Fish Passage Feasibility Assessment
for Bowman Dam Hydroelectric Project
(FERC No. P-14791)

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1 INTRODUCTION

1.1 Background

Ochoco Irrigation District (OID) and the City of Prineville (City) are proposing to add a hydropower unit onto the U.S. Bureau of Reclamation’s (USBR) existing Arthur R. Bowman Dam (Bowman Dam) on the Crooked River. OID holds a Preliminary Permit for the Bowman Dam Hydropower Project (Hydropower Project) from the Federal Energy Regulatory Commission (FERC No. 14791) and has filed a Pre-Application Document (PAD) with the FERC which initiated agency consultation on the Hydropower Project’s effects. Concurrent with the preparation of a License Application, OID and the City are pursuing a waiver to Oregon Department of Fish and Wildlife (ODFW) requirement for fish passage at the dam (ORS 509.580 through 509.910). As part of that waiver application and consultation, ODFW staff have requested a feasibility-level fish passage assessment study at Bowman Dam similar in scope and detail to the 2014 Study 14-2: Evaluation of Fish Passage Options for Ochoco Dam, completed as part of the Deschutes Basin Habitat Conservation Plan for the Deschutes Basin Board of Control and the City of Prineville, Oregon (R2 and Biota 2014). ODFW’s review comments on the PAD (personal communication with Ted Wise, Oregon Department of Fish and Wildlife, East Region Hydropower Coordinator, June 3, 2019) requested that:

“The study be designed to examine options to meet the stated goal of ‘utilizing habitat above Bowman Dam to support reintroduced populations of steelhead trout and spring Chinook salmon.’ The evaluation of installation and operation of fish passage facilities at Bowman Dam is necessary as part of OID’s proposed Bowman dam hydroelectric Project. This study would identify the various options available for providing fish passage at Bowman Dam, including evaluating at a preliminary level the technical, financial, biological, and operational implications of each option. Engineering plans should be developed to safely accommodate fish passage both upstream and downstream at variable discharge flows and reservoir levels. Criteria used in designing passage facilities should be in compliance with specifications outlined by the National Marine Fisheries Service for streams inhabited by anadromous fish.”

1.2 Project Setting and Fish Passage Considerations

Bowman Dam was developed to supply irrigation water and for flood control by the USBR, and is located about 15 miles south of Prineville, Oregon along State Highway 27 on the Crooked River, a tributary to the Deschutes River in Crook County. The dam is an earth fill structure,
with a hydraulic height of 182 feet and crest length of about 800 feet. Flow passes through the
dam via an outlet works with control gates and an ungated surface spillway. The outlet works
has a low-level intake with a hydraulic capacity of 3,300 cubic feet per second (cfs). The
spillway is located at the right abutment (looking downstream) of the dam and has a capacity of
about 8,120 cfs. Figure 1-1 provides an overview photograph of Bowman Dam. Addition detail
on the dam and its current and planned operation with the proposed Hydropower Project is
provided in Section 4.2.

![Figure 1-1](image)

**Figure 1-1. Photograph looking upstream at Bowman Dam and Prineville Reservoir.**

Anadromous fish access to the Crooked River downstream of Bowman Dam had been blocked
since 1958 by the construction of the Pelton Round Butte Hydroelectric Project dams (Pelton
Round Butte Project), as shown on Figure 1-2, which is owned jointly by Portland General
Electric (PGE) and the Confederated Tribes of the Warm Springs Reservation of Oregon
(CTWSRO, or The Tribes). Therefore, no anadromous fish passage facilities were required at
Bowman Dam when it was completed in 1961. Subsequently, Opal Springs Dam was completed
in 1985 on the Crooked River, located downstream of Bowman Dam and upstream of the
Pelton Round Butte Project, also without anadromous fish passage facilities. Anadromous fish
restoration on the Deschutes and Crooked Rivers began during the recent relicensing of the
Pelton Round Butte Project, and anadromous fish passage facilities were constructed and
functional there beginning in 2011. Similarly, anadromous fish passage facilities were recently
completed and operational at Opal Springs Dam last year (fall of 2019).
Currently there is no existing or planned program to reintroduce anadromous fish above Bowman Dam. However, the ongoing efforts to re-establish steelhead trout and spring Chinook Salmon upstream of the Pelton Round Butte Project and Opal Springs Dam, if successful, will give both species access to the Crooked River potentially upstream as far as Bowman Dam.
1.3 Study Scope of Work

This study provides a feasibility assessment to provide fish passage for Bowman Dam that would be compatible with ongoing irrigation and flood control operations as well as the proposed Hydropower Project and support the fish passage waiver application to ODFW noted in Section 1.1. R2 Resource Consultants, Inc. (R2) prepared this study under contract to OID, in coordination with Black Rock Consulting, Inc. (Black Rock), who is providing engineering support to the preparation of the License Application and fish passage waiver; and Mount Hood Environmental (MHE) who is providing biological study support for the Hydropower Project.

This study identifies various options considered feasible for providing upstream and downstream fish passage at Bowman Dam and evaluates them at a preliminary level including the technical, financial, biological, and operational implications of each option to inform the fish passage waiver application. To meet the fish passage waiver application conditions, the study will assess options for volitional passage along with non-volitional passage methods. Fish passage alternatives were developed to function within established irrigation operations (seasonal storage and release of water) and the congressionally mandated flood control rule curve for Bowman Dam, in conjunction with the planned hydropower plant as described in the PAD (OID 2018). For each alternative, the study provides a planning level opinion of probable capital and operational costs. Development of detailed cost estimates for the identified fish passage alternatives was not part of the scope; however, a likely range of costs based on experience and comparisons with similar scale fish passage facilities in the region is provided to allow for comparison of the alternatives. Additional detailed examination and engineering development would be required to further advance any of the identified options.
2 METHODS

2.1 Review of Existing Biological Information

Estimates of any biological potential of the upper basin was not part of this scope, rather, the intent was to focus on fish passage measures that would be successful for the anadromous species anticipated to have access to the watershed above Bowman Dam. Necessary biological data for the study was provided by the PAD (OID 2018), consultation with MHE and OID representatives, our other experience in the basin, and review of the consultation documents to date including a draft Assessment of Native Migratory Fish Production Report (Mount Hood Environmental 2019), and ODFW’s response letter to the above draft report (ODFW 2019). Additional information on biological information is provided in Section 3.

2.2 Review of Site and Engineering Information

Technical considerations utilized for this study were based on:

- A site visit and examination of Bowman Dam and its setting in the Crooked River watershed conducted with OID and Black Rock representatives in December 2019,
- Information provided by OID and their consultant team on the dam’s operation and planned hydroplant system operation, and engineering drawings of the dam,
- Review of information provided in the PAD (OID 2018), including drawings provided as Exhibits F and G, and consultation with Black Rock’s project engineer,
- Consultation with the USBR on project flows and reservoir elevations, and
- Professional experience with similar fish passage systems in the region, including the 2014 study at Ochoco Dam (R2 and Biota 2014).
3 DESIGN CRITERIA

3.1 Biological Criteria

3.1.1 Anadromous Species for Passage Consideration

Migratory fish species for passage considerations in this study will focus on steelhead trout (*Onchorhynchus mykiss*), and spring Chinook Salmon (*O. tshawytscha*) as requested by ODFW. Mountain Whitefish (*Prosopium williamsoni*) are present, and resident Redband Trout (*O. mykiss gairdneri*) populations exist upstream and downstream of Bowman Dam, along with other resident and planted species but these species are not the focus of this passage feasibility assessment.

3.2 Fish Run Periodicity and Planning Level Run Sizes

The following information was summarized to assist with the analysis of the potential fish passage facilities.

3.2.1 Adult Upstream Migration Timing

An understanding of the potential run timing for upstream migrants at Bowman Dam is necessary to help assess passage facility requirements. As noted earlier, with the addition of fish passage facilities at the Pelton Round Butte Project in 2011, and the new passage facilities at Opal Springs Dam in 2019, steelhead trout and Chinook Salmon may now have access up to Bowman Dam. Prior to these new passage facilities located downstream, anadromous fish have not had access to the Crooked River at Bowman Dam since the late 1950s.

Similar to the process used for the Ochoco Dam Passage Feasibility Assessment (R2 and Biota 2014), the best available data to provide an initial estimate of returning adult abundance and migration timing can be found at the Pelton Reregulating Dam, located over 70 miles downstream of Pelton Dam. PGE and the Tribes maintain a website with the Pelton Round Butte Project fish passage information that is kept up to date and has a wealth of information regarding that project and the fish passage species, run timing, and fish counts. Periodicity for steelhead trout and Chinook Salmon observed at Pelton Round Butte is presented Figure 3-1, which provides some initial guidance of when fish may arrive at Bowman Dam for our initial planning level assessment.
Based on Figure 3-1, continuous upstream fish passage activity is a potential all year at Bowman Dam for planning purposes, with peaks in October-December for summer steelhead. In addition to the above figure, a review of the fish run data from PGE’s website also indicates the summer steelhead run peaks occur in January and February (Appendix A). Spring Chinook runs are shown peak in June-July in Figure 3-1, which was also confirmed with the review of fish run data (Appendix A). This study will not focus on the potential for Fall Chinook Salmon; however, based on the migration windows shown in Figure 3-1, the facilities identified would be capable of passing the late run as well. ODFW also provided a life history periodicity chart in their comments on the PAD (personal communication with Ted Wise, Oregon Department of Fish and Wildlife, East Region Hydropower Coordinator, June 3, 2019), which we have included in our review of data in Appendix A.

To summarize, there is not a large amount of data available because of the overall low numbers of fish returns to date. However, there is sufficient data to provide a conservative upstream migration window for use in this feasibility assessment study. Table 3-1 provides a conservative summary of anticipated adult run timing that we will use as design criteria for the feasibility assessment.
Table 3-1. Assumed adult upstream migration timing for summer steelhead and spring Chinook at Bowman Dam.

<table>
<thead>
<tr>
<th>Species</th>
<th>Month</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>J</td>
</tr>
<tr>
<td>Summer Steelhead</td>
<td>+</td>
</tr>
<tr>
<td>Spring Chinook</td>
<td>-</td>
</tr>
</tbody>
</table>

- denotes months where fish are running
+ denotes months with peak runs

3.2.2 Adult Upstream Planning Level Run Sizes

Quantitative estimates of potential fish run sizes at Bowman Dam are outside the scope of this study, but a qualitative assessment was helpful to assist with the facility assessment exercise. The PGE website noted above provides information on the number of fish passed upstream at the Pelton Round Butte Project. Fish passing the Pelton Round Butte project will have the choice on which basin they would enter upstream of Pelton Dam: the Metolius River, Whychus Creek, the Deschutes River, or the Crooked River / Ochoco Creek. As such, we would expect numbers of adults arriving at Bowman Dam to be less than the total fish counts at the Pelton Round Butte Project.

We also do not have a strong understanding of how successful any reintroduction programs may be, and how fish numbers observed since 2011 may trend in the future. What is important for fish ladder or collection-transport facility design is a reasonable estimate of peak daily numbers of fish expected at the dam. To help develop an initial planning level of peak numbers of fish per day, the monthly average and annual average fish counts at the Pelton Round Butte Project (Table 3-2) were used as a proxy for Bowman Dam passage estimates (Appendix A). Note that the data indicates relatively low and manageable potential numbers of fish per day for upstream passage facilities, so these numbers will not likely control the design of any facilities.
Table 3-2. Summary of peak adult daily run sizes for fish passage at Pelton Round Butte Dam.

<table>
<thead>
<tr>
<th>Species</th>
<th>Base Estimated Peak Daily Run Size</th>
<th>High Peak Daily Run Size</th>
<th>Month of Peak Run</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer Steelhead</td>
<td>33</td>
<td>100</td>
<td>February</td>
</tr>
<tr>
<td>Spring Chinook</td>
<td>60</td>
<td>200</td>
<td>June</td>
</tr>
</tbody>
</table>

### 3.2.3 Smolt Downstream Migration Timing

Estimated run timing for outmigrants is summarized in Table 3-3 for summer steelhead trout and spring Chinook Salmon, based on information used in 2014 for the Ochoco Dam fish passage assessment (R2 and Biota 2014). We understand from discussions with OID and their consulting team that this information provides a reasonable planning level assumption for expected fish behavior and outmigration at Prineville Reservoir. As noted in the 2014 Ochoco study:

“Summer steelhead smolt sizes during the outmigration period are estimated at 120-180 mm fork length (Quesada et al. 2012). Steelhead fry (0+-age) may also move out of the upper watershed in the fall if conditions are not good upstream. Similarly, spring Chinook smolt sizes are estimated at 80-130 mm fork length (Quesada et al. 2012). Peak smolt outmigration would likely occur in April and May, with collection facilities operating from February through June of each season. If there was a desire to collect summer steelhead fry, a collection system would need to also operate in October through December.”

To assist with the facility assessment, this information is summarized in Table 3-3. As noted for the upstream migration summary, the outmigration periods shown in Table 3-3 also concur with and are more conservative than the life history periodicity chart provided by ODFW (see Appendix A).
Table 3-3. Assumed juvenile outmigration timing for summer steelhead and spring Chinook at Bowman Dam.

<table>
<thead>
<tr>
<th>Species</th>
<th>Month</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>J</td>
</tr>
<tr>
<td>Summer Steelhead</td>
<td></td>
</tr>
<tr>
<td>Spring Chinook</td>
<td>-</td>
</tr>
</tbody>
</table>

Legend: - denotes months where fish are running  
+ denotes months with peak runs  
F denotes possible fry outmigration (0+ age) if conditions are not good upstream  

Source: R2 and Biota 2014, Table 3-5.

3.2.4 Juvenile Downstream Passage Preliminary Run Size Estimates to Assess Passage Facilities

Similar to the run timing, estimating smolt production capacities or peak daily run sizes in the upper Crooked River watershed and Prineville Reservoir was beyond the scope of this document. Nevertheless, cursory daily peak run estimates are identified to assist with the engineering assessment of fish passage facility analysis and planning. Based on discussions with OID and their consultants, we feel the planning level run size estimates would be similar to the Ochoco Creek planning level numbers shown in Table 3-4, so quote the following from the 2014 Ochoco Dam fish passage assessment study (R2 and Biota 2014):

“Steelhead trout are anticipated to be more abundant than spring Chinook salmon in the Ochoco basin, and steelhead abundance and timing may be the driving factor for sizing and costing the passage facilities. Since there are no fish in the basin above Ochoco Dam at this time, the anticipated smolt production and adult returns for steelhead trout were based on surface areas of available habitats during dry and wet years as discussed in Section 3.1.2.1 Upper Ochoco Creek Watershed Habitat Conditions-Quantity, and a generic smolt production factor arbitrarily modified for less than optimal habitat conditions. The estimated peak numbers of smolts per day, and total numbers for the various downstream collection points anticipated for this analysis, are provided in Table (table number updated for this study). These numbers are approximate, but they are sufficient to assist with defining the potential needs for downstream smolt collection and passage facilities.”
Table 3-4. Estimated numbers of juvenile fish to be used for initial assessment of fish passage facilities at Bowman Dam (total numbers of fish). Based on Table 4-8 in the 2014 Ochoco Dam Fish Passage Assessment Study.

<table>
<thead>
<tr>
<th>Location</th>
<th>Dry Year</th>
<th>Wet Year</th>
<th>Peak Monthly</th>
<th>Peak Daily</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Reservoir Collection assumed for Prineville Reservoir.</td>
<td>37,100</td>
<td>67,500</td>
<td>33,750</td>
<td>1,125</td>
</tr>
</tbody>
</table>

For planning purposes, downstream passage of 1,125 smolts is not a large number and can be easily managed, so these numbers will not control the design of passage facilities.

### 3.3 Fish Passage Criteria and Laws

A detailed listing of fish passage criteria and guidelines is outside the scope of this document. However, relevant criteria will be noted during the description of alternatives based on R2’s experience with the planning and design of similar facilities. The following two sections provide the relevant criteria references for future use.

#### 3.3.1 Fish Passage Laws

Some of the specific criteria for fish passage facilities are provided in codified form in the Oregon State laws. Oregon laws regarding fish passage are found in:

- ORS 509.580 through 910, and in
- Oregon Administrative Rules (OARs), Oregon Department of Fish and Wildlife, Division 412 Fish Passage.

#### 3.3.2 Fish Passage Criteria and Guidelines

Established criteria and guidelines also exist for the design of fish passage facilities. The OAR, Division 412 contains relevant State of Oregon criteria. Relevant Federal criteria and fish passage design guidelines are found at:

- Fish Protection at Water Diversions (USBR 2006).

Note the NMFS 2011 criteria will be updated in the near future. R2 personnel have reviewed and commented on the draft update document, and no significant changes are expected that would change the analysis presented below.
Specific criteria examples relevant to this study include the following references to the NMFS (2011) criteria and guideline document:

- Truck and Hopper Holding Volume: 0.15 cu ft/lb of fish (NMFS 2011, Section 6.7.2.1).
- Holding Pond Volume: 0.25 cu ft/lb of fish, based on water temperature less than 50° F, and dissolved oxygen between 6 and 7 parts per million (NMFS 2011, Section 6.5.1.2).
- Flow for short term holding: 0.67 gpm per adult fish (NMFS 2011, Section 6.5.1.3). However, this criterion is based on Senn's Compendium (Senn et al. 1984), which is a bit more specific relative to fish size. We will use 0.067 gpm/pound of fish, and assume a spring Chinook average weight is 20 lbs, for a total of 1.34 gpm/fish for planning.

Fish passage design is typically very site specific, and these criteria are intended to help owners and designers provide facilities that will function well and meet the project goals. There are typically some negotiations related to project specific details for fish passage facilities, to meet specific project needs.

3.3.3 Fish Passage Design Flows

Per NMFS criteria (NMFS 2011), typical fish passage design flows provide for fish passage system operation between the 95 percent and 5 percent exceedance flows (NMFS 2011) during the period of migration. In regulated systems, these flows typically are selected as the low and high normal operating flows from the regulated system. Additionally, facilities are designed to avoid any significant flood damage from the design flood level (typically selected by the owner and the regulatory body, such as the 100-year flood).

Project specific design flow corresponding with the anticipated run timing reported above are provided in Section 4.2.4.
4 FACILITY INFORMATION AND RELEVANT FISH PASSAGE DATA

4.1 Crooked River Basin and Associated Facilities

To help understand the Crooked River basin and developed irrigation system of storage dams and pump stations, information developed by the OID and project partners in their Draft Deschutes Basin Habitat Conservation Plan (DBHCP) (Arnold Irrigation District et al. 2019) is useful to reference and review. The DBHCP is intended to minimize and mitigate the effects of the proposed incidental take on the covered species within the Deschutes Basin (including the Crooked River Basin), and the Draft was prepared in cooperation with a multi-stakeholder Working Group representing the U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), U.S. Bureau of Reclamation (USBR), U.S. Bureau of Land Management (BLM), Oregon Department of Fish and Wildlife (ODFW), Oregon Department of Environmental Quality (ODEQ), Oregon Water Resources Department (OWRD), the Confederated Tribes of the Warm Springs, Crook County, and several non-governmental entities.

The Ochoco Dam fish passage assessment study (R2 and Biota 2014) was prepared to support development of the DBHCP. Additional information on Bowman dam and the overall project is also provided in the DBHCP Chapter 3 – Scope of the HCP; however, Bowman Dam is not included as a covered facility in the DBHCP. That information is not repeated in this study, but we have utilized relevant information below for reference and to facilitate a good understanding of the project setting.

Figure 4-1 (taken from the Draft DBHCP) provides an overview of the covered lands and an overview of map of the Deschutes Basin and the irrigation districts covered by the Draft DBHCP.
Figure 4-1. Map of the Deschutes Basin showing irrigation districts covered by the Deschutes Basin HCP (Source: Arnold Irrigation District et al. 2019).
4.1.1 OID Overview

Ochoco Irrigation District provides water to approximately 850 patrons on 20,062 acres mostly north and east of the Crooked River in Crook County. Figure 4-2 is an overview map of the OID, which operates Bowman Dam and Prineville Reservoir under contract with the USBR, and both owns and operates Ochoco Dam and Reservoir.

Figure 4-2. Overview map of the Ochoco Irrigation District and Crooked River Project (Source: Arnold Irrigation District et al. 2019)
The OID conveyance system is comprised of four main canals (Crooked River Diversion Canal, Crooked River Distribution Canal, Ochoco Main Canal, and Ryegrass Canal) and roughly 99 miles of smaller canals and associated laterals illustrated in Figure 4-3. Water is diverted from the Crooked River at the Crooked River Diversion, and 34 downstream pumps are operated by individual OID patrons. Water is diverted from Ochoco Creek at Ochoco Dam, downstream of which are three small diversions operated by OID, two infiltration galleries operated by OID, and 33 pumps operated by individual patrons. OID also diverts water from multiple locations on Johnson Creek, Dry Creek, McKay Creek, and Lytle Creek. Some of the diversions and portions of the canal systems are Federally owned, with operation and maintenance transferred to OID. The remaining structures are owned and operated by OID.
Figure 4-3. Detail map of the Ochoco Irrigation District (Source: Arnold Irrigation District et al. 2019, Figure 3-8).
4.2 Bowman Dam Description

4.2.1 Existing Dam and Reservoir

This section provides a description of Bowman Dam in its existing configuration, compiled from information in the PAD (OID 2018) and from the USBR project web site (https://www.usbr.gov/projects/index.php?id=45). Figure 1-1 provides an overview photograph of the dam and reservoir, and Figures 4-4 through 4-6 provide aerial views of the dam and vicinity with primary features labeled.

Figure 4-4. Aerial view of Bowman Dam and Prineville Reservoir showing length of reservoir. Yellow line is 7-miles long for reference. (Image Source: Google Earth Pro 2019)
Figure 4-5. Aerial view of Bowman Dam and Prineville Reservoir showing boat launch (Source: Google Earth Pro 2019).

Bowman dam is a zoned embankment (earth-fill) structure, with a concrete parapet wall added in 2011 along the upstream side of its crest for dam safety and protection from overtopping due to the Probable Maximum Flood (PMF). The top of the parapet wall is at elevation of 3,270 ft MSL. The road crest is at EL 3,264 ft MSL, and the dam has a hydraulic height of 182 ft at normal operating depth. The maximum structural height of the dam is 240 feet. The dam crest is 35 feet wide and nearly 800 feet long, with Oregon State Highway 27 passing along its crest. The Dam impounds the Crooked River and releases water for the purpose of irrigation and environmental flow benefits, and flood control. Operationally, water is generally impounded during winter storage months and discharged during irrigation flow months from April to October. Reservoir operation was recently modified by the Crooked River Collaborative Water Security and Jobs Act of 2014 (Crooked River Act), which was signed into law in December 2014. Among other things, the Crooked River Act authorized the use of a portion of the storage capacity in Prineville Reservoir to managed flows in the lower Crooked River for fish and wildlife. Additional information on project flows is provided in Section 4.2.3.
There are two flow routes through the dam:

1. An outlet works is supplied via a low-level intake (invert elevation 3,112 ft) located at the upstream toe of the dam on the north side of the original river channel. The intake is a 20-foot-high hexagonal reinforced concrete structure protected by a trashrack, and sits on top of a 9-foot-diameter, 15-foot-high vertical shaft with a 90-degree elbow that transitions to an 11-foot-diameter circular tunnel (invert elevation 3,080 ft) leading to the gate chamber. The intake is a hexagonal structure with 6 trash racks that are approximately 9.5 feet wide by 17 feet high. The total trashrack area is approximately 970 sf. A pair of 4-foot-wide by 6-foot high control gates, in series with a pair of emergency closure gates, are operated from the surface and lead to an 11-foot
modified horseshoe tunnel downstream from the gate chamber that discharges into a stilling basin that is shared with the spillway. The outlet works has a hydraulic capacity of 3,300 cfs at normal water surface elevation of 3,234.8 ft, which is the spillway crest elevation.

2. A concrete spillway located at the right abutment (looking downstream) of the dam. Flow is allowed into the spillway via an uncontrolled 20-foot-wide ogee crest with an invert elevation 3,234.8 ft, which is also the normal full pool elevation. The ogee leads to a concrete spillway chute and stilling basin shared with the outlet works. Capacity of the spillway is 8,120 cubic feet per second at maximum water surface elevation of 3,257.9 ft.

The total capacity of Prineville Reservoir when it was completed in 1961 was 154,690 acre-feet (active 152,800 acre-feet), and according to the USBR website a reservoir sedimentation survey completed in 1998 estimates the total capacity at 150,200 acre-feet (active 148,600 acre-feet).

Bowman Dam has no provisions for upstream fish passage. Downstream passage could occur over the ungated spillway when it is flowing, and is also possible through the intake and outlet works; however, there is no data on downstream fish passage survival.

Additional photographs of Bowman Dam are provided in Figures 4-7 through 4-11.

Figure 4-7. Photograph looking upstream at Bowman Dam spillway viewpoint access and parapet wall.
Figure 4-8. Photograph looking to the south across Bowman Dam crest. The 6-foot-high parapet wall is on the reservoir side of the crest, added in 2011 for PMF.

Figure 4-9. Photograph looking upstream at the dam, spillway chute, and outlet works discharge to the stilling basin.
Figure 4-10. Photograph from the top of the dam looking down the spillway chute.

Figure 4-11. Photograph from the south side of the dam looking downstream.
4.2.2 Proposed Hydropower Project

OID has applied to add a new hydropower project onto Bowman dam. This section summarizes information provided in the PAD (OID 2018) and provided by Black Rock to give the reader an understanding of the Hydropower Project’s physical features and operation to help identify and assess compatible fish passage systems. Quoted sections are taken directly from the PAD, with minor edits for brevity. The Hydropower Project would provide a new source of low impact hydroelectric power and allow the OID to generate renewable electricity at Bowman Dam for the term of their license.

The Hydropower Project is designed to utilize flows currently released from the dam and will be designed to operate on a run-of-release basis that meets the required minimum flow, irrigation, and reservoir operation releases. As noted in the PAD, “the project will not modify reservoir operations or minimum flow releases in any way.” Therefore, the existing flow and operational regimes described in Section 4.2.3 will still apply for assessment of fish passage facilities. A new powerhouse containing a 2-unit, 300 cfs capacity Francis turbine is proposed near the south side of the downstream end of the spillway chute as shown on Figure 4-12. Additional conceptual design drawings of the Hydropower Project are provided in Appendix B.

Figure 4-12. Partial view of proposed Hydropower Project Site Plan (Source: OID 2018, Exhibit F).
The Francis turbine will be connected to the modified outlet works of the dam via a new steel penstock leading to the gate house and routed through the existing outlet works tunnel. The gate house will be modified and reinforced to be pressure rated with a steel transition fitting that will transition from the rectangular gate shape to an approximate 10-ft. or 10.5 ft. steel pipe shape based on the preliminary design. The round pipe will convey all normal discharges up to 3,300 cfs to a new gate house located at the end of the tunnel just upstream of the energy dissipation pool, and normal flows will be limited to 3,000 cfs. Flows from the turbine will discharge back to the Crooked River at the existing stilling basin via a new concrete tailrace as shown in Figure 4-13.

![Figure 4-13](image)

**Figure 4-13.** View of proposed Hydropower Project powerhouse and tailrace (Source: OID 2018, Exhibit F).

The conceptual design description in the PAD notes that the

“...10-foot diameter tunnel pipe would bifurcate just above the proposed gatehouse to a 9-foot diameter steel penstock, and penstock will exit the 10-foot pipe..."
in a designed wye that would pass under the existing spillway toward the proposed powerhouse. The steel 9-foot diameter penstock would extend to the east of the proposed powerhouse where it would again bifurcate into two turbine steel supply pipes. One continuing to the powerhouse at 8-foot in diameter to the 2 MW turbine and the second continuing to the powerhouse at 5 ft. in diameter to the 1 MW turbine. The powerhouse would house one 2 MW and one 1 MW (subject to verification in design) horizontal Francis turbine and generator assemblies and all necessary appurtenances, controls, inlet valves to operate the facility and positively close the penstock as needed for operation and maintenance. The foundation and draft channel/tunnel system would be constructed of reinforced concrete. The finished floor elevations of the powerhouse structures would be set to exceed the water surface at maximum spillway discharge (to be verified in design). The turbine and draft channel system would be optimized to operate during the normal flow release range up to 3,000 cfs with a normal low flow of 80 cfs.”

The tailrace shown in Figure 4-13 would connect to the turbine discharge via

“...conventional rectangular concrete horizontal shafts conveying discharge water toward the Crooked River pool adjacent to (south of) the existing spillway energy dissipation channel. Concrete wing walls would be constructed from the powerhouse exit wall to the existing energy dissipation channel to the north and to the bank on the south. The floor and walls of the draft channel would be constructed to reinforced concrete approximately 25 ft. from the southwest wall of the powerhouse and then transition to rip-rap and then to existing channel bottom.”

Regarding operations, the PAD states that

“the powerhouse will include conventional controls for synchronization, major valve operations, and HMI screen(s) to monitor and implement plant operation (power output, hydraulic pumping unit status, wicket gat position(s), intake and discharge water surface elevations, bypass valve, etc.). Remote monitoring is also planned; however, plant re-start is planned to be performed at the plant only.”
Additionally,

“The project would be operated remotely via a SCADA control system. The control system would be programmed to run through a series of checks in both normal start-up and shut-down procedures, as well as emergency shutdown. In case of an emergency shutdown, the control system would divert the powerhouse flow to the spillway stilling basin insuring instream flow requirements are met at all times.”

Access to the Powerhouse will be provided by a new access road constructed on or near the original dam construction access road along the south side of the dam as shown in Figure 4-12. The road will be gated, and access to the Powerhouse will be limited to OID personnel and approved guests.

4.2.3 Bowman Dam System Operations, Flows, and Reservoir Elevation Data

4.2.3.1 General Overview of Operations

Prineville Reservoir is managed to meet the OID’s irrigation season, which begins in April and typically runs through mid-October. Flows in the Crooked River are primarily driven by snow melt in the spring. As noted in the PAD,

“Operations at Bowman Dam have changed the magnitude and timing of peak flows in the lower Crooked River. Before dam construction and operation, 66 percent of the average flow of the Crooked River occurred in the months of March, April, and May. Today, flows are typically 200-250 cfs during the summer irrigation season and 30-75 cfs during the winter storage season. Before the construction of Bowman Dam in 1961, average peak discharges typically ranged from 3,000-7,000 cfs. Since construction of the reservoir, flows have ranged from as low as 10 cfs during winter months, the minimum flow required by the project prior to 2014, to as high as 3,000 cfs. The goal of flood control operations at the dam is to limit the outflow from the reservoir so as not to exceed 3,000 cfs.”

As an initial reference and as documented in the PAD, Monthly flow exceedance curves at the Prineville gauge for the period of 1962 through 2006, following Bowman Dam construction are shown in Figure 4-14.
The reservoir generally fills in December to April, is relatively stable at or near full pool from April through June, and begins drawn down to supply irrigation flows beginning in July and continues to drop through November. The project operates using a dynamic forecast-based rule curve that dictates volume reserved in the reservoir as a function of inflow forecast volume. Overall, the OID utilizes a combination of in-channel reservoir storage and live flow to meet its irrigation needs. The amount of water diverted at any time is determined by the amount available (storage and live flow combined), the surface water rights to which the district delivers water, the operational constraints of the conveyance system, and patron demand.

There is a streamflow gauge approximately ¼ -mile downstream of Bowman Dam currently maintained by the Oregon Water Resources Department (OWRD). Flow records are reported via the USBR’s Hydromet system, and can be accessed via the USBR website at [https://www.usbr.gov/pn/hydromet/destea.html](https://www.usbr.gov/pn/hydromet/destea.html) and on the USGS NWIS website ([https://nwis.waterdata.usgs.gov/nwis](https://nwis.waterdata.usgs.gov/nwis)) as Gauge 14080500. Starting in Water Year 2015 (October 2014), reservoir operation changed as a result of the Crooked River Act. The Act made a portion of the uncontracted storage in Prineville Reservoir available for fish and wildlife in the lower Crooked River and directed USBR to consult with USFWS and NMFS on the use of that water. One objective of the Act was to increase the minimum flow below Bowman Dam from the previous 10 cfs. Determining the best use of the uncontracted water has been a process of
adaptive management; the most recent recommendation from USFWS and NOAA was to maintain a winter minimum flow of 50 cfs when uncontracted storage is available.

4.2.3.2 Exceedance Flow Summaries by Month, outflow immediately below Bowman Dam

For this fish passage assessment, the flow period of record from WY 2015 through 2020 will be most representative of current and future project operations and flows as this accounts for the new minimum flows started in WY 2015. Table 4-1 provides a summary of flows developed from this gauge for use in assessing fish passage facilities to illustrate the 95% low flow, 50% median flows, and 5% high fish passage design flows by month, and Figure 4-15 provides a summary plot of these data. For historical reference, Table 4-1 also provides a summary of the monthly exceedance flows for the period of record prior to dam construction, and between the dam construction and WY 2014.

Figure 4-15 was prepared illustrating the 95%, 50%, and 5% exceedance flows by month based on average daily flows from October 2014 through March 2020.

![Figure 4-15. Plot of exceedance flows by month, based on average daily flow data (source: USBR Hydromet Gauge Data).](image-url)
### Table 4-1.  Exceedance flow data by month in the Crooked River near Prineville (Gauge ID #PRVO).

<table>
<thead>
<tr>
<th>Monthly Exceedance</th>
<th>Period of Record</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crooked River near Prineville (PRVO) WY 1942-1962</td>
<td>Oct 1941-Sep 1962</td>
<td>930</td>
<td>2180</td>
<td>2330</td>
<td>3270</td>
<td>1555</td>
<td>662</td>
<td>147</td>
<td>89</td>
<td>88</td>
<td>106</td>
<td>199</td>
<td>710</td>
<td>1690</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Monthly 50% Exceedance</th>
<th>Period of Record</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Annual</th>
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</thead>
<tbody>
<tr>
<td>Crooked River near Prineville (PRVO) WY 1942-1962</td>
<td>Oct 1941-Sep 1962</td>
<td>140</td>
<td>335</td>
<td>591</td>
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<td>8</td>
<td>15</td>
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<td>79</td>
<td>108</td>
<td>95</td>
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<table>
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<tr>
<th>Monthly 95% Exceedance</th>
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<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crooked River near Prineville (PRVO) WY 1942-1962</td>
<td>Oct 1941-Sep 1962</td>
<td>41</td>
<td>55</td>
<td>88</td>
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<td>12.5</td>
<td>43</td>
<td>37</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Crooked River near Prineville (PRVO) WY 1963-2014</td>
<td>Oct 1962-Sep 2014</td>
<td>30</td>
<td>30</td>
<td>32</td>
<td>68</td>
<td>177</td>
<td>192</td>
<td>184</td>
<td>189</td>
<td>112</td>
<td>33</td>
<td>15.9</td>
<td>12.0</td>
<td>33.0</td>
</tr>
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4.2.3.3 Exceedance Flow Summaries by Month, Inflow to Prineville Reservoir

Flows into the reservoir are also gauged by USBR at Crooked River above Prineville Reservoir near Post, OR (ID # CRPO), which has a period of record from September 1993 to March 2020. To help understand the overall system, Table 4-2 provides a summary of flows developed from this gauge, and Figure 4-16 provides a summary plot of this data.

Figure 4-16 was prepared illustrating the 95%, 50%, and 5% exceedance flows by month based on average daily flows for the period of record (from September 1992) and from October 2014 through March 2020 so we have a similar data period for the inflow to compare with the new regulations on the outflow.
Table 4-2.  Exceedance flow data by month in the Crooked River inflow to Prineville Reservoir (Gauge ID #CRPO).

<table>
<thead>
<tr>
<th>Monthly 5% Exceedance</th>
<th>Period of Record</th>
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<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crooked River above Prineville (CRPO) POR</td>
<td>Sep 1993-Mar 2020</td>
<td>1043</td>
<td>1652</td>
<td>2422</td>
<td>2507</td>
<td>1173</td>
<td>519</td>
<td>63</td>
<td>16</td>
<td>19</td>
<td>72</td>
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<td>1343</td>
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<th>Mar</th>
<th>Apr</th>
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<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Annual</th>
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</thead>
<tbody>
<tr>
<td>Crooked River above Prineville (CRPO) POR</td>
<td>Sep 1993-Mar 2020</td>
<td>144</td>
<td>262</td>
<td>657</td>
<td>716</td>
<td>240</td>
<td>41</td>
<td>6.9</td>
<td>1.5</td>
<td>3.1</td>
<td>30</td>
<td>58</td>
<td>78</td>
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<tr>
<td>Crooked River above Prineville (CRPO) 2015-2020</td>
<td>Oct 2014-Mar 2020</td>
<td>140</td>
<td>287</td>
<td>415</td>
<td>740</td>
<td>119</td>
<td>23</td>
<td>3.1</td>
<td>0.9</td>
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<table>
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<th>Mar</th>
<th>Apr</th>
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<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crooked River above Prineville (CRPO) POR</td>
<td>Sep 1993-Mar 2020</td>
<td>54</td>
<td>80</td>
<td>172</td>
<td>176</td>
<td>32</td>
<td>4.1</td>
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<td>0.0</td>
<td>1.7</td>
<td>34</td>
<td>45</td>
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<tr>
<td>Crooked River above Prineville (CRPO) 2015-2020</td>
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<td>97</td>
<td>140</td>
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<td>26</td>
<td>2.0</td>
<td>0.0</td>
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Figure 4-16.  Plot of Exceedance flows by month for inflow to Prineville Reservoir, based on average daily flow data (Source: USBR Hydromet Gauge Data ID #CRPO).

4.2.3.4  Flood Flow Conditions below Bowman Dam

Flood flow conditions were also considered for the assessment of fish passage facilities, based on peak flow data available from the USGS (Gauge #14080500) for 1963 through 2010. Table
4-3 provides a summary of flood flows calculated using the U.S. Army Corps of Engineers Hydrologic Engineering Center’s Statistical Software Package (HEC-SSP). The current version of HEC-SSP performs flood flow frequency analysis based on Bulletin 17B (Interagency Advisory Committee on Water Data 1982) and Bulletin 17C (England et al. 2018), as well as other hydrologic statistical analysis. The results in Table 4-3 were produced using method 17C, the station skew, and the multiple Grubbs-Beck low outlier test.

Table 4-3. Flood flow design values for initial fish passage facility assessment (based on peak flow data for USGS #14080400, WY 1963-2010).

<table>
<thead>
<tr>
<th>Return Interval (years)</th>
<th>Flow (cfs)</th>
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<tbody>
<tr>
<td>500</td>
<td>4,635</td>
</tr>
<tr>
<td>200</td>
<td>4,470</td>
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<tr>
<td>100</td>
<td>4,307</td>
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<td>4,102</td>
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<td>3,741</td>
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<td>10</td>
<td>3,376</td>
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<td>5</td>
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<td>2</td>
<td>1,937</td>
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<tr>
<td>1.25</td>
<td>1,110</td>
</tr>
</tbody>
</table>

4.2.3.5 Reservoir Elevations and Annual Fluctuation

This operational scenario and the resulting pool fluctuations are important to understand in the review of applicable fish passage facilities. Key elevations of the reservoir include:

- Top of Parapet Wall EL 3,270 ft (prevents overtopping of dam under PMF conditions)
- Maximum pool elevation 3,257.9 ft, spillway capacity of 8,120 cfs.
- The normal full pool elevation is at the top of the spillway crest, EL 3,234.8 ft, which provides a total storage capacity of 152,800 ac-ft. The reservoir is managed to achieve the maximum storage available for irrigation water.
- Top of Inactive Conservation Pool EL 3,114 ft.
- Intake Invert, and Top of Dead Storage Pool EL 3,112 ft. This invert is the minimum pool elevation determined for dam safety requirements for the earth-filled dam.
Figure 4-17 provides an overview of monthly reservoir elevations, and Table 4-4 provides a summary of the pool elevations useful for the examination of fish passage facilities at the dam based on data from October 1, 1975 to January 31, 2020.

Figure 4-17. Monthly reservoir exceedance elevations (feet, MSL).

Source: (based on average daily data from Reclamation Pacific Northwest Region Hydromet system Data, 1975 through 2020).
Table 4-4 provides a summary of relevant dam feature and reservoir elevations for use with the fish passage assessment.

**Table 4-4. Reservoir pool annual exceedance and key facility elevations.**

<table>
<thead>
<tr>
<th>Reference Elevation</th>
<th>Elevation (feet MSL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMF Parapet Wall Crest Elevation</td>
<td>3,270.00</td>
</tr>
<tr>
<td>Dam Crest Elevation</td>
<td>3,264.00</td>
</tr>
<tr>
<td>Maximum Working WSE (from original design drawings)</td>
<td>3,257.90</td>
</tr>
<tr>
<td>Maximum Elevation of Record</td>
<td>3,242.70</td>
</tr>
<tr>
<td>5% Exceedance Elevation</td>
<td>3,235.27</td>
</tr>
<tr>
<td>Full Pool and Spillway Crest Elevation</td>
<td>3,234.80</td>
</tr>
<tr>
<td>25% Exceedance Elevation</td>
<td>3,228.11</td>
</tr>
<tr>
<td>Mean Elevation of Record</td>
<td>3,216.31</td>
</tr>
<tr>
<td>50% Exceedance Elevation</td>
<td>3,215.46</td>
</tr>
<tr>
<td>75% Exceedance Elevation</td>
<td>3,210.22</td>
</tr>
<tr>
<td>95% Exceedance Elevation</td>
<td>3,188.43</td>
</tr>
<tr>
<td>Minimum monthly 95% Exceedance Elevation (for low pool  design consideration)</td>
<td>3,177.40</td>
</tr>
<tr>
<td>Minimum Elevation of Record</td>
<td>3,162.38</td>
</tr>
<tr>
<td>Top of Dead Pool</td>
<td>3,112.00</td>
</tr>
</tbody>
</table>

**Source:** Based on average daily data from Reclamation Pacific Northwest Region Hydromet system Data; WY 1975 through 2019.
4.2.3.6 Storage Elevation Curve

Figure 4-18 provides a correlation between the reservoir level and the storage volume.

Figure 4-18. Monthly reservoir elevations in feet MSL.
4.2.3.7 Bowman Dam Discharge Curves

Figure 4-19 provides the original discharge curves for Bowman Dam that will be helpful to correlate design flows with tailwater elevations.

![Discharge Curves Diagram](image)

Figure 4-19. Discharge curves (Source: USBR As-Built Drawings dated 3/28/1962).

4.2.4 Fish Passage Design Information Summary

4.2.4.1 Upstream Passage Design Flows and Tailwater Elevations

Upstream fish passage facility locations will be considered in this study for the Crooked River immediately below Bowman Dam, with fish collected near the base of the dam and released in the Prineville Reservoir. Based on the fish run timing data provided in Section 3.2 and the hydrologic analysis, Table 4-5 provides a summary of the relevant fish passage design flows for facility assessment that will conservatively address a full year-round upstream fish passage capability. Because the Hydropower Project’s tailrace is located in the existing stilling basin, the tailwater curve provided in Figure 4-19 will provide a reasonable estimate of the expected tailwater elevation for a fishway entrance across the range of design flows. Table 4-5 also provides a column to summarize the approximate tailwater elevations associated with each design flow case.
Table 4-5. Suggested fish passage design flows and associated tailwater elevations for collection of upstream migrating fish at Bowman Dam tailrace.

<table>
<thead>
<tr>
<th>Flow Case</th>
<th>Flow (cfs)</th>
<th>Tailwater Elevation (feet MSL)</th>
<th>Basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme Low Fish Passage Design Flow</td>
<td>10-20</td>
<td>3,074.1</td>
<td>Observed minimum flows during drought years that may occur. Passage facilities could still operate.</td>
</tr>
<tr>
<td>Minimum 95% Exceedance flow during migration season</td>
<td>34</td>
<td>3,074.2</td>
<td>Data point for reference (Table 4-1).</td>
</tr>
<tr>
<td>Minimum regulated flow at tailrace</td>
<td>50</td>
<td>3,074.8</td>
<td>Flow released to meet current recommended operating regulations.</td>
</tr>
<tr>
<td>Approximate “normal” Fish Passage Design Flow for summer months</td>
<td>300</td>
<td>3,077.0</td>
<td>About 5% exceedance flow.</td>
</tr>
<tr>
<td>Maximum 5% Exceedance Flow during migration season</td>
<td>2,423</td>
<td>3,081.2</td>
<td>For reference only (Table 4-1).</td>
</tr>
<tr>
<td>100-year Flood Protection Flow</td>
<td>4,307</td>
<td>~3,083 (outside range of curve)</td>
<td>This is intended to be a maximum flow level to represent an approximate 100-yr design flood. From Table 4-3 (this number should be verified in the future).</td>
</tr>
</tbody>
</table>

A fishway entrance near the tailrace must be able to accommodate the minimum flow up to the maximum 5% exceedance flow during the period where fish are migrating, which is year-round. Table 4-6 provides a summary of necessary design elevations for fish collection facilities in the tailrace area.

Table 4-6. Summary upstream fish passage design flows and tailwater elevations at base of Bowman Dam.

<table>
<thead>
<tr>
<th>Flow Case</th>
<th>Flow (cfs)</th>
<th>Tailwater Elevation (feet MSL) / range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme Low Fish Passage Design Flow</td>
<td>10-20</td>
<td>EL 3,074.1</td>
</tr>
<tr>
<td>Maximum 5% Exceedance Flow during migration season</td>
<td>2,423</td>
<td>EL 3,081.2</td>
</tr>
<tr>
<td>Range of Design Elevations</td>
<td>N/A</td>
<td>7.1 feet</td>
</tr>
</tbody>
</table>
4.2.4.2 Upstream Passage Reservoir Design Elevations

Figure 4-17 and Table 4-4 provide key design elevations based on full pool and minimum expected pool elevations to be accommodated for fish passage. Typical fish passage design elevations range from the full pool elevation, to the 95 percent exceedance elevation during the period of fish passage. For Bowman Dam, it would be wise to consider designing to a high pool elevation of either the maximum elevation of record, or the maximum working water surface elevation. For the low pool design elevation, it would be reasonable to use the minimum monthly 95% exceedance elevation, as that would occur in October when adult fish could be migrating. Therefore, a pool range of 3,243 to 3,177 feet MSL will be noted for assessment of passage facilities, for a design pool fluctuation range of 66 feet as summarized in Table 4-7.

Table 4-7. Prineville Reservoir upstream fish passage design elevations.

<table>
<thead>
<tr>
<th>Reference Elevation</th>
<th>Design Elevation (feet MSL) or Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Elevation of Record (accommodate fish passage, above full pool elevation of 3234.8)</td>
<td>EL 3,243</td>
</tr>
<tr>
<td>Minimum monthly 95% Exceedance Elevation (for low pool design consideration)</td>
<td>EL 3,177</td>
</tr>
<tr>
<td>Range of Design Elevations</td>
<td>66 feet</td>
</tr>
</tbody>
</table>

4.2.4.3 Downstream Fish Passage Design Flows

Flow conditions at two locations must be considered for assessing downstream fish passage facilities. Release from the reservoir will be important to consider for downstream fish collection systems that must rely on attracting fish near the dam. Similarly, unregulated flows coming into the reservoir must be considered for any head-of-reservoir downstream fish collection systems. As summarized in Table 3-3, the downstream passage window for summer steelhead and spring Chinook is from February-June, with peak runs in April and May. There may also be the potential for a fry outmigration in October through December. This initial assessment is focused on the February through June period for smolt outmigration. Tables 4-8 and 4-9 summarize design flows for these two locations.
Table 4-8.  Downstream fish passage design flows at Prineville Reservoir release (to consider for fish collection near the dam).  See Table 4-1 and Figure 4-15.

<table>
<thead>
<tr>
<th>Flow Case</th>
<th>Flow (cfs)</th>
<th>Basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme Low Fish Passage Design Flow</td>
<td>10</td>
<td>Observed minimum flows during reservoir fill period.  Consider if flows drop below desired?</td>
</tr>
<tr>
<td>Minimum regulated outlet flow (at tailrace)</td>
<td>50</td>
<td>Flow released to meet current recommended operating regulations.</td>
</tr>
<tr>
<td>Approximate “normal” Fish Passage Design Flow for summer months</td>
<td>300</td>
<td>5% Exceedance Flow during summer months</td>
</tr>
<tr>
<td>Maximum 5% Exceedance Flow during migration season from February through June</td>
<td>2,423</td>
<td>5% flow in March</td>
</tr>
</tbody>
</table>

Table 4-9.  Downstream fish passage design flows at inlet to Prineville Reservoir release (to consider for fish collection at upstream end of reservoir). See Table 4-2 and Figure 4-16.

<table>
<thead>
<tr>
<th>Flow Case</th>
<th>Flow (cfs)</th>
<th>Basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme Low Fish Passage Design Flow</td>
<td>0</td>
<td>Inflows can dry up in summer months</td>
</tr>
<tr>
<td>Maximum 5% Exceedance Flow during migration season from February through June</td>
<td>2,500</td>
<td>5% exceedance in March</td>
</tr>
</tbody>
</table>

4.2.4.4  Downstream Passage Reservoir Design Elevations

Reservoir elevations for downstream fish passage systems are considered separate from the upstream passage criteria as the smolt outmigration period only runs from February through June each season, versus year-round for the upstream passage facilities. Key design elevations for that period observed on Figure 4-17 and Table 4-4 are summarized below in Table 4-10. Note the minimum pool elevation from February through June is about 13 feet higher than the full annual season.
Table 4-10. Prineville Reservoir downstream fish passage design elevations.

<table>
<thead>
<tr>
<th>Reference Elevation</th>
<th>Elevation (feet MSL) or Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Elevation during Outmigration Season of February-June (accommodate fish</td>
<td>El 3,243</td>
</tr>
<tr>
<td>passage, above full pool elevation of 3234.8)</td>
<td></td>
</tr>
<tr>
<td>Minimum monthly 95% Exceedance Elevation from February-June (for low pool design</td>
<td>El 3,190</td>
</tr>
<tr>
<td>consideration)</td>
<td></td>
</tr>
<tr>
<td>Range of Design Elevations for downstream passage facilities</td>
<td>53 feet</td>
</tr>
</tbody>
</table>
5  FISH PASSAGE OPTIONS

This section provides a summary of upstream and downstream fish passage options for Bowman Dam. The scope of this study is to identify feasible engineering alternatives based on the system understanding and the Design Team’s experience with similar fish passage facilities in the region, without doing a full feasibility level design development.

The alternatives are organized into upstream, and then downstream passage alternatives, and the following information is provided for each:

- A general description of the fish passage alternative, with photographs of similar facilities where appropriate to help communicate the alternative. The description includes its location, design constraints, any technical limitations, water needs and operational information.

- A description of the biological and technical issues associated with each alternative, such as potential benefits (rates of survival, relative contribution to recovery, etc.), and risks (mortality, inefficiencies of passage, etc.).

- An Opinion of Probable Construction Cost (OPCC), which provides an estimate of capital costs to construct the alternative in 2020 dollars. R2 maintains a database of recent and historical fish passage facility costs, and the numbers provided represent an analysis and professional judgment for the total construction cost of each facility including any need for modification to existing facilities. Additional costs would be required for planning, permitting, engineering, construction contract procurement, construction management services, and compliance monitoring. The resulting cost estimates are reasonable for planning and comparison of alternatives; however, they should not be used for program budgeting. The Engineering News Record (ENR) 20-City Construction Cost Index (CCI) as of March 2020 was 11,396.97. Adjustments to this cost can be made in the future by applying the ratio of the current ENR CCI to this number.

- An estimate of annual Operation and Maintenance (O&M) costs, including labor, electricity for pumping, hoists, fuel, etc. This is a high-level estimate for comparison of alternatives only based on regional experience.

- Long-term implications to OID operations. Short term implications during construction of any of these facilities are not addressed.

A summary table of the alternatives and the above information is provided in Section 6 for ease of review and comparison of alternatives.
5.1 Options for Upstream Passage

This section is organized beginning with upstream fish passage alternatives at Bowman Dam and moving downstream for other opportunities to collect fish and haul them to a release point above the dam. Alternatives are designated by UP #1, UP #2, etc. to differentiate the upstream passage alternatives from the downstream. The suite of alternatives considered for upstream passage includes:

- UP #1 – Volitional Passage at Bowman Dam, Fish Ladder
- UP #2 – Collection-and-Transport at Bowman Dam
- UP #3 – Collection-and-Transport at Bowman Dam with Whooshh System
- UP #4 – Collection-and-Transport from Downstream Location at Pelton Round Butte Project
- UP #5 – Collection-and-Transport from Downstream Location at Opal Springs Dam

5.1.1 UP #1 – Volitional Passage at Bowman Dam, Fish Ladder

5.1.1.1 Description and Technical Considerations

A fish ladder at Bowman Dam would provide for volitional passage from the tailrace of the dam to a release point in the reservoir near the dam. As noted in Table 3-1, the peak migration seasons are expected in October through February for summer steelhead, and in June-July for spring Chinook, but fish could be migrating year-round so the full fluctuation of both the tailwater and reservoir water levels would likely need to be accommodated. Other similar projects sometimes have an opportunity to design for more limited water surface fluctuations associated with a specific run timing and associated hydrologic parameters, so any final design conditions for the seasonality could be studied further. Based on year-round migration, a fish ladder would need to move fish from a range of tailwater elevations of EL 3,074.1 to EL 3,081.2 (per Table 4-6), to a fluctuating reservoir design elevation of EL 3,177 to 3,243 (per Table 4-7). These estimates represent a maximum design range of 170.6 feet, and a minimum range of about 103 feet to accommodate the reservoir elevation range of 66 feet (Table 4-7). This range is a feasible height for the target species but would be considered a high-head ladder relative to similar facilities in the Pacific Northwest, which have performance risks. The ladder exit structure would also need to accommodate the pool level fluctuation.

A schematic alignment of a volitional fish ladder is shown in Figure 5-1, illustrating the necessary features and approximate locations that would be feasible at Bowman Dam.
The fish ladder entrance is an important feature for effective upstream passage, fish must be able to find and navigate the entrance at all flow conditions. Key design issues with fish ladder entrance design include the entrance location, attraction flows, and entrance configuration. A fish ladder entrance at Bowman Dam would likely function very well and could be incorporated into the Hydropower Project tailrace and the existing stilling basin. The tailrace area is quite confined, so fish approaching the dam with a well-designed fishway entrance would have a high efficiency in finding the ladder with minimal to no delay across the full range of design flows. The entrance could be designed to accommodate up to the 5% exceedance flow design value of

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**Fish Ladder Entrance**

The fish ladder entrance is an important feature for effective upstream passage, fish must be able to find and navigate the entrance at all flow conditions. Key design issues with fish ladder entrance design include the entrance location, attraction flows, and entrance configuration. A fish ladder entrance at Bowman Dam would likely function very well and could be incorporated into the Hydropower Project tailrace and the existing stilling basin. The tailrace area is quite confined, so fish approaching the dam with a well-designed fishway entrance would have a high efficiency in finding the ladder with minimal to no delay across the full range of design flows. The entrance could be designed to accommodate up to the 5% exceedance flow design value of
2,423 cfs which would be coming from the outlet works or could even be designed to function to the full 3,000 outlet works capacity. The entrance design should also be optimized to operate in the range of approximately 20 to 300 cfs, which matches the Hydropower Project capacity, and represents the majority of the flows during the adult migration period as shown on Figure 4-15.

The PRVO gauge has an average annual flow of 335 cfs and attraction flow guidelines for facilities with mean annual stream flows less than 1,000 cfs suggest using all, or as much as possible of all the streamflow available for the fishway entrance (NMFS 2011). Additionally, NMFS guidelines recommend a minimum fishway entrance width of 4 feet, with an entrance depth of at least 6 feet, utilizing a submerged weir style entrance for these target species with a head drop over the submerged weir of 1.0 to 1.5 feet. This configuration is a proven entrance configuration that would be applicable to this site. Based on the hydraulics of this entrance, a maximum attraction flow required to meet the above entrance geometry would be 5 to 10% of the total flow, or 150 to 300 cfs. Because the outflow from the dam is a regulated system, we recommend the ladder entrance be designed to match the minimum flow of 20 cfs as determined in Section 4.2.4 to assure it can function when adult fish are migrating and accommodate the fish passage design flows (see Table 4-6). A fishway entrance with an adjustable width weir could accommodate this flow range, and for this site we would recommend a maximum capacity of 150 cfs based on the assumption that an efficient entrance layout can be designed to work with the Hydropower Project tailrace and the existing stilling basin.

A short entrance ladder that will accommodate the 7.1 foot fluctuation in the tailrace (EL 3074.1 to EL 3,081.2) per Table 4-6, would lead to a fixed entrance pool in the ladder.

**Fish Ladder**

A typical ladder style for this site and these target species would be a pool-and-weir with orifice ladder style, also called a “Half-Ice Harbor Ladder”, similar to the River Mill fish ladder. That fish ladder was completed on PGE’s River Mill hydro project in 2006, which has a total rise of 87 feet and a 1,000 foot length. The River Mill ladder has 1-foot drops at each weir, with an overflow/orifice arrangement requiring 20 cfs to operate. The ladder pool dimensions are 6 feet wide by 10 feet long and are 6 feet deep, and it is constructed of reinforced cast-in-place concrete. This configuration results in a maximum slope of 10 percent when the ladder is ascending uniformly. Figures 5-2 and 5-3 provide examples of the River Mill fish ladder, which is constructed into a rock abutment along that project’s right bank below the powerhouse.
For Bowman Dam, a decision would need to be made on overall ladder slope and pool heights, as some recent ladders are designed to accommodate resident species with a 0.75-foot step height, which typically results in smaller pool sizes and a maximum slope of about 8 percent. For this initial assessment, we will assume a 10 percent maximum slope ladder similar to the River Mill ladder as this slope is a proven design to pass summer steelhead and spring Chinook.
(at least for the 87-foot height at River Mill). The ladder could start at EL 3,081 from the entrance ladder and would need to provide passage to reservoir level 3,243 (Table 4-7), for total height of 162 feet. At a 10-percent slope, a minimum ladder length of 1,620 feet would be required, not counting turning pools.

The schematic alignment shown in Figure 5-1 is approximately 2,750 feet long, including the release section in the reservoir. The ladder would connect to the entrance section adjacent to the new powerhouse and is shown crossing to the left bank downstream of the toe of the dam to stay away from the base of the dam. The alignment could then traverse the base of the access road to gain elevation and follow the planned access road alignment up towards the reservoir. Because Bowman Dam is an earth-fill structure, for dam safety and to maintain the integrity of the dam, FERC will typically not allow any modifications to the earth-fill section. The only feasible options to cross the dam structure are to tunnel through the bedrock (assuming it is sound rock), or to bring the fish ladder up and over the dam. The alignment shown has the ladder tunneling through the rock and under the road, exiting at a multi-level release structure. A similar alignment could be examined along the right bank along the spillway; however, the release structure could cause fallback when spilling at that location. Consultations with the USBR and FERC would be required for further analysis, and additional geotechnical investigations would be recommended to help design a proper foundation for the ladder structure and assure dam safety.

**Ladder Exit**

There are two primary options to facilitate a fish ladder exit into the reservoir that could accommodate the 66-foot pool fluctuation. The first approach is shown in Figure 5-1, would provide a ladder that ascends the entire hydraulic height of the dam, cuts through the dam or its abutment at an elevation that will accommodate the low design pool elevation, and is fed with full gravity flow water. As the reservoir rises, adjustable weirs in the exit section would be necessary that would track the water surface and maintain maximum 1-foot drops over each weir. The disadvantage to this approach is that a 66-foot deep ladder section with 66 adjustable weirs would be necessary to track this water surface. The exit structure could be compartmentalized, and feed into six or seven 10-pool sections that could be constructed in a staggered layout along the left bank abutment slope. Each channel would be capable of accommodating a smaller water surface fluctuation range. For example, six channels could each be constructed to accommodate about 11 feet of pool fluctuation. This design would require a large structure with the complexity of multiple control gates.

An alternate exit structure strategy would be to construct a single ladder to the full pool height, which would operate by gravity at full pool, or at a designated elevation below full pool that
would accommodate adjustable exit gates (assume about 10-15 feet for discussion). Once the pool dropped below the lowest gravity operation level, the exit would be perched above the pool level. In this situation, a pumped water supply from the reservoir could be provided to supply water to the highest ladder exit level. Fish would then ascend the full 171 feet of height, and then be released into the reservoir via a fish release pipe that functions as a slide. This approach could allow the ladder to fully ascend the hydraulic height necessary and be constructed along the left bank without tunneling to the extent of a lower release structure. While it has structural advantages, it would have the disadvantage of requiring pumped flow at lower pool elevations.

**Water Supply**

As noted above, the ladder could be supplied by gravity flow from the reservoir, or with a pumped supply based on a selected low-reservoir elevation. Another concern with the height of the Bowman ladder is thermal warming in the fish ladder. While the tunneling option may help minimize thermal warming, this design would require a very high ladder so it would be conservative to plan for a one- to three-outlet supplemental temperature control water supply, fed from the deep reservoir. Additional colder water could be added at the half to quarter points of the ladder to help maintain desirable water temperatures. One disadvantage to this approach would be the potential for fish to delay, hold or turn around when they encounter the different water temperature.

Attraction flow water at the ladder entrance would be relatively easy at this site and could be fed from the powerhouse discharge up to some level, then be supplemented with flow from the outlet works, requiring no pumping.

### 5.1.1.2 Biological and Technical Considerations

The following biological pros and cons/risks were identified for the fish ladder alternative.

**Pros**

- Fish ladders provide a true volitional passage system when operating, and fish can decide to enter/ascend the ladder or can turn around at any stage if they have wandered into an area away from their natal spawning grounds. No human handling of fish is required for passage.
- A fish ladder alternative would provide for fish “self-sorting” in the tributaries upstream of the reservoir, as fish leaving the reservoir would be free to choose their final destination on their own volition.
- A fish ladder at this site should provide for good attraction based on the configuration of the tailrace and planned powerhouse.
- A fish ladder exit could be located well away from the spillway, to minimize any risk of fallback during spill.

**Cons/Risks**

- Some high-head fish ladders do not perform well. Given the length and height of the ladder there is a biological risk that fish may not ascend this height range or could delay in the ladder.
- Designing an outlet structure for a 66-foot reservoir fluctuation is a complex and costly effort. Either the 66-gate outlet structure or a combination gate/slide alternative are both complex systems, bordering on the range of being infeasible.
- The surface water temperature at the ladder exit in the reservoir may be higher than the temperature supplying the lower level turbine intake in the warmer summer and fall months that supplies the attraction pool at the ladder, so fish could delay at the thermal interface.
- Depending on temperature gradients and general fish behavior, there may be some delay for fish to migrate upstream through the 3.25-mile-long reservoir.
- Tunneling or the slide alternatives for the ladder exit would be very costly.

### 5.1.3 Opinion of Probable Construction Cost

A fish ladder alternative for Bowman Dam would be nearly double size and height to PGE’s River Mill ladder completed in 2007, which is 87 feet high and approximately 1,000 feet long. The River Mill facility cost about $15 million, not including planning, permitting, engineering and administration. Given the different operating conditions, the need for an exit structure to accommodate a larger reservoir fluctuation, dam safety concerns, the alignment and foundation concerns, we estimate the OPCC for a similar ladder at Bowman Dam would be in the range of $50 to over $100 million.

### 5.1.4 Opinion of Probable Annual O&M Costs

Annual costs to operate this ladder could be in the range of $150,000 to $400,000 per year, including necessary gate maintenance.

### 5.1.5 Implications to OID operations

A gravity-fed fish ladder at Bowman Dam would be relatively easy to maintain, but could represent a substantial increase in operating costs at the un-manned dam due to the need for daily inspection. Operations and maintenance issues such as a daily inspection, monitoring, and
general maintenance of gates and flow control features would be expected. Fish ladders are generally simple to operate, but maintenance would be needed on the adjustable gates, structure, etc. Additionally, sometimes daily inspections would be necessary to remove any trash that accumulates at the ladder exit (where flow enters) and within the pools, etc., confirm that pumps are operating correctly, and maintain general site security.

5.1.2 UP #2 – Collection-and-Transport at Bowman Dam

5.1.2.1 Description and Technical Considerations

A collection-and-transport facility at Bowman Dam would provide for collection of fish at the base of the dam, and provisions to load fish into fish trucks for transport upstream. A schematic overview of a collection-and-transport facility location is shown in Figure 5-4.

Fish could be collected near the dam at the same entrance location as Alternative UP #1. The short ladder to accommodate the 7-foot tailwater fluctuation would lead to a fish holding and loading facility, where fish would be trapped and held until they could be loaded into trucks for transport upstream. The easiest upstream release point would be at the boat launch just upstream of the dam along the left bank. The route shown on Figure 5-4 is about 1.25 miles long, and this release site would be far enough upstream to minimize the potential for fallback down the spillway. It would also allow for fish to self-select their migration path through the reservoir and would allow them to choose any tributaries within the reservoir basin. An alternate release site would be in the Crooked River upstream of the reservoir. The road system within the reservoir area is primitive, so as a conservative assumption fish trucks could traverse the dam to the north, follow Highway 27 back to Prineville, follow Highway 380 back to the river for release upstream, a one-way trip of about 35 miles as shown in Figure 5-5. Major components of a collection-and-transport facility are described below.
Figure 5-4. **Collection-and-transport facility at base of Bowman Dam, with truck route to existing boat launch near dam for fish release upstream of dam.**

Figure 5-5. **Collection-and-transport facility at base of Bowman Dam, with truck route along major roads for fish release in Crooked River upstream of the reservoir.**
**Fishway Entrance / Collection Pool**

The collection-and-transport system entrance location, configuration, and attraction flows would be the same as the system described for Alternative UP #1 with the volitional fish ladder. The short ladder necessary to accommodate the fluctuating tailwater would lead to a collection pool and fish short-term holding / truck loading facility. There is plenty of space available adjacent to the powerhouse location, and the planned access road down the left bank to the Hydropower Project could be graded and improved to allow fish truck access. The grade of the road may need to be lower than planned for the powerhouse access and guard rails added for safety, but this route would be more feasible than building a bridge across the spillway. The water supply for the attraction flows would be the same as noted for Alternative UP #1, and holding pool water supply can be gravity fed from the new penstocks leading to the powerhouse.

**Fish Holding / Truck Loading Facility**

The collection/holding pool would trap fish via a V-trap and provide a holding area between truck transport cycles. The size and flow requirements for a holding facility are typically designed to accommodate the daily peak runs of fish expected to enter the facility. For the Bowman site, the data provided in Table 3-2 indicate a planning level estimate ranging from 33 to 200 fish per day. These numbers are likely higher than would occur at this site, but it is worth noting that even the high estimate is a relatively small number of fish to be handled as compared to the sophisticated collection-and-transport facilities located on larger rivers in the region. This observation would likely lead the design for this alternative to be a relatively simple facility intended for manual operation rather than a fully automated facility.

The size of holding pond necessary is a function of the number of fish to be held at one time, the desired maximum fish holding time, the fish truck size, and the frequency of fish transport. To avoid any delay in natural migrations, recent collection-and-transport facility designs in the region plan for a maximum of 24-hour holding in the trap facilities, and this is a requirement per the latest NMFS criteria (NMFS 2011, Section 6.3.1.4). This requirement means that all fish collected in one day must be transported upstream within 24 hours.

The following preliminary calculations will help to size this facility:

- **Maximum weight of fish:** Assume 200 spring Chinook at 20 lb/fish = 4,000 lbs of fish/day
- **Fish truck planning:** Assume maximum transport of 200 fish/day. Volume required is calculated as 0.15 cu ft/lb X 4,000 lb = 600 cu ft, or about 4,500 gal. A typical fish truck is about 1,000 to 2,000 gallons, so a smaller 1,000 truck would need from one trip per day for most of the migration season up to four trips per day at the peak (this estimate
A minimum of two fish trucks should be provided for the program so there is always a backup in case of mechanical failure, and peak runs can also be accommodated with overtime.

- **Fish Holding Capacity and holding pool configuration:** Assume all fish will be transported once per day based on the truck sizing above. Therefore, a holding capacity of 0.25 cu ft/lb \(\times\) 4,000 lb = 1,000 cu ft of holding volume would be required to accommodate a peak day. A holding pool sized at 10 feet wide by 25 feet long by 4 feet deep would be a conservative estimate for these needs, which is about \(\frac{1}{4}\) of a standard fish hatchery raceway. The holding pool could be configured in two bays, to allow loading of fish at the same time fish are ascending into the collecting pool. A crowder could also help facilitate truck loading.

Other considerations for designing fish holding facilities are the need or desire to sort fish. For example, in some restoration programs, various species are transported to different basins or facilities. Because the habitat upstream of Bowman Dam is relatively limited, we will assume that all fish collected at an adult trap could be held, transported, and released at the same location, and no sorting facilities would be needed. One exception to this would be the possible need to sort and cull or return to the river any species not desired to move upstream; therefore, this assumption should be confirmed if passage analysis advances beyond this study.

In addition to the holding facilities, a truck loading facility would be necessary to lift fish from the holding pond and load them into a fish transport truck. There are several levels of complexity available for fish truck loading, but for a project of this scale a fish hopper that rests in the holding pool, and then lifts fish into the truck would be appropriate. A water-to-water fish transfer protocol is recommended to minimize fish handling and stress. Figure 5-6 provides an overview of a small scale collection-and-transport facility with the above features, and Figure 5-7 provides a more modern fish truck facility with a hopper style loading facility that would be appropriate for Bowman Dam with a fish truck in the loading position.

General site improvements, road grading and surfacing, a small staff building with office space and restroom facilities, security fencing, lighting, and intrusion alarms are typical improvements provided for collection-and-transport facilities. As noted above, the access road would need to be designed to allow fish truck operation in the winter season with potential for snow and ice.
Figure 5-6.  Sample small scale collection-and-transport facility (Kalama Fish Hatchery, Washington).

Figure 5-7.  Truck loading facility with hopper (Landsburg Facility, Washington).
**Water Supply**

Three water sources would be required for the collection-and-transport facility.

1. **Attraction Flow:** Water needed for the fish trap entrance attraction flows would be as described in Alternative UP #1.

2. **Fish Trap Flow:** The fish trap would utilize a short fish ladder to bring fish from the creek level up to a holding pond, protected from the flood levels. Flow for this ladder would be the same as Alternative UP #1, about 20 cfs. This flow would be required any time the trapping facility is operating, and for equal comparison to the ladder it is assumed to occur all year.

3. **Circulation water** would be needed in the holding pool, with flow sized to meet the maximum daily holding capacity. Using the 1.34 gpm per fish (Section 3.3.2), a 200 fish per day peak run would require about 270 gpm for the holding pool. We will assume 300 gpm supply required for the fish holding period. This water should be good quality first-pass water, to maintain fish health in the holding pool, and can run in series to supply the entrance ladder.

**Fish Release Site**

A collection-and-transport program has the advantage that fish can be released upstream of the dam at any location. As noted in the introduction, two sites are reasonable for planning for this facility:

- Immediately upstream of the dam, along the left bank at the existing boat launch (Figure 5-4).
- In Crooked River above the upstream end of the reservoir (Figure 5-5).

The release facilities required is a boat launch ramp that can accommodate a fish truck. The fish truck can back down the ramp, and release fish through an exit gate that can also be supplemented with an extendable chute to assure fish are released at a deeper pool in the receiving water. At lower pool elevations, the ramp would need to be accessible for vehicles, and sometimes a winch anchor point is provided to allow use at extreme low pools with a winch provided on the front of the truck. A fixed open channel release chute along the launch ramp can also be used to accommodate low water levels at the site.

Each of the two locations has its own advantages and disadvantages, which basically relate to the overall program. For example, fish released near the dam would need to negotiate the entire reservoir that could have warm temperatures, predators, may cause migration delay, etc. Fish released at the head of the reservoir or in the creeks upstream may find cooler water and better access to habitat during some seasons, but alternately spring chinook moving upstream
in late summer may find the river upstream of the reservoir to be very low and warm. If that was the case, they may move back into the reservoir and hold in the cooler water. A thorough discussion of these variables can be developed outside of this study; however, an advantage of the collection-and-transport over the ladder is the flexibility of the desired release point.

5.1.2.2 Biological and Technical Considerations

The following biological pros and cons/risks were identified for this alternative.

Pros

- A collection-and-transport system would be technically feasible at this site for the target species and would be more cost effective than a ladder.
- Modern fish handling protocols and facilities result in a 99 percent or better fish survival after collection and hauling.
- As compared to a fish ladder, there is less risk associated with the successful transport upstream via a collection-and-transport system, as success is limited for fish navigating ladders higher than 100 feet.
- Because fish could be released upstream of Prineville Reservoir, a collection-and-transport would have less potential than a fish ladder for migration delay, except for the time between transport cycles that are a function of the operational protocol.
- Collection-and-transport would provide flexibility to release fish upstream of the dam at any desired location.
- Fish survival via transport to the watershed above Prineville Reservoir would be high with properly design fish loading system and fish trucks.
- Releasing the fish near the upstream end of the reservoir would provide a riverine environment for ease of access that is not affected by the fluctuating reservoir elevation.

Cons/Risks

- Fish would not be able to turn around of their own volition once they entered the trap.
- Human handling of fish is required for passage.
- There is the potential for accidents during handling and transport. For example, a traffic accident or truck breakdown could result in the loss of one load of fish.
- The water temperature at the potential release points in or upstream of the reservoir may be higher than the gravity trap supply flow that withdraws from a low reservoir level. Fish exiting through a fish truck release or slide may have thermal delay or migration disruptions due to the potential difference in temperatures.
5.1.2.3 Opinion of Probable Construction Cost

The OPCC for a collection-and-transport facility for this site would likely range from $2 to $5 million for this site. Much of the costs will depend on how automated the facility would be. A dedicated fish truck would likely cost between $150,000 and $300,000, depending on the size and complexity of features, and a spare would be recommended.

All facilities could be all provided during one construction phase, or a phased approach could be implemented that begins with more modest facilities requiring manual fish handling, and permanent and automated facilities added in the future depending on the program success.

5.1.2.4 Opinion of Probable Annual O&M Costs

Annual costs are estimated at $300,000 to $500,000 per year.

5.1.2.5 Implications to OID operations

Notable implications to OID operations include:

- As far as daily impacts to OID operations, a collection-and-transport facility would require daily operation and trucking, plus daily inspection, monitoring, and general maintenance. The collection-and-transport facility would take more operations effort than a fish ladder.

- Flows necessary for a collection-and-transport facility at Bowman Dam would be compatible with the planned Hydropower Project and would not substantially affect operations.

5.1.3 UP #3 – Collection-and-Passage at Bowman Dam with Whooshh System

5.1.3.1 Description and Technical Considerations

A fish passage system identical to UP #2 could be configured to utilize a Whooshh Innovations (Whooshh) fish transport tube over Bowman Dam, for release upstream in the reservoir. The alignment and exit could be similar to that shown for the fish ladder in Alternative UP #1 or could be shorter with an ascent directly up the earth fill dam. The fish size for summer steelhead and spring Chinook are similar such that one Whooshh tube would be sufficient to provide for passage. Given the remote location, the system would need to be designed to protect against vandalism and to protect the fish tubes from the summer heat. Examples of some recent Whooshh systems installed in the Pacific Northwest are shown in Figures 5-8 and 5-9.
Figure 5-8.  Whooshh tube suspended by a cable up ascending the Cle Elum Dam face on the Yakima River, with a heat protection shroud.

Figure 5-9.  Whooshh tube suspended by a cable up ascending the Chief Joseph Dam face on the Columbia River, with a heat protection shroud.
5.1.3.2 Biological and Technical Considerations

The pros and cons/risks for this alternative are similar to Alternative UP #2, with the following observations.

Pros

- A Whooshh system would be technically feasible at this site for the target species and would be more cost effective than a ladder or a collection-and-transport system.
- Preliminary tests of the Whooshh system indicate high expected fish survival.
- Similar to the collection-and-transport system as compared to a fish ladder, there is less risk associated with the successful transport upstream via a Whooshh system, as success is limited for fish navigating ladders higher than 100 feet.
- Fish could be transported soon after they ascend the entrance ladder, for the least delay or transport time of any of the alternatives.
- The Whooshh system would be much less costly than the fish ladder alternative and may be similar or less than new collection-and-transport alternatives.
- A Whooshh system could be deployed more rapidly than conventional systems.
- Whooshh Innovations offers a lease program for system testing, or long term contracting for installation, operations and maintenance.

Cons/Risks

- Fish would not be able to turn around of their own volition once they entered the fish trap entrance.
- Mechanical handling of fish is required for passage.
- The water temperature at the potential release points in or upstream of the reservoir may be higher than the gravity trap supply flow withdraws from a low reservoir level. Fish exiting through the Whooshh slide may have thermal delay or migration disruptions due to the potential difference in temperatures.
- The system is relatively new and is currently undergoing evaluations at several projects. NOAA Fisheries currently classifies the system as “experimental technology” in their criteria, but they will allow its use on ESA listed species. This classification requires three years of scientific evaluation to prove the system. The risk would be if the system is not ultimately accepted by NOAA Fisheries, the OID would need to provide a conventional fish loading and transport system per Alternative UP #2).
- Some agencies have concerns for fish injury, such as possible effects on slime, eye abrasions, disease or injury. Preliminary tests are currently underway to evaluate these concerns.
5.1.3.3 Opinion of Probable Construction Cost

A Whooshh tube system connected to the fish collection and holding pool system would be similar to Alternative UP #2, with an OPCC ranging from $2 to $5 million. Some savings could be possible with a less robust collection system, but given the year-round operation needs we do not recommend that approach.

5.1.3.4 Opinion of Probable Annual O&M Costs

Annual costs for this alternative would be the similar to Alternative UP #2, but the tube cost would replace the fish truck and transport labor costs. An estimated range of $200,000 to $400,000 will provide a reasonable estimate for comparison.

5.1.3.5 Implications to OID operations

Notable implications to OID operations are the same as Alternative UP #2, without the travel costs necessary for trucking.

5.1.4 UP #4 – Collection-and-Transport from Downstream Location at Pelton Round Butte Project

5.1.4.1 Description and Technical Considerations

A collection-and-transport facility at the Pelton Round Butte Project represents another opportunity to collect fish and pass them via fish trucks to the upper Crooked River above Bowman Dam.

There are existing facilities at PGE and the Tribes' Pelton Round Butte Project to collect adult fish as they ascend the Deschutes River. The addition of a Bowman Dam fish collection-and-transport program would require coordination with PGE and the Tribes' existing operations and possibly their facilities to add additional sorting capabilities at their facility to separate upper Crooked River fish from fish migrating to other drainages within the basin. Further research would need to be conducted with PGE and the Tribes to clarify exact facility and staffing needs; however, we anticipate new facilities at the Pelton Round Butte Project would be minimal in comparison to constructing new facilities at the other sites noted above. If space is available to accommodate new facilities, they would likely include additional sorting flumes and holding ponds for a Bowman Dam passage program. Fish trucks would transport the fish destined for the watershed above Bowman Dam via the existing state highway system, which would be a one-way trip of about 70 miles.
5.1.4.2 Biological and Technical Considerations

The pros and cons/risks for this alternative are the same as Alternative UP #2, with the following exceptions.

**Pros**

- The addition of one more sorting requirement at the Round Butte Project is feasible and would require minimal capital facilities to implement.
- A reliable fish barrier exists that would accommodate collection at the Round Butte Facility without risk of fish passing the system.
- Fish survival via transport to the watershed above Prineville Reservoir would be high with properly design fish loading system and fish trucks.

**Cons/Risks**

- Fish sorting would be necessary at the Pelton Round Butte Project to determine whether upmigrating fish are heading to the upper Crooked River. This process is significant, and any sorting program such as this would require capture and marking of outmigrating juveniles so they could be identified when they return as adults.
- Depending on the effectiveness of the marking program, fish intending to spawn between the Round Butte Project and Bowman Dam may not have access to that reach of river, so this alternative could represent a loss of habitat and natural migration into to desired river reaches.
- Transportation risks of trucking as noted in Alternative UP #2, especially in winter months.

5.1.4.3 Opinion of Probable Construction Cost

A collection-and-transport facility for this site would likely cost less than Alternative UP #2, as fewer facilities would be required. The unknown is how extensive the outmigrant marking program would need to be. An OPCC estimate of between $500,000 and $2 million is reasonable, assuming the addition of upstream sorting and holding facilities and two fish transport trucks (unless the truck is provided for downstream alternatives, where costs could be shared).

5.1.4.4 Opinion of Probable Annual O&M Costs

Annual costs for this alternative would be the similar to Alternative UP #2; however, we assume that there would be some efficiencies with staff with the existing facility. But the efficiencies would be more than offset with the need for a new fish marking program requiring some level
of sorting. An estimated range of $250,000 to $600,000 will provide a reasonable estimate for comparison.

5.1.4.5 Implications to OID operations

Notable implications to OID operations are the same as Alternative UP #2, with additional travel costs necessary for the approximately 140-mile round trip of the fish truck. This alternative would also require coordination and likely joint funding, operational protocols, access easements, etc. to allow access and use of PGE and the Tribes’ Pelton Round Butte Facility. Operational impacts of a downstream fish marking program would need further definition and would need to be accounted for either in the upstream or downstream program operations and costs.

5.1.5 UP #5 – Collection-and-Transport from Downstream Location at Opal Springs Dam

5.1.5.1 Description and Technical Considerations

A collection-and-transport facility utilizing the new fish ladder at Opal Springs Dam is one more opportunity to collect fish and pass them via fish trucks to the upper Crooked River above Bowman Dam. The ladder could be modified to provide a collection and fish sorting system, and truck loading facility similar to the PGE and the Tribes’ facilities at the Pelton Round Butte Project. This alternative likely would not have the savings potential that adding on to the Pelton Round Butte Program would have because it would require the addition of a collection and sorting facility, but it would be easier to identify fish already destined for the Crooked River as fish arriving at Opal Springs dam have already made that choice when they chose the Crooked River downstream of Opal Springs.

The addition of a Bowman Dam fish collection-and-transport program at Opal Springs Dam would require new collection and sorting facilities connected to one of the ladder pools, two new fish trucks, and coordination with the Deschutes Valley Water District (DVWD) on operations. Fish trucks would transport the fish destined for the watershed above Bowman Dam via the existing state highway system, which would be a one-way trip of about 60 miles. Access road improvements to Opal Springs Dam would also likely be necessary for routine fish truck access. Further research would need to be conducted with DVWD to clarify exact facility and staffing needs.

5.1.5.2 Biological and Technical Considerations

The pros and cons/risks for this alternative are the same as Alternatives UP #2 and UP #4 at Pelton Round Butte, with the following observations.


**Pros**

- The addition of collection and sorting facilities at Opal Springs is feasible and would require fewer new capital facilities to implement than at Bowman Dam.
- Fish survival via transport to the watershed above Prineville Reservoir would be high with properly design fish loading system and fish trucks.

**Cons/Risks**

- Fish sorting would be necessary at the Opal Springs to determine whether upmigrating fish are heading to the Crooked River above Bowman Dam. The addition of a sorting facility is significant, and any sorting program such as this would require capture and marking of outmigrating juveniles so they could be identified when they return as adults.
- The current Opal Springs low-head ladder is expected to have a very high passage performance, but the addition of fish collection and sorting facilities could add delay and reduce overall effectiveness.
- Depending on the effectiveness of the marking program, fish intending to spawn between Opal Springs and Bowman Dam may not have access to that reach of river which could represent a loss of habitat and natural migration into to desired river reaches.

5.1.5.3  **Opinion of Probable Construction Cost**

A collection-and-transport facility at Opal Springs Dam would be about the same cost as Alternative UP #2. While it would avoid the need for a trap entrance and transport facility at Bowman Dam, it would require sorting facilities at Opal Springs. The unknown is how extensive the outmigrant marking program would need to be. An estimate of between $500,000 and $2 million is reasonable, assuming the addition of upstream sorting and holding facilities would be needed, and two fish transport trucks (unless the truck is provided for downstream alternatives, where costs could be shared).

5.1.5.4  **Opinion of Probable Annual O&M Costs**

Annual costs for this alternative would be the similar to Alternative UP #2; however, we assume that there would be some efficiencies with staff with the existing facility. But the efficiencies would be more than offset with the need for a longer fish truck transport times, and a new fish marking program requiring some level of sorting. An estimated range of $250,000 to $500,000 will provide a reasonable estimate for comparison.
5.1.5.5 Implications to OID operations

Notable implications to OID operations are the same as Alternative UP #2, with additional travel costs necessary for the approximately 120-mile round trip fish trucking. This alternative would also require coordination and likely joint funding, operational protocols, access easements, etc. to allow access and use of DVWD’s Opal Springs facility. Operational impacts of a downstream fish marking program would need further definition and would need to be accounted for either in the upstream or downstream program operations and costs.

5.2 Options for Downstream Passage

Downstream passage facilities at high-head dams are costly and complex systems that don’t always have a high success rate. Much research and project work has been conducted in the Pacific Northwest Region, Alaska, and California over the last 10 years. The downstream fish passage assessment for Prineville Reservoir, with a fluctuation of over 53 feet (Table 4-10, and summarized in Section 4.2.4.4) and varying design flows during the anticipated outmigration period from February-June (Table 3-3), creates a real challenge to providing effective and affordable downstream passage options.

As some general background, this study was to be modeled after the similar Ochoco Passage Feasibility assessment report (R2 and Biota 2014) on the Crooked River tributary Ochoco Creek. There are a few additional papers and studies that have been published since that study in 2014, and one helpful overview reference report for high-head downstream passage is the Review of Fish Passage Technologies at High-Head Dams (NPCC 2016). R2 has also led and/or supported design teams for several recent fish passage studies for high head dams including Santa Felicia Dam in California, Los Padres Dam in California, and Detroit Dam in Oregon, and our staff have helped teach a Downstream Passage at High-Head Dam Short Course with colleagues from other consulting firms and agency representatives at the International Fish Passage Conference in Corvallis, OR in June, 2017. The common theme from this work and short course is that downstream passage at high head dams is a difficult and an often costly undertaking, and the completed projects that have been constructed have a varying rate of success and don’t always meet the performance goals or expectations.

This section is organized beginning with downstream fish passage alternatives at Bowman Dam and moving upstream into the reservoir to examine other opportunities to capture and haul downstream migrating fish to a release point below the dam. We have included a full range of possible options typically identified with other recent studies for completeness and comparison. Alternatives are designated by DN #1, DN #2, etc. to designate “Downstream” passage alternatives, and differentiate these from the upstream alternatives. The suite of
alternatives considered for downstream passage that includes an overview of the latest and most promising downstream passage technology includes:

- DN #1 – Volitional Passage through Existing Bowman Dam Outlet, as Modified for Hydropower Project (No-action alternative for comparison)
- DN #2 – Volitional Passage through Multi-Port Gated Intake with Bypass Helix
- DN #3 – Volitional Passage through Screened Intake and Bypass at Bowman Dam
- DN #4 – Floating Surface Collector in Prineville Reservoir
- DN #5 – Floating Surface Collector in Upper End of Prineville Reservoir
- DN #6 – In-River Collector Upstream of Prineville Reservoir

5.2.1 DN #1 – Volitional Passage through Bowman Dam Outlet, as Modified for Hydropower Project (No-action Alternative)

5.2.1.1 Description and Technical Considerations

This alternative describes using the existing Bowman Dam Outlet Works as modified for the proposed Hydropower Project with no fish passage modifications as a baseline condition for comparison and discussion. This alternative recognizes that outmigrating fish could pass through the existing spillway and outlet works, both as-is and with the proposed modifications. A description of the spillway and outlet works is provided in Section 4.2 which describes the intake, flow routes through the dam, and the outlet facilities. While fish could pass through this system, we are not aware of any studies quantifying the survival or injury rate through the system.

Based on the spillway and stilling basin design, we would expect some survival when the project is spilling, and it may be relatively better than expected; however, the project rarely spills with its current operation and is generally filling the reservoir during the spring outmigration period with lower flows. Recent modifications to reservoir storage and release brought about by the Crooked River Act are expected to result in even fewer spills than have occurred historically. The flows that are passed are typically via the outlet works, which at full capacity has an average velocity in the pipes and tunnel over 30 fps at the 3,000 cfs flow. Therefore, the survival of smolts passing through the intake, outlet works, and tunnels/conduits is estimated to be low. The addition of the 300 cfs Francis turbines and additional bifurcation would make survival through an unscreened system even lower, as Francis turbines with greater than 150 feet of head have low fish survival.

The general summary would be that while some fish would likely survive the spillway and outlet works routes, it would not be an effective passage system. It may be possible to change
outflows from the outlet works to spill when the reservoir is at full pool, but it is typically filling through most of the outmigration period. In that case it may also be feasible to improve the spillway and stilling basin for fish passage survival and to reduce managed flows through the low-level intake for increased overall survival. These ideas would also require a change in management protocol, including the flood-control rule curve, and are only provided to document that they were considered as they are not recommended as viable options for Bowman Dam.

5.2.1.2 Biological and Technical Considerations

Fish injury or mortality could be high for this alternative, and could occur at the following locations in this system given their current configuration:

- At the intake, depending on water level and flows; or fish may not be very attracted to or able to find the deep intake.
- Through the regulating gate, depending on reservoir level and flow.
- In the stilling basin at the base of the spillway.
- Via the new Francis turbines.
- Any combination of the above

5.2.1.3 Opinion of Probable Construction Cost

There are no capital costs associated with this alternative.

5.2.1.4 Opinion of Probable Annual O&M Costs

There are no annual O&M annual costs associated with this alternative.

5.2.1.5 Implications to OID Operations

There are no implications to OID operations, as this is a baseline alternative only for comparison, and to note it was considered.

5.2.2 DN #2 – Volitional Passage through Multi-Port Bypass Helix

5.2.2.1 Description and Technical Considerations

A new Helix system currently under construction at the USBR’s Cle Elum Dam in Washington State provides volitional passage over a similar reservoir that fluctuates 50 feet during the outmigration season. This system would also be feasible at Bowman Dam and would provide a downstream passage route with flows ranging from 200 to 400 cfs. Figure 5-10 provides an
overview of the Helix system, with a multi-port outlet structure fed by multiple overflow gates that track the varying water surface, and lead to a helical open channel leading to the tailrace.

![Diagram of Helix Design](image)

Figure 5-10. Overview of USBR Helix Design downstream passage system at Cle Elum Dam, Washington (NPCC 2016).

This system would be very amendable to the existing conditions at Bowman Dam; however, it would not provide screened flow to the Hydropower Project that would have priority flow during the first 300 cfs of release to function as intended. This alternative would be a hybrid of the Helix, in that an expansion chamber at the downstream end could be added to allow slow enough velocities for a 300 cfs fish screen and bypass.

The overall development and construction cost for the system at Cle Elum Dam is about $100 million without any screening. Addition of a 300 cfs screen and necessary facilities would likely increase the cost by another $7 to $15 million at this site, so this would not be economically feasible but can be considered an upward bounding case.

5.2.2.2 Biological and Technical Considerations

This alternative would likely function well as 300 to 400 cfs could be available for attraction flow, which is well within the normal 300 cfs flow seen at Bowman dam during most of the
outmigration period (Table 4-8). It is also over 10% of the attraction flow during the maximum 5% exceedance flow during the outmigration (Table 4-8) which is shown to be relatively effective with surface collection systems.

**Pros**

- Fish have the full access to the reservoir for rearing due to the location near the dam (note this may also be considered a con based on concerns such as predation, temperature, and lack of guiding currents).
- Fish would likely be attracted to and be able to find the surface outlet with fish-friendly overflow gates leading into the bypass system.
- With a 300 cfs screen system, the system would be compatible with the Hydropower Project.

**Cons/Risks**

- Operation of multiple gates has many opportunities for problems and would require close monitoring and instrumentation/automation.
- Fish migrating downstream through the reservoir could be susceptible to high temperatures and predators.
- Without any sorting facilities, this facility would allow all fish species to move downstream. Currently non-native species are maintained in the reservoir for recreational fishing, but they are kept out of the river downstream of the dam where a valuable trout fishery exists. This issue would need further consideration.
- It is a large, costly facility.

### 5.2.2.3 Opinion of Probable Construction Cost

Estimating the cost of this alternative would require more refined development of the design flows, system components, and overall design definition. However, because the size and flows are similar to the Cle Elum dam project, the OPCC would likely range from $80 million to over $120 million.

### 5.2.2.4 Opinion of Probable Annual O&M Costs

Annual O&M costs would include more active trash rack cleaning and operation of a 300 cfs fish screen system. Estimated O&M costs are from $300,000 to $600,000 annually.

### 5.2.2.5 Implications to OID Operations

The system would be adaptable to the existing system and would add routine inspection and maintenance tasks to the existing project.
5.2.3 DN #3 – Volitional Passage through Screened Intake and Bypass at Bowman Dam

5.2.3.1 Description and Technical Considerations

This alternative represents another upper bounding cost case for conventional and feasible downstream passage alternatives that would provide for a criteria screen and fish bypass system designed to meet NMFS (2011) criteria for screen velocities, attraction flow and bypass flows. To fully meet the criteria, exclusionary screens would need to be designed for 2,500 cfs to satisfy the 5% exceedance flow during the outmigration period. By observing the exceedance flow summaries shown in Figure 4-15, it is clear with this regulated system that the 95% and 50% exceedance flows are primarily in the range of 50 to 400 cfs. It is worth further examination to consider a reduced screen capacity of 400 cfs with the provision that excess flows be managed to allow spill over the spillway rather than passing through the low level intake and outlet works, although this approach would likely conflict with flood control operations.

For this alternative, we will assume a 400 cfs screen in order to show the minimum possible cost of a screened alternative for comparison. A screen and bypass facility similar to PGE and the Tribes’ Pelton Round Butte Tower would be required, however this facility would be able to operate with gravity flow into the bypass and Hydropower Project. The challenge with the Bowman Dam site is the screen facility would need to be floating or movable on a new tower structure, such that the screened intake could track with the water level given the high level of fluctuation. A V-screen structure designed to operate between the minimum potential regulated flow of 20 cfs, and with normal flows ranging from 50 cfs to 400 cfs will define this alternative. The 400 cfs high flow will exceed the 300 cfs capacity of the Hydropower Project, so all fish that enter the system would be screened and led into a bypass system, which could pass to a smaller pipe down the dam abutments similar to the River Mill Dam bypass. A long pipe with flatter slope likely in a helical configuration would be required to maintain desirable velocities.

5.2.3.2 Biological and Technical Considerations

This system is similar to Alternative DN #2, but it screens the fish prior to entering the tower at the existing intake location. The following biological pros and cons/risks were identified for this alternative.
**Pros**

- Fish have the full access to the reservoir for rearing due to the location near the dam (note this may also be considered a con based on concerns such as predator, temperature, and lack of guiding currents).
- Fish would be screened and provided with a high-survival bypass system to the tailrace.
- Sorting facilities could be added to maintain non-native species in the reservoir (see similar issue with cons).

**Cons/Risks**

- Operation of multiple gates has many opportunities for problems and would require close monitoring and instrumentation/automation.
- Fish migrating downstream through the reservoir could be susceptible to high temperatures and predators.
- Without any sorting facilities, this facility would allow all fish species to move downstream. As noted above, non-native species are currently maintained in the reservoir for recreational fishing, but they are kept out of the river downstream of the dam where a valuable trout fishery exists. This issue would need further consideration.
- It is a large, costly facility.

**5.2.3.3 Opinion of Probable Construction Cost**

Estimating the cost of this alternative would require more refined development of the design flows, system components, and overall design definition. Based on the Pelton Round Butte Project costs plus the need for a tower that supports a movable screen, we expect this system would be in the range of $75 to $110 million.

**5.2.3.4 Opinion of Probable Annual O&M Costs**

Based on the high capital cost, an annual operational cost of $0.5 million to $1.5 million is reasonable, considering long term maintenance of the facility.

**5.2.3.5 Implications to OID Operations**

This alternative is not considered practical for Bowman Dam; however, we have kept it in the analysis for the sake of completeness as this type of system is typically analyzed for fish passage studies. Screen cleaning and system maintenance would be the key elements of operations.
5.2.4 DN #4 – Floating Surface Collector in Prineville Reservoir

5.2.4.1 Description and Technical Considerations

A Floating Surface Collector (FSC) is considered a partial screening facility that floats on the surface and creates an attraction flow by pumping flow into the screened intake and returning the screened attraction flow through pumps in the floating structure back into the reservoir. The idea of the FSC is to mimic a natural lake outlet into a river. Fish are attracted into the facility, screened from the attraction flow, and then bypassed via a lower flow into a bypass system or holding tanks on the floating barge structure. This concept is based on the original “gulper” system utilized and improved upon at the Puget Sound Energy (PSE) Baker River Project in western Washington. Currently there are state of the art FSCs in place at PSE’s Upper Baker and Lower Baker Dams in Washington, at PacifiCorp’s Swift Hydroelectric Project on the Lewis River in Washington, at Tacoma Power’s Cushman Project in Washington, at PGE’s North Fork Project on the Clackamas River in Oregon, a lower flow system on the Cougar Project on the McKenzie River in Oregon operated by the U.S. Army Corps of Engineers, and a small system is operational at Los Padres Dam on the Carmel River in California.

Bowman Dam would be very amenable to an FSC, and the system could be located upstream of the intake and spillway near the dam as shown in Figure 5-11.
Figure 5-11. Conceptual location of an FSC at Bowman Dam. Shown far enough upstream to avoid North Fork FSC with gravity bypass pipe.
We would recommend an attraction flow in the range of 250 to 300 cfs for a Bowman Dam FSC system, which given the reservoir configuration flow regime would likely be highly effective as a fish collection system. An exclusionary net system is included as part of this alternative upstream of the FSC to prevent fish from entering the existing low-level intake. Exclusionary nets at Prineville Reservoir may not be as difficult as at other sites in the region due to the more limited spillway and flood flows expected at this site, but these large net systems have proven to be expensive and costly to maintain. It is anticipated that exclusionary nets could be installed for the full outmigration season, and if fry are not a concern they could be removed after the smolt runs and redeployed at the beginning of each outmigration season. Their location would need to be sited to accommodate spillway flows as well as adult release facilities so upstream migrants are not reintroduced into the reservoir downstream of the nets.

At Bowman Dam, fish passing the screens would ideally be routed to a gravity bypass and release system similar to PGE’s North Fork system that could discharge fish directly to the tailrace. Given the location upstream of the dam, this configuration may be challenging to design, so an alternate approach would be to use holding tanks like on the Baker and Swift FSC, and shuttle floating “pods” of fish to the dam for release downstream. The FSC could be anchored upstream of the dam, or for personnel and dam safety reasons could benefit from a mooring trestle system similar to the Swift FSC. Figure 5-12 provides an illustration of the Swift FSC and Trestle, which is designed for 600-cfs attraction flow to compete with up to 10,000 turbine flows, and Figure 5-13 provides a photograph of the North Fork System showing the gravity bypass pipe through the dam.

Figure 5-12. Swift FSC shown moored at trestle while under construction.
This system envisioned would be located upstream of the deep intake near the right bank, and upstream of the spillway. Therefore, fish would have full access to Prineville Reservoir similar to Alternatives DN #1 through DN #3. Assuming exclusionary nets are used, it would effectively screen fish from the intake, and the existing intake system could remain unchanged. The following biological pros and cons/risks were identified for this alternative.

Pros

- Fish would have the full access to the reservoir for rearing, foraging, etc. (may also be a con as noted above).
- The FSC would have strong fish attraction due to the pumped flow, and Bowman Dam has a generally good setting for potentially high FSC collection efficiency.
- An exclusionary net and screen system on the FSC would prevent fish from entering the deep intake or spillway, except at high spill flows, and a gravity bypass/transport system would be fish friendly.
- A 60 to above 90% collection effectiveness is anticipated for this alternative.
- Sorting facilities could be added to maintain non-native species in the reservoir (see similar issue with cons).
**Cons/Risks**

- All fish may not be attracted to FSC.
- Some fish may get through the nets, and would then likely pass through the turbines or outlet works.
- Net systems in fluctuating reservoirs are a challenge, and costly to install and maintain.
- Costly construction alternative.

**5.2.4.3 Opinion of Probable Construction Cost**

The cost for a 250 to 300-cfs range FSC, net, and mooring system, would likely range from $35 to $70 million, based on recent experience in the industry.

**5.2.4.4 Opinion of Probable Annual O&M Costs**

Annual O&M costs would include pumping and labor to operate and maintain the system. We estimate annual O&M costs for this system from $500,000 to $700,000.

**5.2.4.5 Implications to OID Operations**

Implications for an FSC at Bowman Dam are as follows:

- The system would be automated with controls for the pumps, ballast system, and screen cleaning, but would still need daily monitoring and maintenance for the FSC and net system.
- An active debris management program in the reservoir could help to reduce maintenance (cleaning and repair) work on the nets; however, the use of exclusionary nets will require ongoing annual maintenance issue due to algae, ice, etc.

**5.2.5 DN #5 – FSC Collector in Upper End of Prineville Reservoir**

**5.2.5.1 Description and Technical Considerations**

An FSC similar to the facility described for Alternative DN #4 could be located near the upstream end of the reservoir. This location would have the distinction of collecting the outmigrant fish before they get into the reservoir which may have predation risks and high water temperatures that could negatively affect migration through the reservoir. Given the design flows of 0 to 2,500 cfs (Table 4-9) and the necessary 53 foot range of pool level fluctuation (Table 4-10) during the outmigration season, the same 250 to 300 cfs attraction flow size as described for Alternative DN #4 is recommended for initial sizing. The FSC could be located about 300 feet downstream of the low pool near the upstream end of the reservoir, where there would still be sufficient depth to allow the FSC to avoid hitting the bottom of the reservoir.
reservoir at low pool. Further investigations would need to be performed to optimize the facility siting at this location, but it appears a location about 4 miles downstream from the Crooked River near the intersection of Highway 380 and the Prineville Access Road would accommodate the FSC with a low reservoir elevation as shown in Figures 5-14 and 5-15.

**Figure 5-14.** FSC located at upstream end of Prineville Reservoir. For reference the red line show is about 4 miles long.

**Figure 5-15.** Conceptual layout of FSC with barrier nets shown near upstream end of Prineville Reservoir.
An access road with access to the shore and a loading dock or facility would be necessary near the FSC to allow personnel access to the system, and to accommodate transfer of fish from the FSC to the shore. Fish collected in the system would be transported via truck to below the dam. Power would need to be brought into the site for shore-based personnel and loading systems, and FSC operation of the pumps and supporting systems.

5.2.5.2 Biological and Technical Considerations

The primary advantage of this location is to be able to collect outmigrants before they enter the reservoir.

Pros

- The FSC would have strong fish attraction due to the pumped flow, and collection at this location during normal flows would likely have high efficiencies.
- An exclusionary net and screen system on the FSC would prevent fish from entering the reservoir.
- A 60% to above 90% collection effectiveness is anticipated for this alternative.
- Sorting facilities could be added to maintain non-native species in the reservoir (see similar issue with cons).

Cons/Risks

- Location is more susceptible to flooding and high flows of an unregulated river.
- Some fish may get through the nets.
- Net systems in fluctuating reservoirs are a challenge, and costly to install and maintain.
- This alternative would need to be integrated with upstream passage facilities that would release adult fish upstream of the nets. This alternative would not be compatible with upstream release sites near the dam.
- Fish not collected upstream may be lost to the reservoir.
- Remote access, more difficult to maintain.
- Would interfere with recreation access.
- Costly alternative.

5.2.5.3 Opinion of Probable Construction Cost

An FSC at this location would be similar in cost to Alternative DN #4, with an OPCC ranging from $35 to $70 million.
5.2.5.4  **Opinion of Probable Annual O&M Costs**

Annual O&M costs would be similar or slightly higher than Alternative DN #4 at about $500,000 to $700,000.

5.2.5.5  **Implications to OID Operations**

Implications for an FSC at the upper end of Prineville Reservoir are similar to Alternative DN #4 along with the following observations.

- More debris management and maintenance of the nets would be expected, and debris would not be able to settle out or be managed in the reservoir.
- Access for fish transfer and maintenance is 35 miles by the state highway system from Bowman Dam.

5.2.6  **DN #6 – In-River Collector Upstream of Prineville Reservoir**

5.2.6.1  **Description and Technical Considerations**

An in-river collector upstream of Prineville Reservoir would have the same goals as Alternative DN #5 to collect outmigrating fish prior to entering the reservoir, and then transport the fish to below Bowman Dam. These systems are commonly examined as an opportunity to capture fish before they enter reservoir systems where collection may be more efficient in the smaller river section. The challenge in these systems is to have an effective collection system at a majority of the season with low flows, but to protect the system during high flow events. Similar concepts have been examined for other high head projects that utilize a rubber dam across the river to lead fish into a screened collection-and-transport facility. The rubber dam would be lowered to pass flood flows and protect the facility. While this approach could work for lower flow periods, Figure 4-16 illustrates that to be highly effective a screening facility of 3,500 cfs would be necessary to reliably collect fish.

The upstream end of Prineville Reservoir is near the intersection of State Highway 380 and the Prineville Access Road as seen in Figure 5-14. If a rubber dam was located in the river at this location to create enough depth for a fish screen and collection system, it could backwater the highway and private property upstream of the intersection. This alternative is only included to show that it was considered and is recommended to be dropped from further consideration as it is not feasible or effective for the Bowman Dam assessment.
6 SUMMARY OF ALTERNATIVES

Tables 6-1 and 6-2 provide summaries of the upstream and downstream passage alternatives described in Section 5. Categories summarized in these tables include:

- **Modifications Needed to Existing Structures.** This category provides an overview of necessary changes or new construction to Bowman Dam and other structures.

- **Technical limitations.** Captures limitations for various options, such as the ability of a downstream tributary collector to capture fish during high flows, limitations on alternative due to high stream flows, channel morphology, dam height, etc.

- **Biological Benefits.** Addresses an opinion on rates of survival of an alternative, relative contribution to recovery, etc.

- **Biological Costs/Risks.** Provides an overview of likely fish survival or mortality, inefficiencies of passage, etc.

- **Capital Cost (OPCC).** This column provides a summary of the estimated OPCC (capital construction cost) necessary to construct an alternative. Its intent is to reflect the total construction cost to implement an alternative for comparison between the alternatives, as described in Section 5. This number should not be used for program budgeting, and an additional 10% to 25% in total project costs could be incurred for administration, permitting, design, and construction procurement costs.

- **O&M cost.** This category provides an estimate of the annual operation and maintenance costs necessary to operate the facility, as described in Section 5.

- **Water Requirements.** Lists the estimated amount of flow over what period would be necessary to operate the various fish passage facilities.

- **Implications to OID operations.** Impacts and requirements to the OID’s operation are noted in this column.
### Table 6-1. Bowman Dam upstream passage alternative summary.

<table>
<thead>
<tr>
<th>Alternative / Characteristic</th>
<th>Modifications to Existing Structures</th>
<th>Technical Limitations</th>
<th>Biological Benefits</th>
<th>Biological Costs/Risks</th>
<th>Capital Cost OPCC Range (estimate)</th>
<th>Annual Operation and Maintenance Cost (estimate)</th>
<th>Water Requirements</th>
<th>Implications to OID Operations</th>
</tr>
</thead>
</table>
| **UP #1. Volitional Passage at Bowman Dam (Fish Ladder).** | • Fish ladder entrance pool near new powerhouse tailrace.  
• Ladder ascending and penetrating the dam along left abutment.  
• Exit facilities to accommodate the 66-foot reservoir fluctuation.  
• Water supply and ancillary support site. | • Dam height and penetration.  
• 66-foot reservoir fluctuation requires complex exit structure or pumped flow to release slide.  
• Ladder flow would need to be coordinated with minimum flows and is feasible.  
• Tunnel through bedrock likely required to route ladder to reservoir.  
• Complex ladder outlet operation due to 66' range of pool fluctuation.  
• Not a typical fish ladder due to exit conditions. | • Full volitional system does not need any human interaction.  
• Habitat is available up to the dam base, and immediately upstream of the dam.  
• Fish can self-select their migration route once they enter the reservoir.  
• Ladder Height is on the high side for proven facilities (171’ is 75' higher than River Mill). High risk of failure.  
• Potential for migration delay and warm temperatures in over 7-mile long reservoir. | • Ladder Height is on the high side for proven facilities (171’ is 75' higher than River Mill). High risk of failure.  
• Potential for migration delay and warm temperatures in over 7-mile long reservoir.  
• No ability for fish to self-sort or return to lower creek after they enter the trap.  
• Potential for human error and accidents in operations / maintenance.  
• Potential thermal delay or migration disruptions due to temperature differentials. | $50 to over $100 million  
Plus any marking/monitoring program costs. | $150,000 to $400,000  
Plus any marking/monitoring program costs. | • 10-20 cfs minimum year round for ladder operation. 50 cfs desirable and feasible most times except droughts.  
• Ladder supplied by gravity flow from the reservoir  
• Attraction flow water fed from the powerhouse discharge  
• Assume higher attraction flows in tailrace only necessary when spilling.  
• 30 gpm for holding ponds. | • Generally a passive operation. Daily monitoring, maintenance, etc. |
| **UP #2. Collection-and-Transport at Bowman Dam.** | • Fish entrance pool near new powerhouse tailrace (same at UP #1).  
• Short fish ladder to holding pool, truck loading facilities.  
• Water supply and ancillary support site improvements and support facilities.  
• Improved access road to trap and powerhouse.  
• Potential fish release site improvements. | • Water needs for trap entrance and ladder would need to be compatible with minimum flows and powerhouse flows.  
• Personnel requirements to operate and maintain facility. | • High upstream fish passage effectiveness expected.  
• Habitat is available up to the dam base, and immediately upstream of the dam or the beginning of the River depending on the release point.  
• Flexibility of various release points.  
• Less potential for delay in ladder, and in reservoir depending on fish release point.  
• Potential for migration delay in reservoir.  
• No ability for fish to self-sort or return to lower creek after they enter the trap.  
• Dependent on human operations.  
• Potential for human error and accidents in operations / maintenance.  
• Potential thermal delay or migration disruptions due to temperature differentials. | • Potential for migration delay in reservoir.  
• No ability for fish to self-sort or return to lower creek after they enter the trap.  
• Dependent on human operations.  
• Potential for human error and accidents in operations / maintenance.  
• Potential thermal delay or migration disruptions due to temperature differentials. | $2 to $5 million.  
Could Phase the facility to start small and expand / automate facilities depending on numbers of fish. | $300,000 to $500,000  
Plus any marking/monitoring program costs. | • 10 to 20 cfs minimum year-round for collection facility entrance ladder operation. 50 cfs desirable and feasible most times except drought.  
• Assume higher attraction flows in tailrace only necessary when spilling.  
• 30 gpm for holding ponds. | • Staffing for daily operations, monitoring and inspection.  
• Trucking of 70-mile round trip. |
<table>
<thead>
<tr>
<th>Alternative / Characteristic</th>
<th>Modifications to Existing Structures</th>
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<th>Capital Cost OPCC Range (estimate)</th>
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<th>Water Requirements</th>
<th>Implications to OID Operations</th>
</tr>
</thead>
</table>
| **UP #3. Collection-and-Passage at Bowman Dam with Whoosh System** | - Fish entrance pool near new powerhouse tailrace (same at UP #1).  
  - Short fish ladder to holding pool, Whooshh system.  
  - Water supply and ancillary support site improvements and support facilities.  
  - Improved access road to trap and powerhouse.  
  - Potential fish release site improvements. | - Water needs for trap entrance and ladder would need to be compatible with minimum flows and powerhouse flows.  
  - Personnel requirements to operate and maintain facility.  
  - Protection against vandalism and heat required for Whooshh tubes. | - High upstream fish passage effectiveness expected.  
  - Habitat is available up to the dam base, and immediately upstream of the dam  
  - Fish can self-select their migration route once they enter the reservoir.  
  - Minimal delay in transport times, less fish handling than trucking. | - Potential for migration delay in reservoir.  
  - No ability for fish to self-sort or return to lower creek after they enter the trap.  
  - Potential thermal delay or migration disruptions due to temperature differentials.  
  - Considered an experimental technology.  
  - Agency concern for fish injury. | - $2 to $5 million.  
  - $200,000 to $400,000 Plus any marking/monitoring program costs. | - 10 to 20 cfs minimum year-round for collection facility entrance ladder operation. 50 cfs desirable and feasible most times except drought.  
  - Assume higher attraction flows in tailrace only necessary when spilling.  
  - 30 gpm for holding ponds. | - Staffing for daily operations, monitoring and inspection. |
| **UP #4. Collection-and-Transport from Downstream Location at Pelton Round Butte Project** | - Take advantage of existing collection-and-transport facility at Pelton Round Butte Project  
  - Additional sorting flumes and holding ponds at Pelton Round Butte for the Bowman Dam passage program. | - Ability to modify Pelton Round Butte facility.  
  - Personnel requirements to operate and maintain facility.  
  - Need agreement with PGE and the Tribes for facilities, program, and site access. | - Minimal capital facilities to implement.  
  - High upstream fish passage effectiveness expected.  
  - Flexibility of various release points.  
  - Less potential for delay in ladder, and in reservoir depending on fish release point. | - Potential for migration delay in reservoir.  
  - Dependent on human operations.  
  - Potential for human error and accidents in operations / maintenance.  
  - Potential thermal delay or migration disruptions due to temperature differentials.  
  - Lose ability for fish to self-select habitat upstream of Pelton Round Butte.  
  - No access to the river reach between the Round Butte Project and Bowman Dam  
  - Lose ability for fish to self-select habitat upstream of Pelton Round Butte. | - $500,000 to $2 million.  
  - $250,000 to $600,000 Plus any marking/monitoring program costs. | - None at Bowman Dam.  
  - Staffing for daily operations, monitoring and inspection.  
  - Fish sorting required  
  - Trucking of 140-mile round trip  
  - Coordination and joint funding with PGE and the Tribes. |
<table>
<thead>
<tr>
<th>Alternative / Characteristic</th>
<th>Modifications to Existing Structures</th>
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<th>Implications to OID Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>UP #5. Collection-and-Transport from Downstream Location at Opal Springs</td>
<td>• Modify ladder at Opal Springs for collection-and-transport capabilities</td>
<td>• Ability to modify Opal Springs project.</td>
<td>• Minimal capital facilities to implement.</td>
<td>• Potential for migration delay in reservoir.</td>
<td>$500,000 to $2 million.</td>
<td>$250,000 to $500,000 Plus any marking/monitoring program costs.</td>
<td>None at Bowman Dam</td>
<td>• Staffing for daily operations, monitoring and inspection.</td>
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<td></td>
<td>• Personnel requirements to operate and maintain facility.</td>
<td>• Personnel requirements to operate and maintain facility.</td>
<td>• High upstream fish passage effectiveness expected.</td>
<td>• Dependent on human operations.</td>
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<td>• Fish sorting required.</td>
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<td></td>
<td>• Need agreement with DVWD for facilities, program, and site access.</td>
<td>• Flexibility of various release points.</td>
<td>• Potential for human error and accidents in operations / maintenance.</td>
<td>• Potential for human error and accidents in operations / maintenance.</td>
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<td></td>
<td>• Trucking of 120-mile round trip.</td>
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<td>• Ability to modify Opal Springs project.</td>
<td>• Less potential for delay in ladder, and in reservoir depending on fish release point.</td>
<td>• Potential thermal delay or migration disruptions due to temperature differentials.</td>
<td>• Lose ability for fish to self-select habitat upstream of Pelton Round Butte.</td>
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<td></td>
<td>• Coordination and joint funding with DVWD.</td>
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<td></td>
<td>• Personnel requirements to operate and maintain facility.</td>
<td>• No access to the river reach between the Opal Springs Project and Bowman Dam.</td>
<td>• Lose ability for fish to self-select habitat upstream of Pelton Round Butte.</td>
<td>• No access to the river reach between the Opal Springs Project and Bowman Dam.</td>
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<td>• Need agreement with DVWD for facilities, program, and site access.</td>
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<td>• No access to the river reach between the Opal Springs Project and Bowman Dam.</td>
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Note: Fish marking program costs are not included in upstream alternatives, and this issue would need further study if an upstream alternative is preferred that requires the downstream fish marking program as these programs can be quite costly.
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<th>Water Requirements</th>
<th>Implications to OID Operations</th>
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</thead>
<tbody>
<tr>
<td>DN #1. Volitional Passage through Existing Ochoco Dam Outlet, as Modified for Hydropower Project (no action alternative)</td>
<td></td>
<td>Fish attraction concerns given wide flow range during outmigration season.</td>
<td>Some successful fish passage expected, more through the spillway at high flows and some through outlet-works bypass.</td>
<td>Mortality and injury rates expected, not considered to be an effective fish passage program.</td>
<td>None</td>
<td>None</td>
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<td></td>
<td>None. This alternative utilizes existing facilities with no additional changes to outlet-works planned for the hydropower project.</td>
<td>Low intake elevation not conducive to fish attraction.</td>
<td>No data quantifying survival or injury rates through the existing spillway or outlet-works system.</td>
<td>Attraction to low level intake likely poor.</td>
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<td>May need to run/stop intake to pass fish when migrating. Could pulse on hourly or daily basis when fish are known to be migrating.</td>
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<td>Energy dissipation concerns at regulating gate and stilling basin could cause fish injury.</td>
<td>Attraction to full reservoir prior to bypass. Risk of predation and residualization in reservoir, and potential exposure to warm water temperatures at times.</td>
<td>Outmigrants must negotiate full reservoir prior to bypass.</td>
<td>None</td>
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<td>Francis turbines with high head have poor fish survival performance.</td>
<td>Helix is still unproven</td>
<td>Attraction to intake a concern depending on flows and pool elevation.</td>
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<td>Outmigrants must negotiate full reservoir prior to bypass. Risk of predation and residualization in reservoir, and potential exposure to warm water temperatures at times.</td>
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<td>Allows all fish species to move downstream, including non-native species in reservoir for recreational fishing. Could impact valuable trout fishery below dam.</td>
<td>Helix is still unproven</td>
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<td>Addition of major facilities to operate and maintain.</td>
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<td>Add routine inspection &amp; maintenance tasks.</td>
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<td>Monitoring and removal of debris.</td>
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<td>May need to run/stop intake to pass fish when migrating. Could pulse on hourly or daily basis when fish are known to be migrating.</td>
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<tr>
<td>DN #2. Volitional Passage through Multi-Port Bypass Helix.</td>
<td>Add regulating gates and multi-port bypass to open channel flow for primary and bypass pipes.</td>
<td>Ability to provide good foundation for helix structure.</td>
<td>Passive, full volitional system for fish up to design flow.</td>
<td>Attraction to intake a concern depending on flows and pool elevation.</td>
<td>$80 to over $120 million</td>
<td>$300,000 to $600,000 Plus any marking/monitoring program costs.</td>
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<td>Possible to provide multiple full port bypass pipes.</td>
<td>Routing of multi-port pipe and open channel flow return conduit.</td>
<td>Fish friendly energy dissipation for outlet works, would likely reduce potential for injuries and mortality.</td>
<td>Outmigrants must negotiate full reservoir prior to bypass. Risk of predation and residualization in reservoir, and potential exposure to warm water temperatures at times.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>New 300-cfs Screen for Hydropower Flow.</td>
<td>May not function as well at low flows.</td>
<td>Helix is still unproven</td>
<td>Helix is still unproven</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Likely need to modify spillway and stilling basin for better survival to supplement helix system.</td>
<td></td>
<td>Allows all fish species to move downstream, including non-native species in reservoir for recreational fishing. Could impact valuable trout fishery below dam.</td>
<td>Helix is still unproven</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Addition of major facilities to operate and maintain.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alternative / Characteristic</td>
<td>Modifications to Existing Structures</td>
<td>Technical Limitations</td>
<td>Biological Benefits</td>
<td>Biological Costs/ Risks</td>
<td>Capital Cost OPCC Range (estimate)</td>
<td>Annual Operation and Maintenance Cost (estimate)</td>
<td>Water Requirements</td>
<td>Implications to OID Operations</td>
</tr>
<tr>
<td>-----------------------------</td>
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</tr>
<tr>
<td>DN #3. Volitional Passage through Screened Intake and Bypass at Bowman Dam.</td>
<td>• Provide new intake tower with exclusionary screens and bypass. Similar to Pelton Round Butte Project, but movable screen to accommodate variable reservoir levels. • Assume 400-cfs capacity screens. • Likely need modifications to spillway and stilling basin for better survival to accommodate passage during spill above screen capacity.</td>
<td>• Design flow, must agree on flow first; 400 cfs assumed for analysis. • Tower with movable screens is a major undertaking. On verge of being technically infeasible. • 2-zone screen may be required for lower flows to meet acceleration criteria. • Fish bypass pipe through dam will also be a challenge.</td>
<td>• Provides for full exclusionary screening to prevent all target species from passing through outlet works up to design capacity. • Screened systems of 400 cfs are highly effective. • Sorting facilities could be added to maintain non-native species in the reservoir (see similar issue risks)</td>
<td>• Outmigrants must negotiate full reservoir prior to bypass. Risk of predation and residualization in reservoir, and potential exposure to warm water temperatures at times. • Effective attraction to screen and bypass system. • Fish passage through outlet works and spillway outside of screen flow range could be lower. • Without sorting facilities, allows all fish species to move downstream, including non-native species in reservoir for recreational fishing. Could impact valuable trout fishery below dam.</td>
<td>$75 to $110 million.</td>
<td>$0.5 to $1.5 million Plus any marking/monitoring program costs.</td>
<td>• 400 cfs screen capacity assumed. • Low flow from 20 to 50 cfs desirable.</td>
<td>• Addition of major facilities to operate and maintain. • Add routine inspection &amp; maintenance tasks. • Monitoring and removal of debris.</td>
</tr>
<tr>
<td>DN #4. Floating Surface Collector (FSC) in Prineville Reservoir.</td>
<td>• Addition of new FSC for partial screening alternative. • Provide for moorage and fish transfer. • Exclusionary nets. • New access road, loading dock, and power to site.</td>
<td>• Agree on design flow. Suggest 250 to 300 cfs capacity for discussion. • Could make flow amount phased for future expansion. • Barrier net systems are necessary, and need maintenance. • Remote site, concern for vandalism, safety of facility.</td>
<td>• Provides proven method to collect fish, without full exclusionary screening. • Floating structure would operate at any flow and/or pool elevation to attract fish. • Could relocate FSC for maximum collection. • Likely performance of 60% to above 90% fish collection efficiency. • Sorting facilities could be added to maintain non-native species in the reservoir.</td>
<td>• Some fish may be lost in nets, or nets may have holes, gaps due to varying reservoir levels. • Attraction flow amount may need to be optimized. • May not collect all outmigrants.</td>
<td>$35 to $70 million</td>
<td>$500,000 to $700,000 Plus any marking/monitoring program costs.</td>
<td>• No flow taken from river or outlet works / powerhouse. • Provisions for holding / transport of collected juveniles. Assume 50 gpm, which can be pumped and returned to reservoir. • Truck filling station.</td>
<td>• Adds Operation and Maintenance of a floating fish collection facility. • Safety of access at all times. • Net maintenance required, and monitoring during spill. • Active debris management in reservoir could help with net maintenance.</td>
</tr>
<tr>
<td>Alternative / Characteristic</td>
<td>Modifications to Existing Structures</td>
<td>Technical Limitations</td>
<td>Biological Benefits</td>
<td>Biological Costs/ Risks</td>
<td>Capital Cost OPCC Range (estimate)</td>
<td>Annual Operation and Maintenance Cost (estimate)</td>
<td>Water Requirements Implications to OID Operations</td>
<td></td>
</tr>
<tr>
<td>------------------------------</td>
<td>--------------------------------------</td>
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<td>---------------------</td>
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<td>----------------------------------</td>
<td>-----------------------------------------------</td>
<td>-----------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>DN #5. Floating Surface Collector in Upper End of Prineville Reservoir.</td>
<td>• Addition of new FSC for partial screening alternative. • Provide for moorage and fish transfer. • Exclusionary nets. • New access road, loading dock, and power to site.</td>
<td>• Ability to collect fish at higher flows, may not be able to hold nets in during high flow events, and fish may bypass FSC. • Ability to access and maintain facility at higher flows. • Daily maintenance and fish transport needed. Assume a manual biased fish transport protocol to load trucks from live box. • Debris management after high flows. • Remote site, concern for vandalism, safety of facility.</td>
<td>• Provides proven method to collect fish, without full exclusionary screening. • Floating structure would operate at any flow and/or pool elevation to attract fish. • Could relocate FSC for maximum collection. • Likely performance of 60% to above 90% collection efficiency, depending on flows, use of lead nets, debris, etc. • Helps fish avoid reservoir, with potential for predation and delay concerns. • Sorting facilities could be added to maintain non-native species in the reservoir.</td>
<td>• Loss of fish during higher flows, heavy debris load. • Some fish may be lost in nets, or if they pass the nets would not be able to pass from the reservoir. • Net system challenging and costly to install and maintain • Incompatible with upstream release sites • Interference with recreation.</td>
<td>$35 to $70 million</td>
<td>$500,000 to $700,000 Plus any marking/monitoring program costs.</td>
<td>• No flow taken from river or outlet works / powerhouse. • Provisions for holding / transport of collected juveniles. Assume 50 gpm, which can be pumped and returned to reservoir. • Truck filling station. • Adds Operation and Maintenance of a floating fish collection facility. • Safety of access at all times. • Net maintenance required, and monitoring during spill. • Active debris management in reservoir could help with net maintenance. • Implications to navigation and recreation.</td>
<td></td>
</tr>
<tr>
<td>Alternative / Characteristic</td>
<td>Modifications to Existing Structures</td>
<td>Technical Limitations</td>
<td>Biological Benefits</td>
<td>Biological Costs/ Risks</td>
<td>Capital Cost /OPCC Range (estimate)</td>
<td>Annual Operation and Maintenance Cost (estimate)</td>
<td>Water Requirements</td>
<td>Implications to OID Operations</td>
</tr>
<tr>
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<td>------------------</td>
<td>---------------------------------</td>
</tr>
</tbody>
</table>
| DN #6. In-River Collector  | Permanent in-river structure with rubber dam, fish screens, fish holding.  
Access roads and power.  
May need property acquisition or easements.  
Not feasible for higher flow months with flows in the range of 3,500 cfs.  
Creation of enough depth for a fish screen/collection alternative could backwater to the highway and private property upstream.  
Not considered feasible.  
Ability to collect fish at upstream end of reservoir.  
Loss of use of reservoir.  
System would not be able to collect fish during high flows, therefore considered infeasible for this site.  
|                       | Not feasible for higher flow months with flows in the range of 3,500 cfs.  
Creation of enough depth for a fish screen/collection alternative could backwater to the highway and private property upstream.  
Not considered feasible.  |                       | Loss of use of reservoir.  
System would not be able to collect fish during high flows, therefore considered infeasible for this site.  | n/a  
|                       |                       |                       |                       | n/a  
|                       |                       |                       |                       |                       |                       |                  |                      |
| Upstream of Prineville Reservoir |                       |                       |                       |                       |                       |                  |                      |
|                           |                       |                       |                       |                       |                       |                  |                      |
|                           |                       |                       |                       |                       |                       |                  |                      |

Note: Fish marking program costs are not included in downstream alternatives, and needs to be addressed outside of this study depending on preference of downstream passage alternative as these programs can be quite costly.
CONCLUSIONS AND OBSERVATIONS

This study examined opportunities to pass fish above and below Bowman Dam on the Crooked River. Migratory fish access to the river below Bowman Dam was historically blocked since its original construction in 1961 until last year when a fish ladder was constructed at Opal Springs Dam (located downstream of Bowman Dam). Additionally, a number of recent and ongoing habitat improvement projects in the Crooked River have improved conditions, and as of 2019, summer steelhead and spring Chinook will not encounter any barriers below Bowman Dam. Other studies have addressed the amount and quality of habitat potential upstream of the dam, and we understand the upstream habitats may be of limited quality due to naturally low flows and high summer water temperatures, and historical management practices that have altered riparian vegetation, degraded stream channels and diverted flows. Additional analysis or comment on that issue is outside the scope of this study, which is focused on how to provide technical solutions to passing fish around the dam.

The study identifies five alternative means of providing upstream passage around Bowman Dam, and six alternatives for downstream passage. All alternatives are conceptual in nature, and would require considerable technical and biological evaluation before they could be considered feasible. The preliminary evaluations provided here are based on a cursory understanding of the structure, operation, and planned Hydropower Project at Bowman Dam, and professional experience designing and constructing fish passage facilities at similar dams in the Pacific Northwest.

Bowman Dam, with its hydraulic height of about 160 feet is considered a high-head dam in the region. Upstream passage at high head dams has been achieved, but is not always successful with volitional fish ladders as fish will not always ascend the higher ladders. Collection-and-transport facilities can eliminate the passage concern for high head ladders, but introduce their own risks. Nevertheless, upstream passage via the collection-and-transport options would likely succeed, at least in moving fish above Bowman Dam. Whether fish are able to utilize and populate the available habitat was not addressed. Costs from $2 to $5 million are estimated to construct these upstream collection-and-transport facilities.

Downstream passage options exist, but they could be quite costly for this dam. Fluctuating reservoir levels and varying flows present a challenge for conventional systems. The concepts believed to have the highest chance of success are Alternatives DN #2, the Helix Bypass, and DN #4, the FSC near Bowman Dam. Those may both be quite costly depending on the desired flow capacity, but the 300 to 400 cfs flow range identified in this study are reasonable for this
system. Costs from $50 million to over $120 million are estimated to construct these downstream systems.

8 ACKNOWLEDGMENTS

R2 wishes to acknowledge and thank the following individuals for their input and information provided to help us understand and describe the physical and operational setting of the project, the fisheries resources, the proposed Hydroelectric Project, and for reviewing the information we compiled for this study.

Mr. Bruce Scanlon – General Manager, Ochoco Irrigation District

Mr. Kevin Crew, P.E. – Black Rock Consulting, Inc.

Mr. Sean Gibbs and Mr. Ian Courter – Mount Hood Environmental

Mr. Jonathan Rocha – U.S. Bureau of Reclamation

Mr. Marty Vaughn – Biota Pacific Environmental Sciences, Inc.
REFERENCES


R2 Resource Consultants, Inc. and Biota Pacific Environmental Sciences, Inc (R2 and Biota). 2014. Deschutes Basin Habitat Conservation Plan, Final Study Report. Study 14-2:


Wise, Ted. East Region Hydropower Coordinator, Oregon Department of Fish and Wildlife, Bend, OR. June 3, 2019. Personal communication, letter to Bruce Scanlon (Ochoco Irrigation District) regarding Bowman Dam Hydroelectric Project, Docket P-14791; ODFW Comments on the Pre-Application Document.
APPENDIX A

Biological Data: Species Periodicity and Peak Daily Fish Passage
Fish passage counts from Portland General Electric’s Pelton Round Butte Project are utilized to help estimate maximum daily run sizes for initial planning of passage facilities at Bowman Dam. Numbers were compiled from the PGE Website (https://www.portlandgeneral.com/corporate-responsibility/environmental-stewardship/water-quality-habitat-protection/fish-counts-fish-runs/deschutes-fish-runs), and from the Ochoco Fish Passage study (R2 and Biota 2014). The information was summarized and processed as illustrated in Tables A-1 and A-2. Not all fish passing the Pelton Round Butte Project will pass Bowman Dam, but this approach provided a simple basis for examining the adequacy of passage facility alternatives.

These numbers are considered preliminary for planning reasons only. Additional analysis based on other factors (basin capacity, etc.) is recommended should fish passage facilities be implemented at Bowman Dam. Regardless, given the peak numbers of adult fish per day observed at Pelton Round Butte Dam and estimates of juvenile emigrants at Ochoco Dam reported by R2 and Biota (2014), the number of fish passing Bowman Dam is not expected to affect the facility definition or sizing.

Based on the results, the following values are recommended for planning levels in this study.

### Table A-1. Estimated peak numbers of adult fish passing Pelton Round Butte Dam.

<table>
<thead>
<tr>
<th>Species</th>
<th>Estimated Peak Fish / Day (Based on Average Peak Monthly Value)</th>
<th>High Planning Level Number (3 Times the Peak Observed Average Value)</th>
<th>Peak Month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer Steelhead</td>
<td>33</td>
<td>100</td>
<td>February</td>
</tr>
<tr>
<td>Chinook Salmon</td>
<td>60</td>
<td>200</td>
<td>June</td>
</tr>
</tbody>
</table>

Table A-3 is also provided as a reference, which was provided by ODFW in their response comments to the PAD. This figure also confirms the run migration timing noted in the report.
Table A-2. Summary of Summer Steelhead Data at Pelton Round Butte.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>981</td>
<td>665</td>
<td>267</td>
<td>601</td>
<td>518</td>
<td>443</td>
<td>486</td>
<td>246</td>
<td></td>
</tr>
<tr>
<td>Feb</td>
<td>317</td>
<td>927</td>
<td>356</td>
<td>489</td>
<td>447</td>
<td>472</td>
<td>273</td>
<td>277</td>
<td></td>
</tr>
<tr>
<td>Mar</td>
<td>289</td>
<td>567</td>
<td>282</td>
<td>369</td>
<td>143</td>
<td>209</td>
<td>130</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>Apr</td>
<td>87</td>
<td>73</td>
<td>10</td>
<td>63</td>
<td>17</td>
<td>8</td>
<td>26</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Jun</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Jul</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Aug</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Sep</td>
<td>3</td>
<td>31</td>
<td>73</td>
<td>59</td>
<td>35</td>
<td>37</td>
<td>31</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Oct</td>
<td>121</td>
<td>0</td>
<td>448</td>
<td>362</td>
<td>440</td>
<td>273</td>
<td>159</td>
<td>108</td>
<td></td>
</tr>
<tr>
<td>Nov</td>
<td>186</td>
<td>0</td>
<td>391</td>
<td>497</td>
<td>474</td>
<td>385</td>
<td>318</td>
<td>82</td>
<td></td>
</tr>
<tr>
<td>Dec</td>
<td>297</td>
<td>0</td>
<td>655</td>
<td>433</td>
<td>207</td>
<td>278</td>
<td>405</td>
<td>289</td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td>2285</td>
<td>2269</td>
<td>2484</td>
<td>2884</td>
<td>2286</td>
<td>2107</td>
<td>1831</td>
<td>1189</td>
<td>2167</td>
</tr>
</tbody>
</table>

- **Average/Month**: 217
- **Max/Month**: 66
- **Average/Day in Max Month**: 99
- **Average/Day in Max Month**: 100

**Planning Levels for maximum number of fish to be transported per day.**

- Reference value of 10% of average total fish/year as a conservative peak planning level estimate: 217
- Reference value of 2 times the average day in maximum month: 66
- Reference value of 3 times the average day in maximum month: 99
- Number of maximum fish to be transported per day recommended for planning at Bowman Dam (selected based on above metrics): 100

Maximum value of average monthly number of fish, and max average per day: 526

Maximum number of summer steelhead observed in peak month, and max calculated / day: 981
### Table A-3. Summary of Spring Chinook Salmon Data at Pelton Round Butte.

<table>
<thead>
<tr>
<th>Month</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>Average/ Month</th>
<th>Max/ Month</th>
<th>Average/ Day in Max Month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Feb</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Mar</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
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<td>0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Apr</td>
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<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
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</tr>
<tr>
<td>May</td>
<td>580</td>
<td>64</td>
<td>215</td>
<td>165</td>
<td>90</td>
<td>325</td>
<td>395</td>
<td>167</td>
<td>250</td>
<td>8.1</td>
<td>18.7</td>
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<tr>
<td>Jun</td>
<td>1220</td>
<td>935</td>
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<td>404</td>
<td>351</td>
<td>1795</td>
<td>481</td>
<td>245</td>
<td>1795</td>
<td>23.5</td>
<td>59.8</td>
<td>120</td>
</tr>
<tr>
<td>Jul</td>
<td>748</td>
<td>362</td>
<td>98</td>
<td>325</td>
<td>292</td>
<td>412</td>
<td>110</td>
<td>39</td>
<td>748</td>
<td>9.6</td>
<td>24.1</td>
<td>180</td>
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<tr>
<td>Aug</td>
<td>272</td>
<td>81</td>
<td>31</td>
<td>214</td>
<td>88</td>
<td>67</td>
<td>17</td>
<td>29</td>
<td>748</td>
<td>3.2</td>
<td>8.8</td>
<td>200</td>
</tr>
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<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.0</td>
<td>7.0</td>
<td>0.2</td>
</tr>
<tr>
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<td>Dec</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

| Totals | 2832  | 1443  | 558   | 1145  | 825   | 2605  | 1003  | 481   | 1362  | 705            | 24         | 1795                    |

**Maximum value of average monthly number of fish, and max average per day:** 705 24

**Maximum number of summer steelhead observed in peak month, and max calculated / day:** 1795 60

**Planning Levels for maximum number of fish to be transported per day.**

- Reference value of 10% of average total fish/year as a conservative peak planning level estimate: 136
- Reference value of 2 times the average day in maximum month: 120
- Reference value of 3 times the average day in maximum month: 180

**Number of maximum fish to be transported per day recommended for planning at Bowman Dam (selected based on above metrics):** 200
Table A-4. Life History Periodicity Chart for Native Salmonids in the Crooked River Basin (personal communication with Ted Wise, Oregon Department of Fish and Wildlife, East Region Hydropower Coordinator, June 3, 2019).

<table>
<thead>
<tr>
<th>LIFE HISTORY PERIODICITY CHART FOR NATIVE SALMONIDS IN THE CROOKED RIVER BASIN</th>
<th>LIFE STAGE PRESENCE AND ACTIVITY PERIODS</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPRING CHINOOK SALMON</td>
<td></td>
</tr>
<tr>
<td>• UPSTREAM MIGRATION/HOLDING</td>
<td>OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP</td>
</tr>
<tr>
<td>• SPAWNING</td>
<td></td>
</tr>
<tr>
<td>• EGG/INCUBATION</td>
<td></td>
</tr>
<tr>
<td>• OCEAN REARING</td>
<td>One to Three Years</td>
</tr>
<tr>
<td>• STREAM REARING</td>
<td></td>
</tr>
<tr>
<td>• SMOLT EMIGRATION</td>
<td></td>
</tr>
<tr>
<td>• HATCHING/EMERGENCE</td>
<td></td>
</tr>
<tr>
<td>SUMMER STEELHEAD TROUT</td>
<td></td>
</tr>
<tr>
<td>• UPSTREAM MIGRATION/HOLDING</td>
<td>OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP</td>
</tr>
<tr>
<td>• SPAWNING</td>
<td></td>
</tr>
<tr>
<td>• EGG/INCUBATION</td>
<td></td>
</tr>
<tr>
<td>• OCEAN REARING</td>
<td>One – Three Years (Mostly One – Two)</td>
</tr>
<tr>
<td>• STREAM REARING</td>
<td></td>
</tr>
<tr>
<td>• SMOLT EMIGRATION</td>
<td></td>
</tr>
<tr>
<td>• HATCHING/EMERGENCE</td>
<td></td>
</tr>
<tr>
<td>REDBAND TROUT</td>
<td></td>
</tr>
<tr>
<td>• SPAWNING</td>
<td>OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP</td>
</tr>
<tr>
<td>• EGG/INCUBATION</td>
<td></td>
</tr>
<tr>
<td>• HATCHING/EMERGENCE</td>
<td></td>
</tr>
<tr>
<td>MOUNTAIN WHITE FISH</td>
<td></td>
</tr>
<tr>
<td>• SPAWNING</td>
<td>OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP</td>
</tr>
<tr>
<td>• EGG/INCUBATION</td>
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<tr>
<td>• HATCHING/EMERGENCE</td>
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<tr>
<td>• REARING</td>
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<tr>
<td>BULL TROUT</td>
<td></td>
</tr>
<tr>
<td>• UPSTREAM MIGRATION/HOLDING</td>
<td>OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP</td>
</tr>
<tr>
<td>• SPAWNING</td>
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<tr>
<td>• EGG/INCUBATION</td>
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<tr>
<td>• HATCHING/EMERGENCE</td>
<td></td>
</tr>
<tr>
<td>• REARING</td>
<td></td>
</tr>
</tbody>
</table>

**LEGEND:**
- Occurrence

Source: ODFW – East Region Hydropower Program

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1 November 1 – April 31 upper extent of potential upstream foraging is City of Prineville (RM7), May 1 – October 31 upper extent of foraging use is Highway 97 Bridge (RM2). Source personal comm. Brett Hodgesen ODFW, Tim Potter ODFW.
APPENDIX B

Conceptual Design Drawings of Proposed Hydropower Project
The following conceptual design drawings prepared by Black Rock Consulting were provided in the PAD as Exhibits F and G, and are used with permission from OID and Black Rock.