certain "Covered Activities," as described in Chapter 3 of the DBHCP and further defined in this Agreement.

B. In order to fulfill the legal requirements for the Services to issue the Permits, the DBHCP sets forth measures to ensure that any take of the Covered Species on the Covered Lands and Waters as a result of the Covered Activities will be incidental; that the impacts of the take will, to the maximum extent practicable, be minimized and mitigated; that procedures to address changed and unforeseen circumstances will be provided; that adequate funding for the DBHCP will be provided; and that the take will not appreciably reduce the likelihood of the survival and recovery of the Covered Species in the wild. The DBHCP also includes measures that the Services have recommended as necessary or appropriate for inclusion in the DBHCP.

C. Each of the nine Permittees conducts activities that are distinct from the activities of the other eight Permittees, and the activities of each Permittee result in impacts to the Covered Species that are similarly distinct from the impacts of the other Permittees. Under the DBHCP, each Permittee will be responsible for the implementation of "Conservation Measures" to minimize and mitigate the impacts of its own Covered Activities. Thus, for purposes of implementation of the DBHCP, except for Conservation Measures that expressly require coordination between two or more Permittees, the Conservation Measures are in no way interdependent, and the effectiveness of any Conservation Measure being implemented by one Permittee may not necessarily influence the effectiveness of any Conservation Measure being implemented by the other Permittees.

D. While each Permittee will be responsible for the implementation of specific Conservation Measures to address the effects of its own Covered Activities on the Covered Species, and no Permittee will be responsible for implementing Conservation Measures that directly address the effects of another Permittee's Covered Activities, the Services have evaluated all of the Conservation Measures collectively in determining that the implementation of the DBHCP meets the issuance criteria for Permits under Section 10(a) of the ESA. As such, the Permittees understand that the Services' analysis of the Conservation Measures has focused on whether collectively the Conservation Measures would minimize and mitigate the impacts of the collective Covered Activities, and further understand that the Services have not determined that a specific Permittee's Conservation Measures minimize and mitigate the impacts from all of that Permittee's specific Covered Activities.

E. As set forth in Section 3.6 of the DBHCP, the Permittees intend for the Conservation Measures and their other obligations under the DBHCP to be individual and severable in the event that (i) one or more Permittees chooses to terminate or amend their individual incidental take coverage under the Permits, or (ii) one or both Permits is revoked, and one or more of the Permittees seeks reinstatement of the Permit(s) with respect to their Covered Activities, and when under either of these circumstances, the Services determine that the remaining Conservation Measures would continue to meet the issuance criteria for the Permits as to the remaining Covered Activities. For compliance purposes, the Permittees intend that each Permittee will be responsible only for implementing the Conservation Measures assigned to it in Table 3-9 of the DBHCP. In acknowledgment of this framework, the Services have requested additional assurances to clarify the Permittees' responsibilities in the event that one or more Permittees choose to terminate or amend their incidental take coverage under the Permits and their obligations under the DBHCP. This Agreement sets forth those responsibilities.

NOW, THEREFORE, in consideration of the promises and covenants contained in this Agreement and for other good and valuable consideration, the receipt of which is hereby acknowledged, the Parties agree as follows:

AGREEMENT

1. DEFINITIONS

1.1 "Adaptive Management Measures" means those measures described in Section 7.3 of the DBHCP, to which the Permittees have committed to provide information upon which future adjustment to the Conservation Measures may be based.

1.2 "Changed Circumstances" has the meaning set forth at 50 C.F.R. §§ 17.3 and 222.102 and means those circumstances that have been specifically planned for as provided in Sections 9.1 through 9.10 of the DBHCP.

1.3 **"Conservation Measures"** means those measures described in Chapter 6 of the DBHCP, to which the Permittees have committed to minimize and mitigate, to the maximum extent practicable, the impacts of the incidental take of the Covered Species on the Covered Lands and Waters as a result of the Covered Activities.

1.4 **"Covered Activities"** means those activities described in Section 3.5 of the DBHCP and covered by the Permits.

1.5 **"Covered Lands and Waters"** means all aquatic, wetland, riparian and floodplain habitats affected by the Covered Activities and covered by the Permits as described in Section 3.2 of the DBHCP.

1.6 **"Covered Species"** means the species identified in Section 3.4 of the DBHCP and covered by the Permits.

1.7 **"DBHCP"** means the final Deschutes Basin Habitat Conservation Plan prepared by the Permittees for the Covered Activities.

1.8 **"Effective Date"** means the date that the Services issue the Permits or, if the Permits are issued separately, the date that the last Permit is issued.

1.9 **"ESA"** means the Endangered Species Act, 16 U.S.C. §§ 1531–1544.

1.10 **"Permit"** means an incidental take permit issued by the Services to the Permittees pursuant to Section 10(a)(1)(B) of the Endangered Species Act.

1.11 **"Permittee"** means Arnold Irrigation District, Central Oregon Irrigation District, Lone Pine Irrigation District, North Unit Irrigation District, Ochoco Irrigation District, Swalley Irrigation District, Three Sisters Irrigation District, Tumalo Irrigation District, and The City of Prineville, and **"Permittees"** means those entities collectively.

1.12 **"Service"** means the United States Fish and Wildlife Service or the National Marine Fisheries Service, and **"Services"** means those agencies collectively.

1.13 **"Unforeseen Circumstances"** has the meaning set forth at 50 C.F.R. §§ 17.3 and 222.102 and means those changes in circumstances affecting the Covered Species on the Covered Lands and Waters with respect to the DBHCP that could not reasonably have been anticipated by the Permittees and the Services at the time of the DBHCP's negotiation and development, and that result in a substantial and adverse change in the status of the Covered Species.

2. DEFINED TERMS

Terms defined and utilized in the DBHCP, the ESA, and in the Services' regulations implementing the ESA shall have the same meaning when utilized in this Agreement. Otherwise, any definitions and meanings for terms not otherwise defined and utilized in the DBHCP, the ESA, or the Services' regulations implementing the ESA shall only apply to the terms of this Agreement and not to the DBHCP or the Permits.

3. TERM

This Agreement shall become effective on the Effective Date and shall remain in full force and effect until all Permits expire. This Agreement shall also remain in effect if one or both Permits is revoked, and one or more of the Permittees seeks reinstatement of the Permit(s) with respect to their Covered Activities. In such an event, any Permittee who chooses not to seek reinstatement shall be deemed an **"Exiting Permittee,"** and shall be subject to the provisions governing Amending or Exiting Permittees below.

4. INDIVIDUAL PERMITTEE RESPONSIBILITIES

4.1 Conservation Measures and Adaptive Management Measures. Each Permittee shall, to the maximum extent practicable, fully cooperate in implementing all Conservation Measures and Adaptive Management Measures. However, each Permittee shall be individually responsible for implementing and securing funding to implement only those Conservation Measures and Adaptive Management Measures required to minimize and mitigate the impacts of its own Covered Activities as identified in Table 3-9 and further described in Chapter 6 of the DBHCP.

4.2 Changed Circumstances. In the event of Changed Circumstances, each Permittee shall be individually responsible for implementing and securing funding to implement only those additional conservation and mitigation measures required to respond to Changed Circumstances as a result of its own Covered Activities and to minimize and mitigate the impacts of its own Covered Activities, as identified in Chapter 9 of the DBHCP, except that, in the event of those Changed Circumstances covered by this Agreement and described in Section 9.8 of the DBHCP, an Amending or Exiting Permittee shall also comply with all obligations under Paragraph 5.2 of this Agreement.

4.3 Unforeseen Circumstances. In the event that either Service notifies the Permittees of an Unforeseen Circumstance through the process identified in Section 9.8 of the DBHCP, each Permittee shall, to the maximum extent practicable, cooperate with the Service(s) to determine the impacts of and develop an appropriate response to the Unforeseen Circumstance, as set forth in Section 9.8 of the DBHCP. However, each Permittee shall be individually responsible for implementing only those response actions to any Unforeseen Circumstance required as a result of the Permittee's own Covered Activities.

5. PERMITTEE SEEKING AMENDMENT TO OR EXIT FROM THE DBHCP

5.1 Notice Required. In the event that any Permittee voluntarily chooses to amend the DBHCP or terminate its individual incidental take coverage under the Permits, that Permittee shall be deemed an **"Amending or Exiting Permittee."** The Amending or Exiting Permittee shall provide joint written notice to all other Permittees and the Services of the Permittee's intent to amend or exit the DBHCP and amend or terminate incidental take coverage under the Permits at least one year in advance of the effective date of the proposed amendment or exit. Such notice shall describe the status of the Amending or Exiting Permittee's individual obligations under the DBHCP and this Agreement; the Amending or Exiting Permittee's plans and timeline to implement any outstanding individual obligations under the DBHCP and this Agreement; and any individual obligations under the DBHCP or this Agreement that the Amending or Exiting Permittee does not intend to perform. Such notice will be deemed a Changed Circumstance, as further described in Section 9.8 of the DBHCP.

5.2 Amending or Exiting Permittee's Obligations. An Amending or Exiting Permittee shall be individually responsible for ensuring that its proposed amendment to or exit from the DBHCP does not undermine any assumptions, analysis, or conclusions in the DBHCP that were used by the Services to verify compliance with the Section 10(a) permit issuance criteria or continued incidental take coverage under the Permits for all other Permittees. The Amending or Exiting Permittee shall:

a. fully cooperate with all other Permittees and the Services to evaluate the effect of the Amending or Exiting Permittee's proposed amendment to or exit from the DBHCP on the assumptions, analysis, and conclusions in the DBHCP that were used by the Services to verify compliance with the Section 10(a) permit issuance criteria and the continued incidental take coverage under the Permits for all other Permittees; and

b. pay or reimburse, at the Exiting Permittee's sole expense, all costs incurred by the remaining Permittees to (i) maintain the DBHCP as a result of the Amending or Exiting Permittee's proposed amendment to or exit from the DBHCP, including but not limited to all application fees, consultant fees, legal expenses, and costs incurred for additional studies, analysis, compliance with the National Environmental Policy Act, and all other work required to evaluate the effect of the Amending or Exiting Permittee's proposed amendment to or exit from the DBHCP; (ii) revise the DBHCP or the Permits as a result of the Amending or Exiting Permittee's proposed amendment to or exit from the DBHCP; or (iii) otherwise ensure that the Amending or Exiting Permittee's amendment to or exit from the DBHCP does not negatively affect the remaining Permittees' continued incidental take coverage under the Permits.

6. LIABILITY ARISING UNDER DBHCP

The Permittees recognize that the Conservation Measures will be implemented by different Permittees, each having differing legal authorities and jurisdictions, and that each

Permittee shall be individually responsible only for those Conservation Measures, Adaptive Management Measures, and other measures identified in the DBHCP and this Agreement required as a result of the Permittee's own Covered Activities. The Permittees further recognize that no Permittee shall be liable to or have any cause of action against any other Permittee with respect to the DBHCP, except that:

a. in the event that the Services issues any penalty or takes any enforcement action under the DBHCP against the Permittees jointly and severally, this Agreement does not extinguish any Permittee's right of contribution against any other Permittee;

b. any Permittee responsible for implementing a Conservation Measure that expressly requires coordination between two or more Permittees reserves the right to pursue injunctive relief or compensatory damages to enforce any coordinating Permittee's cooperation and compliance with the Conservation Measure; and

c. as set forth in Paragraph 7 of this Agreement.

7. REMEDIES AND ENFORCEMENT

7.1 Remedies in General. The Permittees shall work together in good faith to attempt to resolve disagreements in a mutually satisfactory manner. Such attempts shall include, where feasible, reasonable notice of any default and an opportunity to cure. Notwithstanding the foregoing, each Permittee reserves all causes of action, legal rights, and remedies otherwise available to enforce the terms of this Agreement, subject to Paragraph 7.2 of this Agreement.

7.2 No Monetary Damages. No Permittee shall be liable in damages to any other Permittee or any other person for any breach of this Agreement, any performance or failure to perform a mandatory or discretionary obligation imposed by this Agreement, or any other cause of action arising from this Agreement, except that each Permittee expressly reserves the right to seek compensatory damages from any other Permittee for breach of any obligation in Paragraphs 5.2 or 6(b) of this Agreement.

7.3 Injunctive and Temporary Relief. The Permittees acknowledge that injunctive and temporary relief may be appropriate to ensure compliance with the terms of this Agreement.

7.4 No Release of Other Liability. The Permittees acknowledge that, notwithstanding this Agreement, all Permittees retain whatever individual liability they would possess for their present and future acts or failure to act without existence of this Agreement.

8.0 AMENDMENTS

Except as otherwise set forth herein, this Agreement may be amended, modified, or extended only by a writing signed by each of the Permittees.

9.0 MISCELLANEOUS PROVISIONS

9.1 No Partnership. Except as otherwise expressly set forth herein, neither this Agreement nor the DBHCP shall make or be deemed to make any Permittee the agent for or partner of any other Permittee.

9.2 Successors and Assigns. This Agreement and each of its covenants and conditions shall be binding on and shall inure to the benefit of the Permittees and their respective successors and assigns.

9.3 Notice. Any notice permitted or required by this Agreement shall be delivered personally to the persons set forth below or shall be deemed given five (5) days after deposit in the United States mail, certified and postage prepaid, return receipt requested and addressed as follows or at such other address as any Permittee may from time to time specify to the other Permittees in writing:

Manager
Arnold Irrigation District
19604 Buck Canyon Road
Bend, OR 97702

Manager
Central Oregon Irrigation District
1055 SW Lake Court
Redmond, OR 97756

Board Chairman
Lone Pine Irrigation District
7911 NW Lone Pine Road
Terrebonne, OR 97760

Manager
North Unit Irrigation District
2024 NW Beech Street
Madras, OR 97741

Manager
Ochoco Irrigation District
1001 NW Deer Street
Prineville, OR 97754

Manager
Swalley Irrigation District
64672 Cook Avenue, Suite 1
Bend, OR 97703

Manager
Three Sisters Irrigation District
Post Office Box 2230
Sisters, OR 97759

Manager
Tumalo Irrigation District
64697 Cook Avenue
Bend, OR 97703

City Manager
City of Prineville
387 NE 3rd Street
Prineville, OR 97754

9.4 Entire Agreement. This Agreement, together with the DBHCP, constitutes the entire Agreement between the Permittees. The Agreement supersedes any and all other Agreements, either oral or written among the Permittees with respect to the subject matter hereof and contains all of the covenants and Agreements among them with respect to said matters, and each Permittee acknowledges that no representation, inducement, promise, or Agreement, oral or otherwise, has been made by any Permittee or anyone acting on behalf of any Permittee, that is not embodied herein.

9.5 Counterpart Signatures. This Agreement may be executed by separate counterpart signature pages, but all such counterparts shall be deemed to have been executed as of the date hereof. Delivery of an executed signature page to this Agreement by email transmission shall be as effective as delivery of a manually signed counterpart of this Agreement.

9.6 Third-Party Beneficiaries. This Agreement shall not create any right or interest in the public, or any member thereof, as a third-party beneficiary hereof. Nor shall this Agreement authorize anyone who is not a Permittee to maintain a suit for personal injuries or property damages pursuant to the provisions of this Agreement. The duties, obligations, and responsibilities of the Permittees with respect to third parties shall remain as imposed under existing federal or state law.

9.7 Relationship to the ESA and Other Authorities. The terms of this Agreement shall be governed by and construed in accordance with the ESA and other applicable laws.

9.8 Applicable Laws. All activities undertaken by the Permittees pursuant to this Agreement, the DBHCP, or the Permits must be in compliance with all applicable state and federal laws and regulations.

9.9 Authority. By the signatures of the undersigned, the Permittees represent that they have all necessary authorities to enter into this Agreement and that they understand this Agreement and intend to be legally bound by its terms.

9.10 Severability. Should any of the provisions of this Agreement be rendered invalid by a court or government agency of competent jurisdiction, the Permittees agree that such a decision shall in no way affect the enforceability of the other provisions of this Agreement, all of which shall remain in full force and effect.

IN WITNESS WHEREOF, THE PARTIES HERETO have executed this Agreement to be in effect as of the Effective Date.

ARNOLD IRRIGATION DISTRICT

By: ________________________ Date: _________________________
Colin Wills, Manager

CENTRAL OREGON IRRIGATION DISTRICT

By: ________________________ Date: _________________________
Craig Horrell, Manager

LONE PINE IRRIGATION DISTRICT

By: ________________________ Date: ________________________
Terry Smith, Board Chairman

NORTH UNIT IRRIGATION DISTRICT

By: ________________________ Date: ________________________
Mike Britton, Manager

OCHOCO IRRIGATION DISTRICT

By: ________________________ Date: ________________________
Bruce Scanlon, Manager

SWALLEY IRRIGATION DISTRICT

By: ________________________ Date: ________________________
Jer Camarata, Manager

THREE SISTERS IRRIGATION DISTRICT

By: ________________________ Date: ________________________
Marc Thalacker, Manager

TUMALO IRRIGATION DISTRICT

By: ________________________ Date: ________________________
Ken Rieck, Manager

CITY OF PRINEVILLE, OREGON

By: ________________________ Date: ________________________
Eric Klann, City Engineer

This agreement will be signed by the parties and provided to the Services upon execution and issuance of the incidental take permits. The signed copy will be kept on file with the U.S. Fish and Wildlife Service.

APPENDIX B-2

INTER-DISTRICT AGREEMENT TO AMEND THE 1938 AGREEMENT FOR PURPOSES OF IMPLEMENTING THE DBHCP

This INTER-DISTRICT AGREEMENT TO AMEND THE 1938 AGREEMENT FOR PURPOSES OF IMPLEMENTING THE DBHCP ("Agreement") is made this _____ day of _______ 2020, by and between Arnold Irrigation District ("AID"), Central Oregon Irrigation District ("COID"), Lone Pine Irrigation District ("LPID"), and North Unit Irrigation District ("NUID") (collectively, the "Districts" or "parties"), all of which are irrigation districts operating pursuant to the provisions of Oregon Revised Statutes Chapter 545.

RECITALS

A. On December 7, 2017, COID and NUID entered into an Agreement for Provision of Water, which was amended on December 2, 2019, pursuant to the First Amendment to COID-NUID Agreement for Provision of Irrigation Water; and further, AID, COID, and LPID entered into a Reservoir Storage Allocation Agreement, dated December 7, 2017, which was amended on December 2, 2019, pursuant to the 2019 AID-COID-LPID Reservoir Storage Allocation Agreement (collectively, the "Temporary 1938 Agreement Amendments"). Among other things, the Temporary 1938 Agreement Amendments provided for temporary amendments to the Inter-District Contract, dated January 4, 1938, between the Districts or their predecessors (the "1938 Agreement"), with regard to the filling and allocation of water in Crane Prairie and Wickiup reservoirs, first for the term of an interim biological opinion and incidental take statement issued by the U.S. Fish and Wildlife Service ("USFWS), and then for the additional term of a supplemental interim biological opinion and extended incidental take statement also issued USFWS. The Temporary 1938 Agreement Amendments, as well as the supplemental interim biological opinion and extended incidental take statement, are set to expire no later than December 31, 2020.

B. The Districts are prepared to implement the Deschutes Basin Habitat Conservation Plan ("DBHCP"), approved by the USFWS and the National Marine Fisheries Service ("NMFS") (collectively, "the Services") on ________ __, 2020, pursuant to and consistent with the terms and conditions of the incidental take permits ("ITPs") issued by the Services on the same date. In particular, Conservation Measure CP-1 includes provisions for the operation of Crane Prairie Reservoir, while Conservation Measure WR-1 includes provisions for the operation of Wickiup Reservoir. The Districts' implementation of these measures requires an amendment to the 1938 Agreement.

C. Consistent with their commitments to implement the Conservation Measures and other provisions of the DBHCP, and comply with the terms and conditions of the ITPs, the Districts wish to restate, with modifications to reflect the final Conservation Measures and other provisions of the DBHCP, their agreement with one another as to the filling and allocation of water in Crane Prairie and Wickiup reservoirs during the term of the DBHCP.

D. The Districts believe that neither the DBHCP nor this Agreement will impair the irrigation efficiency of the federal Deschutes Project. Further, Section 509(d) of Public Law

110-229 (Consolidated Natural Resources Act of 2008) amended NUID's contract with the U.S. Bureau of Reclamation ("Reclamation") to authorize NUID to utilize Reclamation project water for irrigation and instream purposes consistent with state and federal law requirements, as described herein.

In recognition of the mutual benefits to be derived from this Agreement, the Districts agree as follows:

1. Consistent with their terms, the Temporary 1938 Agreement Amendments will terminate on or before December 31, 2020. This Agreement shall become effective on January 1, 2021, or the date the DBHCP is approved and the ITPs are issued by the Services, whichever occurs first. This Agreement shall terminate on the date the ITPs expire, or the date that the ITPs are terminated, whether by action of the Services or by action of one or more of the Districts, whichever occurs first. In the event of termination pursuant to the action of one or more of the Districts, such termination shall only occur with at least one full year's prior written notice in advance of November 1 in any given year, and only upon compliance with the Inter-District Coordination Agreement governing the exit of Permittees from incidental take coverage under the ITPs (see DBHCP Appendix B-1). Upon termination of this Agreement, the Districts shall revert to their respective rights as they existed prior to the Temporary 1938 Agreement Amendments.

2. NUID will make available up to 12,000 acre feet of its Wickiup storage at the commencement of each irrigation season for use by AID and LPID. The specific amount of Wickiup stored water to be made available to AID and LPID for each irrigation season will be determined by the amount of stored water in Crane Prairie that is available to "pay back" NUID later in that same irrigation season, and this amount will be the difference between the highest elevation reached at the end of the fill season and the lowest elevation to which the reservoir can be drawn down consistent with the DBHCP and the ITPs issued by the Services. In terms of accounting, each acre foot of water released by NUID from Wickiup storage for use by AID and/or LPID will be "paid back" to NUID by AID and/or LPID from Crane Prairie in the same season.

3. Of the available water described in Section 2 above, LPID would receive the first 5,000 acre feet out of Wickiup. AID will receive the available water up to 5,000 acre feet after LPID receives its 5,000 acre feet. If there is water available in excess of 10,000 acre feet, and up to 12,000 acre feet, it would be divided equally between LPID and AID.

4. Conservation Measure CP-1.H provides for a periodic release of up to 5,000 acre feet of additional stored water from Crane Prairie for Oregon spotted frog flow management downstream of Wickiup Dam. In the event such releases are available for diversion for irrigation use, the Districts agree to meet in advance of the release to determine how the 5,000 acre feet will be allocated among the Districts for that particular irrigation season. Nothing in this Agreement shall bind the Districts to any specific allocation of the 5,000 acre feet.

5. Of the available stored water that is credited to any District pursuant to Sections 2 through 4 above, the other Districts (including AID, COID, LPID, and NUID) may request from the credited District the use of any available unused storage water in the current irrigation season without charge, approval of which shall not be unreasonably withheld. In the event of such a request, the Districts agree to meet and confer in advance of any approval of such use of available unused storage water.

6. COID will forego use of storage in Crane Prairie in exchange for up to 5,000 acre feet of stored water from Wickiup – up to 3,000 acre feet before July 1 and up to 2,000 acre feet for late season in the same irrigation season. COID will provide NUID with access to Deschutes River water in exchange for this early and late season use of Wickiup provided it can do so without making a call on AID, LPID, or TID junior live flow rights. The restriction on COID's ability to make a call on junior live flow rights applies only if it is making a call for purposes of replacing NUID storage water, and does not otherwise re-order priority dates or impair COID's ability to make a call on junior water rights if needed to serve its patrons.

7. If hydrologic conditions, such as a dry year, substantially impact the water available for storage and use, the Districts agree to meet in good faith and attempt to reach consensus to adjust the terms of Section 2 through 6 above, so long as any adjustments are consistent with the Conservation Measures and other provisions of the DBHCP, and comply with the terms and conditions of the ITPs.

8. The Districts will cooperate with the Oregon Water Resources Department as necessary to implement this Agreement.

9. All provisions of the 1938 Agreement that are unaffected by this Agreement and are not otherwise inconsistent with this Agreement, the provisions of the DBHCP, or the terms and conditions of the ITPs, shall remain in full force and effect.

10. This Agreement does not affect any terms or conditions of contracts between the United States and COID or NUID except as those contracts reference the 1938 Agreement, as it may be amended. All provisions of those contracts, including those pertaining to responsibility for the operation and maintenance of transferred works and any allocation of costs will remain unaffected and in full force and effect.

11. General Provisions.

11.1 Binding Effect. This Agreement is binding on and inures to the benefit of the parties and their respective heirs, personal representatives, successors, and assigns.

11.2 Assignment. Neither this Agreement nor any of the rights, interests, or obligations under this Agreement may be assigned by any party without the prior written consent of the other parties, which consent will not be unreasonably withheld.

11.3 No Third-Party Beneficiaries. Nothing in this Agreement, express or implied, is intended or may be construed to confer on any person, other than the parties to this Agreement, any right, remedy, or claim under or with respect to this Agreement.

11.4 Notices. All notices and other communications under this Agreement must be in writing and will be deemed to have been given if delivered personally, mailed by certified mail, or delivered by an overnight delivery service (with confirmation) to the parties at the following addresses (or at such other address as a party may designate by like notice to the other parties):

Manager
Arnold Irrigation District
19605 Buck Canyon Road
Bend, OR 97702

Manager
Lone Pine Irrigation District
7911 NW Lone Pine Road
Terrebonne, OR 97760

Manager
Central Oregon Irrigation District
1055 SW Lake Court
Redmond, OR 97756

Manager
North Unit Irrigation District
2024 NW Beech Street
Madras, OR 97741

Any notice or other communication will be deemed to be given (a) on the date of personal delivery, (b) at the expiration of the fifth day after the date of deposit in the United States mail, or (c) on the date of confirmed delivery by overnight delivery service.

11.5 Amendments. This Agreement may be amended only by an instrument in writing executed by all the parties, which writing must refer to this Agreement.

11.6 Construction. The captions used in this Agreement are provided for convenience only and will not affect the meaning or interpretation of any provision of this Agreement. All references in this Agreement to "Section" or "Sections" without additional identification refer to the Section or Sections of this Agreement. All words used in this Agreement will be construed to be of such gender or number as the circumstances require. Whenever the words "include" or "including" are used in this Agreement, they will be deemed to be followed by the words "without limitation."

11.7 Counterparts. This Agreement may be executed in counterparts, each of which will be considered an original and all of which together will constitute one and the same agreement.

11.8 Electronically Transmitted Signatures. Electronic mail transmission of any signed original document, and retransmission of any signed electronic mail transmission, will be the same as delivery of an original. At the request of any party, the parties will confirm electronically transmitted signatures by signing an original document.

11.9 Further Assurances. Each party agrees to execute and deliver such other documents and to do and perform such other acts and things as any other party may reasonably request to carry out the intent and accomplish the purposes of this Agreement.

11.10 Time of Essence. Time is of the essence with respect to all dates and time periods set forth or referred to in this Agreement.

11.11 Expenses. Except as otherwise expressly provided in this Agreement, each party to this Agreement will bear its own expenses in connection with the preparation, execution, and performance of this Agreement and the transactions contemplated by this Agreement.

11.12 Waiver. Any provision or condition of this Agreement may be waived at any time, in writing, by the party entitled to the benefit of such provision or condition. Waiver of any breach of any provision will not be a waiver of any succeeding breach of the provision or a waiver of the provision itself or any other provision.

11.13 Governing Law. This Agreement will be governed by and construed in accordance with the laws of the state of Oregon, without regard to conflict-of-laws principles.

11.14 Attorney Fees. If any arbitration, suit, or action is instituted to interpret or enforce the provisions of this Agreement, to rescind this Agreement, or otherwise with respect to the subject matter of this Agreement, the party prevailing on an issue will be entitled to recover with respect to such issue, in addition to costs, reasonable attorney fees incurred in the preparation, prosecution, or defense of such arbitration, suit, or action as determined by the arbitrator or trial court, and, if any appeal is taken from such decision, reasonable attorney fees as determined on appeal.

11.15 Injunctive and Other Equitable Relief. The parties agree that the remedy at law for any breach or threatened breach by a party may, by its nature, be inadequate, and that in addition to damages, the other parties will be entitled to a restraining order, temporary and permanent injunctive relief, specific performance, and other appropriate equitable relief, without showing or proving that any monetary damage has been sustained.

11.16 Venue. Any action or proceeding seeking to enforce any provision of this Agreement or based on any right arising out of this Agreement must be brought against any of the parties in Deschutes County Circuit Court or Jefferson County Circuit Court of the State of Oregon or, subject to applicable jurisdictional requirements, in the United States District Court for the District of Oregon, and each of the parties consents to the jurisdiction of such courts (and of the appropriate appellate courts) in any such action or proceeding and waives any objection to such venue.

11.17 Severability. If any provision of this Agreement is deemed to be invalid or unenforceable in any respect for any reason, the validity and enforceability of such provision in any other respect and of the remaining provisions of this Agreement will not be impaired in any way.

11.18 Entire Agreement. This Agreement (including the documents and instruments referred to in this Agreement) constitutes the entire agreement and understanding of the parties with respect to the subject matter of this Agreement and supersedes all prior understandings and agreements, whether written or oral, between the parties with respect to such subject matter.

THIS AGREEMENT is effective as of the date set forth above.

Arnold Irrigation District ("AID")

By: ___________________________________ Date: ________________
Its Board President

By: ___________________________________ Date:________________
Its Board Secretary

Central Oregon Irrigation District ("COID")

By: ___________________________________ Date: ________________
Its Board President

By: ___________________________________ Date:________________
Its Board Secretary

Lone Pine Irrigation District ("LPID")

By: ___________________________________ Date: ________________
Its Board President

By: ___________________________________ Date:________________
Its Board Secretary

North Unit Irrigation District ("NUID")

By: __________________________________ Date: ________________
Its Board President

By: ___________________________________ Date:________________
Its Board Secretary

This agreement will be signed by the parties and provided to the Services upon execution and issuance of the incidental take permits. The signed copy will be kept on file with the U.S. Fish and Wildlife Service.

APPENDIX B-3

MEMORANDUM OF UNDERSTANDING
REGARDING COORDINATION OF STOCK WATER DIVERSIONS

This MEMORANDUM OF UNDERSTANDING REGARDING COORDINATION OF STOCK WATER DIVERSIONS ("MOU") is made this _____ day of _______ 2020, by and between the Arnold Irrigation District ("AID"), the Central Oregon Irrigation District ("COID"), and the Swalley Irrigation District ("SID") (collectively "the Districts"), all of which are irrigation districts operating pursuant to the provisions of Oregon Revised Statutes Chapter 545.

RECITALS

A. The Districts are prepared to implement the Deschutes Basin Habitat Conservation Plan ("DBHCP"), approved by the U.S. Fish and Wildlife Service and the National Marine Fisheries Service, on ________ __, 2020.

B. In particular, Measure DR-1 of the DBHCP provides as follows:

> "Measure DR-1: Middle Deschutes River Flow Outside the Irrigation Season
>
> "Three DBBC Districts (AID, COID and SID) will coordinate stock water diversions and other diversions of live flow from the Deschutes River between November 1 and March 31 to prevent such diversions from resulting in a 1-day average flow of less than 250 cfs (±25 cfs) at Hydromet Station DEBO (OWRD Gage 14070500) below Bend. If flow in the Deschutes River upstream of Bend (Hydromet Station BENO) is less than 250 cfs, the three DBBC Districts will not conduct stock water diversions from the Deschutes River, but they also will have no obligation to release storage beyond the requirements of Conservation Measure WR-1, or otherwise augment flow, in order to provide 250 cfs at DEBO.
>
> "AID, COID and SID shall have no obligation to reduce diversions to account for simultaneous diversions by other parties between BENO and DEBO. If the flow at BENO minus the combined diversions by AID, COID and SID is ≥250 cfs, but the flow at DEBO is < 250 cfs due to simultaneous diversion or retention of water by another party, AID, COID and SID shall be considered in compliance with this measure. In addition, none of the three Districts shall be found out of compliance with this measure during any time they are not actively diverting water from the Deschutes River."

The Districts now seek to memorialize their respective commitments contained in Measure DR-1, as follows:

1. For the term of the DBHCP, which is currently set to terminate on ____________, the Districts shall coordinate their respective stock water diversions so as to ensure compliance with the requirements contained in Measure DR-1. In the event the Districts cannot reach agreement as to which District will divert a particular amount of stock water during a particular period whereby such diversions would otherwise be in violation of Measure DR-1, the priority dates of the District water rights will be controlling.

2. General Provisions.

2.1. Binding Effect. This Agreement is binding on and inures to the benefit of the Districts and their respective heirs, personal representatives, successors, and assigns.

2.2 Assignment. Neither this Agreement nor any of the rights, interests, or obligations under this Agreement may be assigned by any District without the prior written consent of the other Districts, which consent will not be unreasonably withheld.

2.3 No Third-Party Beneficiaries. Nothing in this Agreement, express or implied, is intended or may be construed to confer on any person, other than the parties to this Agreement, any right, remedy, or claim under or with respect to this Agreement.

2.4 Amendments. This Agreement may be amended only by an instrument in writing executed by all the Districts, which writing must refer to this Agreement.

2.5 Counterparts. This Agreement may be executed in counterparts, each of which will be considered an original and all of which together will constitute one and the same agreement.

2.6 Further Assurances. Each District agrees to execute and deliver such other documents and to do and perform such other acts and things as any other District may reasonably request to carry out the intent and accomplish the purposes of this Agreement.

2.7 Injunctive and Other Equitable Relief. The Districts agree that the remedy at law for any breach or threatened breach by a District may, by its nature, be inadequate, and that in addition to damages, the other District or Districts will be entitled to a restraining order, temporary and permanent injunctive relief, specific performance, and other appropriate equitable relief, without showing or proving that any monetary damage has been sustained.

2.8 Entire Agreement. This Agreement constitutes the entire agreement and understanding of the Districts with respect to the subject matter of this Agreement and supersedes all prior understandings and agreements, whether written or oral, between the Districts with respect to such subject matter.

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THIS MOU is effective as of the date set forth above.

ARNOLD IRRIGATION DISTRICT

By: ___________________________________ Date: ________________

Colin Wills, Manager

CENTRAL OREGON IRRIGATION DISTRICT

By: ___________________________________ Date: ________________

Craig Horrell, Manager

SWALLEY IRRIGATION DISTRICT

By: __________________________________ Date: ________________

Jer Camarata, Manager

This agreement will be signed by the parties and provided to the Services upon execution and issuance of the incidental take permits. The signed copy will be kept on file with the U.S. Fish and Wildlife Service.

FINAL

DESCHUTES BASIN HABITAT CONSERVATION PLAN

Appendix C – TSID Diversion Screen Maintenance Plan

OPERATION AND MAINTENANCE PLAN
for
Three Sisters Irrigation District
Pipeline, Fish Screen, Bypass Pipes and Irrigation Dam

4/21/2010

The Three Sisters Irrigation District (TSID) diverts water from Whychus Creek with a concrete dam and a network of canals, ditches, and pipes across National Forest System Lands (NFS). In a 1965 letter from the Office of General Council (OGC), a right of way was recognized for the dam and ditches that predates the acquistion of the land by the Forest Service.

This Operation and Maintenance Plan (O&M Plan) and attachments describes how the TSID facilities within the right of way will be managed. The Three Sisters Irrigation District (TSID) agrees to operate and maintain the facilities and use the occupied NFS lands in accordance with the following stipulations:

1. Inspection and annual or routine maintenance.

2. Access will be according to the approved access plan, which will include approved equipment for maintenance. Current roads are adequate for access to the pipeline and screen (see facilities and access map).

3. Any actions not considered routine maintenance or repairs would require coordination with the Forest Service.

4. The TSID is responsible for prevention and control of soil erosion on land covered by the right of way and the land adjacent thereto resulting from operations and maintenance of use.

5. Monitor stability and correct any unwanted erosion/deposition of the stream channel where it interfaces with the canal pipeline, fish screen, fish and sediment bypass pipes, and the TSID dam. Examples may include: 1) unwanted bank scour at the fish/sediment bypass pipe outlet, 2) streambed scour caused by the TSID dam resulting in a fish passge barrier, or 3) excessive sedimentation at the gate enterances. Stream bed downcutting originating down stream of the influence of the dam will be maintaned by the Forest Service with help from the TSID. All corrective measures to reduce erosion and stream instability around these facilities will be coordinated with the Forest Service and other appropriate agencies prior to taking action.

6. Revegetate or otherwise stabilize all ground where the soil has been exposed along the canal piping project and be responsible for prevention (prewashing equipment), control of, and spread of noxious weeds, as identified by the Forest Service and the local county weed list. Revegetation will be consistent with the approved Restoration Plan for TSID Canal Piping Project.

7. The TSID will notify the Forest Service and ODFW of annual turnoff of water in the fish screen and sediment bay. The TSID will be responsible to rescue any fish stranded and transfer them unharmed to Whychus Creek immediately downstream of the dam.

8. The TSID will notify the Forest Service when cleanout of the sediment bay is needed and will coordinate with the Forest Service and other appropriate agencies where and when the sediment will be transferred back to Whychus Creek.

9. Protection of any items of archaeological or historic value: including but not limited to historic or prehistoric artifacts, structures, monuments, human remains and funerary objects (grave goods) when such articles are discovered, the TSID shall immediately cease all activities which may disturb such items and notify the Forest Service. The TSID shall not resume activities until written approval is given by the authorized officer. Failure to comply with this stipulation may result in civil or criminal penalties under the Archaeological Resources Protection Act of 1979.

10. Visually screen structures from the Forest Road 16, by maintaining vegetation, so that they are not easily seen by people traveling the road. Coordinate any new structure design with the Forest Service to meet the visual screening objectives along the Forest Road 16.

11. This O&M Plan will be reviewed annually by the TSID and may be amended by mutual agreement when signed and dated by the TSID and the District Ranger.

[signature] 4/26/2010

Three Sisters Irrigation District Representative — Date

[signature] 4-26-2010

District Ranger — Date