Draft Technical Report

Report on Fish Entrainment and Mortality at Mason Dam, OR

Mason Dam Hydroelectric Project (FERC No. 12686)

Prepared for:

Baker County
Baker City, OR

Prepared by:

GeoSense
Idaho Falls, ID

February 2011

Introduction

The Federal Energy Regulatory Commission's (FERC) 9-Mar-2007 Study Plan Determination concurs with a Baker County proposal to screen the Mason Dam intake in lieu of performing a study of redband trout and bull trout entrainment through Mason Dam. Subsequent to this Determination, Baker County concluded that it would not be economically feasible to screen the dam intake due to its deep submergence in Phillips Reservoir. Baker County therefore conducted a study to address potential effects of the Mason Dam Hydroelectric Project on entrainment and mortality of fish passing through Mason Dam. The study was conducted by reviewing existing entrainment and mortality studies for projects having similar characteristics to the proposed project. The purpose of this work is to determine the potential changes in fish entrainment and mortality that would occur if the hydropower project was built.

Objectives

The objectives of this study are:

- Compile intake characteristics and turbine specifications for the Mason Dam project Hydroelectric Project;

- Conduct a literature study and select, from the large existing body of work on fish entrainment and turbine mortality, studies that will permit a comparison of entrainment and mortality between existing projects and the proposed project;

- Assess fish entrainment and turbine mortality for the proposed project in comparison to existing conditions at Mason Dam;

Background

Phillips Reservoir and the Powder River below Mason Dam support populations of resident and hatchery fish including both native and non-native species. Fish populations in both the reservoir and river have been significantly altered by the presence of man-made alterations of the Powder River system that have been in place since the early 1900's. Important man-made alterations include Mason Dam, extensive dredge mining in the riverbed upstream of Phillips Reservoir, and irrigation diversions both above and below Mason Dam.

Present Conditions

Fish species in Phillips Reservoir include rainbow trout (*Oncorhynchus mykiss*), crappie (*Pomoxis spp*), smallmouth and largemouth bass (*Micropterus dolomieui, M. salmoides*), yellow perch (*Perca flavescens*), walleye (*Sander vitreus*), northern pikeminnow (*Ptychocheilus oregonensis)* and various species of sucker (Baker County, 2009). Yellow perch and walleye were introduced in the 1980's and yellow perch have subsequently dominated the lake fishery. There have been several attempts to rid the lake of yellow perch, with the most recent attempt in 2010. Lake-wide netting resulted in the collection of 46,522 yellow perch and 1,047 other fish species in 2009, and 337,745 yellow perch and 1,069 other fish species in 2010 (ODF&W, personal communication).

The Powder River subbasin holds 4 distinct populations of redband trout. These occupy the Powder River from the mouth to Thief Valley Dam, Eagle Creek, the Powder River from Thief Valley Dam to Mason Dam and the Powder River above Mason Dam . Fingerling and catchable rainbow trout are stocked in the river annually. In addition, the Powder River below Mason Dam would likely contain populations of yellow perch and other Phillips Lake species that are entrained through the dam.

Bull trout are not known to occur in the immediate study area but do occur in the headwater tributaries of the Powder River. The U.S. Fish and Wildlife Service (FWS) has concluded that the operation and maintenance of Mason Dam by Reclamation is “not likely to adversely affect” bull trout (US Fish and Wildlife Service, 2005). No bull trout were captured during the 2009 lake-wide netting in Phillips Reservoir. There are no known bull trout in the Powder River below Mason Dam. Potential habitat is limited by large fluctuations in reservoir releases over the growing season and the lack of habitat complexity (Ecowest Consulting, 2009).

Mason Dam, which has been operating since 1968, is a barrier to upstream fish passage and an impediment to downstream fish passage. Since 1968, fish in Phillips Reservoir have been and continue to be subject to entrainment through Mason Dam into the downstream Powder River. Fish can enter the dam through a submerged intake into a 56-inch steel penstock (Figure 1). The sill of the intake structure is at a depth of 98 ft below the normal high water elevation of Phillips Reservoir.

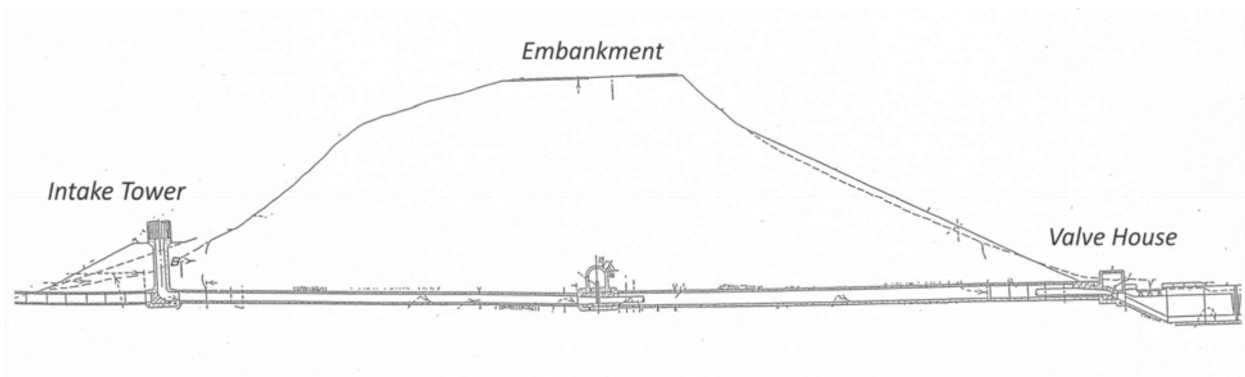


FIGURE 1. CROSS SECTION DRAWING OF MASON DAM (FROM RECLAMATION).

Once entrained, fish currently exit the dam through either of two 33-in slide gate valves. The slide gates operate by controlling the position of a rectangular steel plate within the flow path. During normal releases the flow path is partially blocked by the plate, causing the water to accelerate through the partial opening and exit the valve into the Powder River as a jet of water (Figure 2). An unknown percentage of these entrained fish experience injury or mortality during passage through the valves. Surviving fish become resident in the riverine habitat downstream of the dam.

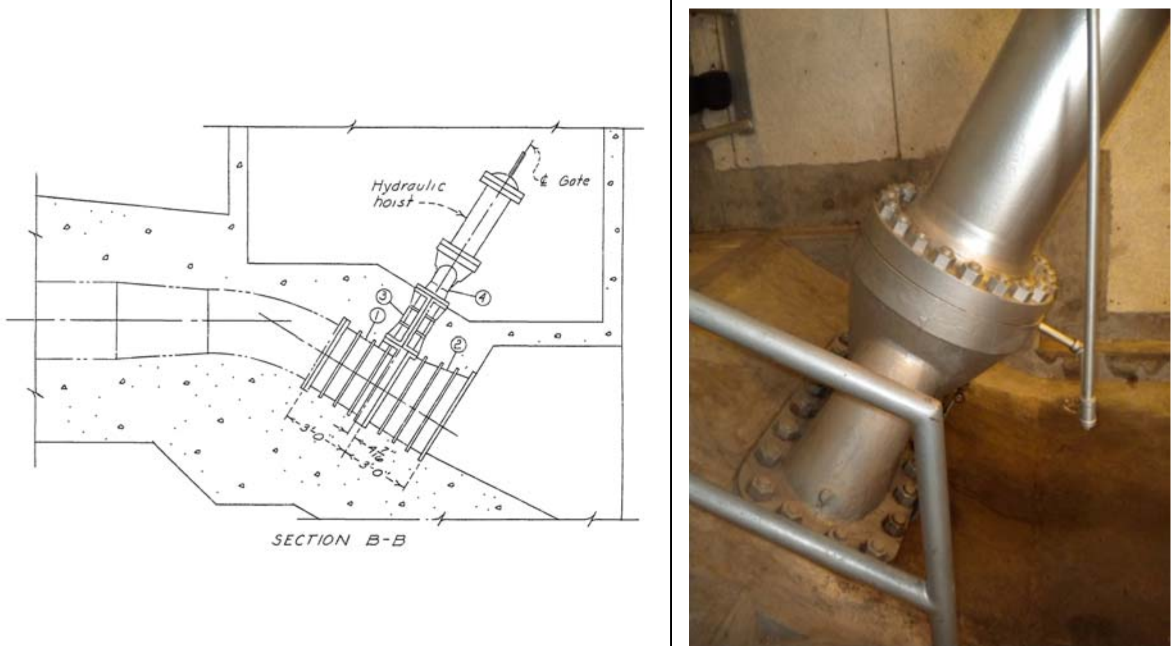


FIGURE 2. DRAWING AND PHOTOGRAPH OF A MASON DAM SLIDE GATE VALVE.

Proposed Conditions

The proposed Mason Dam Hydroelectric project would make no changes to the submerged intake structure that withdraws water from Phillips Reservoir. If constructed the project would only modify the outlet works on the downstream side of the dam. A bifurcation would be installed so that a portion of the withdrawn water flow, including any entrained fish, would pass through the project turbine rather than through the slide gate valves (Figure 3). Under the proposed project, as with existing conditions, fish that survive passage through Mason Dam would become resident in the riverine habitat downstream.

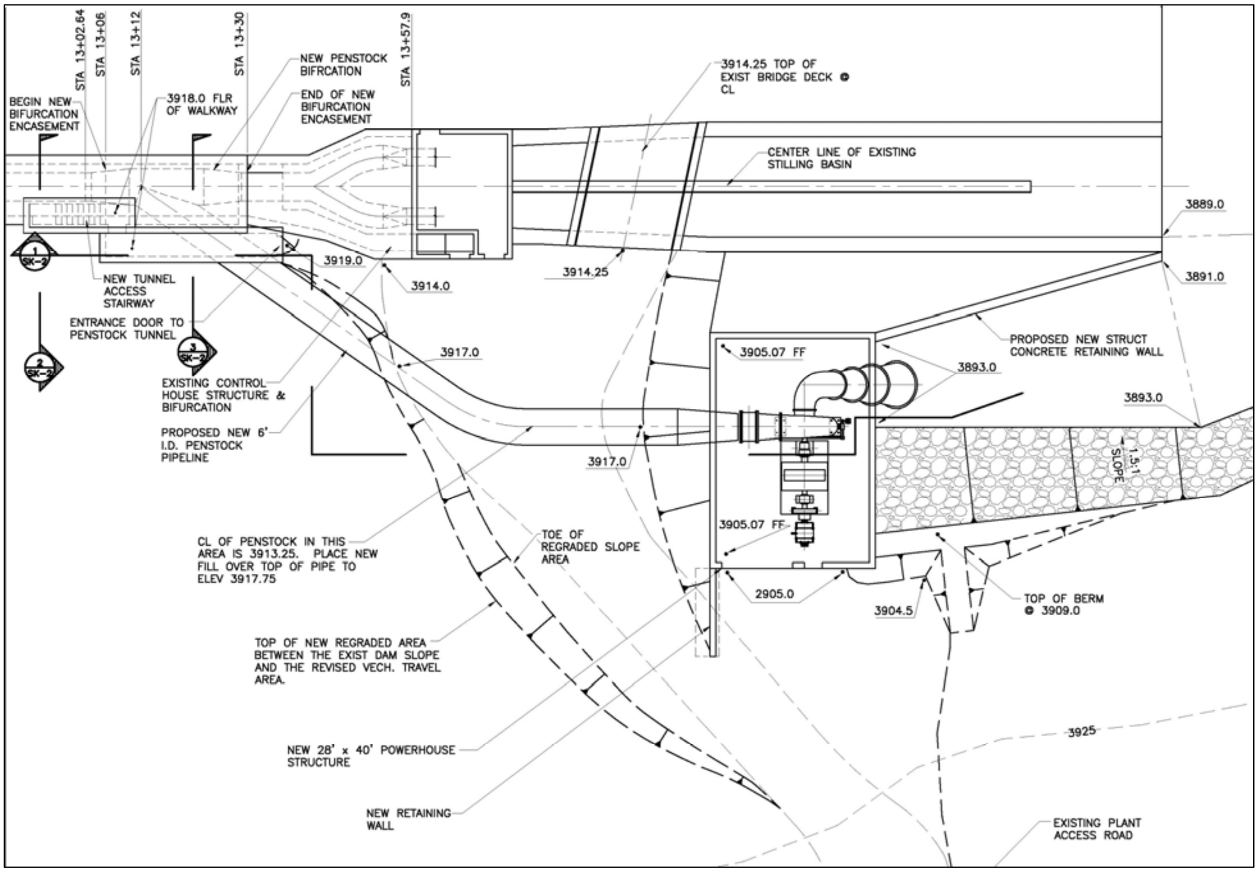


FIGURE 3. DRAWING OF PROPOSED MODIFICATION TO MASON DAM OUTLET WORKS.

Fish Entrainment

In its Preliminary Licensing Proposal, Baker County states that the proposed Mason Dam Hydroelectric Project would make no changes to the submerged intake structure that withdraws water from Phillips Reservoir, would not change the operating rules for Phillips Reservoir, and would not change the amount or timing of water withdrawals through Mason Dam (Baker County, 2009). Under these conditions the rate of fish entrainment would not change as a result of project construction. Fish would be entrained through Mason Dam at the same rate with or without the hydroelectric project.

Estimate of Entrainment Rate at Mason Dam

Entrainment rates through Mason Dam may be estimated by comparison with similar projects where entrainment rates have been measured by scientific studies. The approach for assessing fish entrainment was to compile existing study data from projects having characteristics similar to the proposed project and interpret these data in the context of known fishery data for the Powder River in the project vicinity. In the past 25 years there have been many entrainment studies conducted at dams in cold water and warm water environments similar to the expected conditions at the Mason Dam project site (FERC 1995). Potential physical factors affecting entrainment include reservoir size, water flow through the intake, and dam height/depth of intake. Potential biological factors include fish species, fish size, and seasonal and diurnal movements.

The potential magnitude of annual entrainment through the proposed dam was evaluated by first reviewing trends from entrainment field studies completed at other hydropower projects. Of about 50 studies performed priamily in the 1980s and 1990s, 24 were selected for review and are listed in Table 2 (EPRI 1992; FERC 1995; FERC 1996a; FERC 1996b; FERC 1997). These projects were selected because they have characteristics similar to the proposed Mason Dam Hydroelectric Project in that they are located on small, mainstem rivers with primarily warm water fisheries. Projects missing key information or representing obvious statistical outliers were eliminated from further review.

TABLE 1. ESTIMATES OF FISH ENTRAINMENT AT 24 HYDROPOWER PROJECTS LOCATED ON WARM WATER FISHERIES.

PROJECT/RIVER SYSTEM	STATE	RESERVOIR SIZE (ACRES)	DAM HEIGHT (FEET)	TOTAL HYDRAULIC CAPACITY (CFS)	OPERATING MODE[A]	TOTAL ANNUAL ENTRAINMENT (FISH)
Escanaba Dam 3/Escanaba	MI	182	31	1,250	ROR	21,762
Brule/Menominee	WI	545	63	1,377	PK	25,296
Tower/Black	MI	102	20	360	ROR	30,295
Cataract/Escanaba	MI	180	70	450	PK	31,094
Escanaba Dam 1/Escanaba	WI	75	25	1,175	ROR	45,552
Park Mill/Menominee	WI	539	22	2,500	ROR	46,138
Rogers/Muskegon	MI	610	39	2,400	ROR	55,875
Kleber/Black	MI	270	44	400	ROR	63,145
Crowley/NF Flambeau	WI	422	28	1,480	ROR	66,920
Pine/Pine	WI	180	33	624	ROR	67,977
Thornapple/Flambeau	WI	295	16	1,400	ROR	68,328
Buchanan/St. Joseph	MI	423	20	3,798	ROR	70,006
Caldron Falls/Peshtigo	WI	1,180	80	1,430	PK	78,335
Sandstone Rapids/Peshtigo	WI	150	42	1,400	PK	81,303
Moores Park/Grand	MI	240	21	1,200	ROR	85,848
Grand Rapids/Menominee	WI	300	28	3,870	ROR	91,646
Prickett/Sturgeon	MI	773	57	642	ROR	115,979
Mio/Au Sable	MI	860	36	2,700	ROR	120,323
White Rapids/Menominee	WI	435	29	5,188	PK	144,554
Foote/Au Sable	MI	1,800	52	4,050	PU	154,779
Loud/Au Sable	MI	790	31	2,600	PU	162,526
Rothschild/Wisconsin	WI	1,604	29	3,300	ROR	212,720
Croton/Muskegon	MI	1,209	40	3,700	ROR	219,761
Cooke/Au Sable	MI	1,320	48	3,600	PU	222,423
Mason Dam	*OR*	*2,234*	*153*	*875*	*ROR*	-

[a] PK = peaking; PU = pulsed (intermittent operation to maximize turbine efficiency); ROR = run-of-river

None of the studies available for comparison to Mason Dam had dam heights or overall size comparable to Mason Dam and Phillips Reservoir. The Caldron Falls/Peshtigo project, with an annual entrainment rate of 78,335 fish, was judged to be the best fit to the Mason Dam project with an emphasis on reservoir size and dam height. The Prickett/Sturgeon project, with an annual entrainment of 115,979 fish, was judged to be the best fit to the Mason Dam project with an emphasis on hydraulic capacity.

Reservoir size largely determines the turnover rate and habitat characteristics for a reservoir, which in turn can strongly influence fishery characteristics such as species abundance and composition of resident fishes subject to the risk of entrainment. Figure 4, which shows data from the 24 entrainment studies in Table 2, suggests that greater entrainment would be expected for larger reservoirs. On the basis of reservoir size alone, the proposed Mason Dam project would result in the entrainment of about 250,000 fish per year.

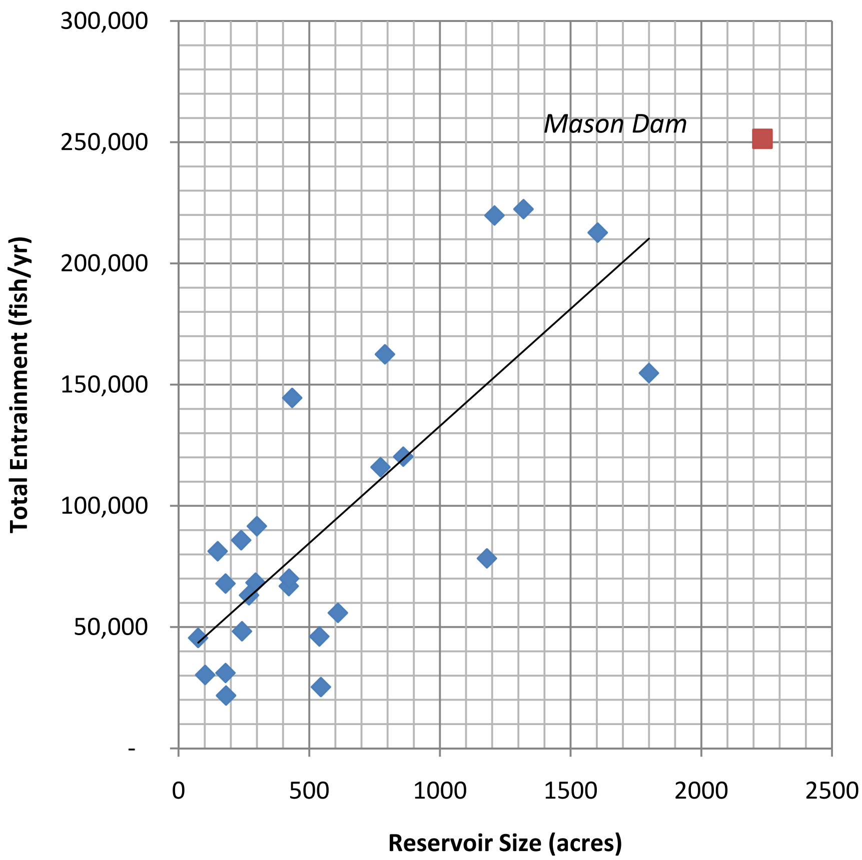


FIGURE 4. PLOT OF TOTAL ANNUAL ENTRAINMENT VS. RESERVOIR SIZE FOR STUDIES LISTED IN TABLE 2.

A project's hydraulic capacity might also be related to annual entrainment since it is an approximate measure of the water flow through the project. Figure 5 shows entrainment as a function of total hydraulic capacity for the Table 2 projects. The plot indicates that greater entrainment would be expected for projects having greater hydraulic capacity. On the basis of hydraulic capacity alone, the proposed Mason Dam project would result in the entrainment of about 74,000 fish per year.

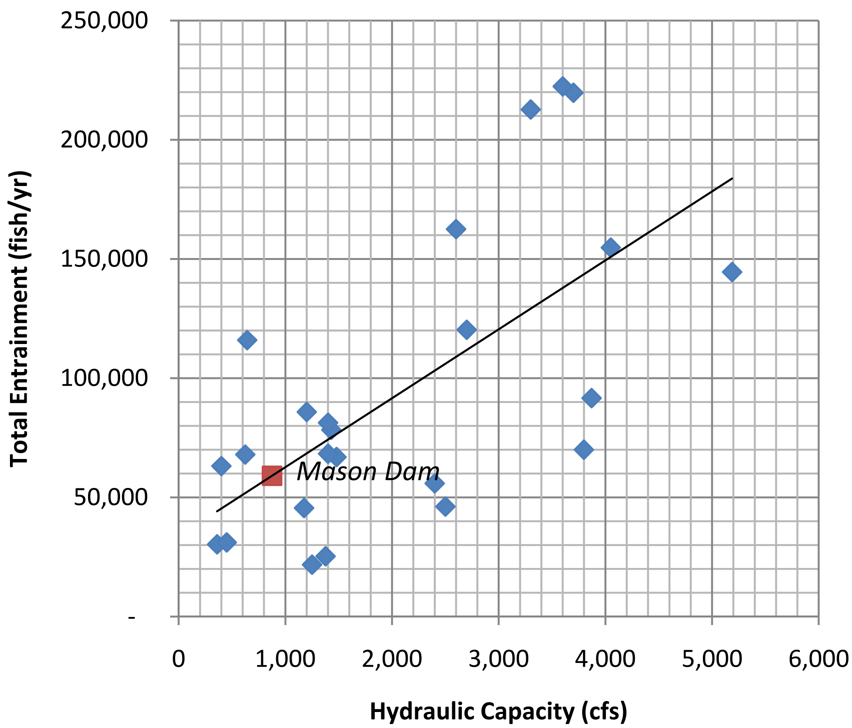


FIGURE 5. PLOT OF TOTAL ANNUAL ENTRAINMENT VS. HYDRAULIC CAPACITY FOR STUDIES LISTED IN TABLE 2.

Dam height might also be related to annual entrainment since abundant shallow water species are less likely to occupy the deep water habitat near high dams. However, the referenced literature contained few entrainment studies for dams over about 50 ft in height and no studies for dams over 80 ft. Mason Dam, with a hydraulic height of 153 ft, is considerably higher than the other dams in the entrainment database. An estimate of annual entrainment based on dam height for the Mason Dam project was therefore not attempted. A general discussion of water depth as a factor in entrainment is provided in the next section.

The various estimates of entrainment for Mason Dam based on comparison with existing projects are summarized in Table 3. The estimates range from about 75,000 to 250,000 fish annually, with an average of 130,130.

TABLE 2. SUMMARY OF ENTRAINMENT ESTIMATES FOR MASON DAM.

ESTIMATE	**ESTIMATE BASIS**	**TOTAL ANNUAL ENTRAINMENT (FISH)**
Caldron Falls/Peshtigo	Project with best overall fit with emphasis on reservoir size and dam height	78,335
Prickett/Sturgeon	Project with best overall fit with emphasis on hydraulic capacity	115,979
Reservoir size	Extrapolated from all 24 studies based on reservoir size	251,934
Hydraulic capacity	Interpolated from all 24 studies based on hydraulic capacity	74,273
	AVERAGE	130,130

Entrainment at Facilities with High Dams

Two reservoirs, Beulah Reservoir on the Malheur River in eastern Oregon and Arrowrock Reservoir on the Boise River in southwestern Idaho, were the subject of recent entrainment-related studies. Beulah and Arrowrock Reservoirs are impounded by relatively high dams with deep intakes as shown in Table 1. In each case, entrainment was qualitatively assessed by fish capture efforts in the river downstream of the reservoirs. Neither study was designed to distinguish between fish that were resident in the waters downstream of the dams versus fish that had been recently entrained through the dams.

TABLE 3. COMPARISON OF RESERVOIR FACILITY DIMENSIONS.

DIMENSION	PHILLIPS RESERVOIR/MASON DAM	BEULAH RESERVOIR/AGENCY VALLEY DAM	ARROWROCK RESERVOIR/ARROWROCK DAM
Elevation normal high water	4,062 ft	3,340 ft	3,216 ft
Hydraulic Height	153 ft	80 ft	257 ft
Spillway elevation	4,077	3,343	3,220
Intake elevation	3,975	3,263	3,012
Intake depth	87 ft	77 ft	204 ft
Valve type	Slide gates	Jet-flow	Clamshell

The Burn Paiute Tribe published a report on capture of bull trout below Agency Valley Dam from 1999 – 2005 (Fenton, 2006). In 2000, operations at Agency Valley Dam were modified to release water through a submerged intake structure rather than over the dam spillway. In the Agency Dam study, fish capture was compared before and after the operational change. Fish were collected downstream from the dam by rod and reel angling. In 1999, when releases were made over the spillway, one bull trout was collected downstream of the dam for every 20 angling hours. In 2000, when releases were made thorough the submerged intake, one bull trout was collected for every 100 angling hours and from 2001 to 2005 no bull trout were collected. These results suggest that bull trout are less susceptible to entrainment through a deep intake than through an intake that withdraws surface waters.

The Bureau of Reclamation published a technical report describing capture of bull trout below Arrowrock Dam on the Boise River in southwestern Idaho from 2000 – 2004 (Reclamation, 2005). The Arrowrock study, which was conducted in support of a project to replace the dam's primary release valves, reported that bull trout capture rates were related to the depth of water withdrawal:

> *"In addition, Reclamation drafted Arrowrock Reservoir to (>1% active pool capacity) in the Fall of 2003 and had a large sample of radio tagged bull trout that were monitored. Entrainment rates through Arrowrock Dam were documented to be significantly higher during the construction period (Salow & Hostettler, 2004). Since the replacement of the Ensign valves allows a higher discharge at a deeper depth in the water column, entrainment rates would be expected to decrease through time at Arrowrock Dam."*

On the basis of these studies at high dams in the region of Mason Dam, it seems likely that the Mason Dam project would entrain fewer fish than otherwise comparable shallow reservoirs. The average depth of the Mason Dam intake tower sill below the reservoir surface ranges form 55 – 74 ft, with shallower depths beginning in late summer and deeper depths occurring March to August (Table 4). The Mason Dam operator has observed yellow perch in the tailrace pool from about mid-August through early October, particularly in low water years, when water levels are low but water is still being released for irrigation (Baker County, personal communication).

TABLE 4. AVERAGE WATER ELEVATION AND DEPTH TO INTAKE SILL FOR PHILLIPS RESERVOIR FROM 1968 – 2008.

MONTH	AVG RESERVOIR ELEVATION (FT ASL)	AVG DEPTH TO INTAKE SILL (FT)
Jan	4031	56
Feb	4033	58
Mar	4038	63
Apr	4045	70
May	4047	72
Jun	4049	74
Jul	4046	71
Aug	4035	60
Sep	4029	54
Oct	4028	53
Nov	4028	53
Dec	4030	55

Size Composition

Of the studies that reported comprehensive size information, small or young-of-year fish generally comprised a large proportion of the fish that were entrained. Over 90% of the fish captured in some studies were less than four inches in length and in most cases over 90% were less than eight inches in length (Table 4). This is important from the standpoint that smaller fish passing through the turbines can generally be expected to suffer lower levels of mortality (usually <6%) and that the emigration of young-of-year fish from an impoundment usually constitutes a minimal impact to the harvestable component of the upstream population (EPRI 1992). The predominance of fish less than four inches in length at most sites suggests that many of the larger fish that could physically pass through the trashracks either avoid doing so or show an overall lower tendency towards downstream emigration than young-of-year fish.

TABLE 5. SIZE DISTRIBUTION OF ENTRAINED FISH (FROM EPRI 1992; FERC 1995; FERC 1996A; FERC 1997).

PROJECT AND LOCATION	STATE	SIZE DISTRIBUTION OF ENTRAINED FISH
Kleber	MI	46% < 3.9 in (100 mm) 96% < 7.9 in (200 mm)
Prickett	MI	84% < 4 in 99% < 8 in

PROJECT AND LOCATION	STATE	SIZE DISTRIBUTION OF ENTRAINED FISH
Tower	MI	50% < 3.9 in (100 mm) 82% < 7.9 in (200 mm)
Centralia	WI	95% < 3.9 in (100 mm)
Pine	WI	49% < 3.9 in (100 mm) 94% < 7.9 in (200 mm)
Wisconsin River Diversion	WI	96% < 3.9 in (100 mm)
Thornapple	WI	68% < 4 in 85% < 8 in
Escanaba Dam #1	MI	59% < 5.0 in 93% < 7.5 in
Escanaba Dam #3	MI	75% < 5 in 96% < 7.5 in
Rothschild	WI	88% young-of-year
Brule	WI	86% < 6 in
White Rapids	WI	82% < 4 in
Grand Rapids	WI	81% < 4 in
Park Mill	WI	79% < 4 in
Caldron Falls	WI	63% < 4 in 91% < 6 in
Sandstone Rapids	WI	93% < 4 in
Crowley	WI	78% < 4 in

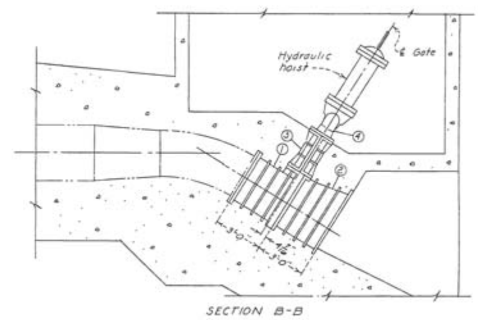
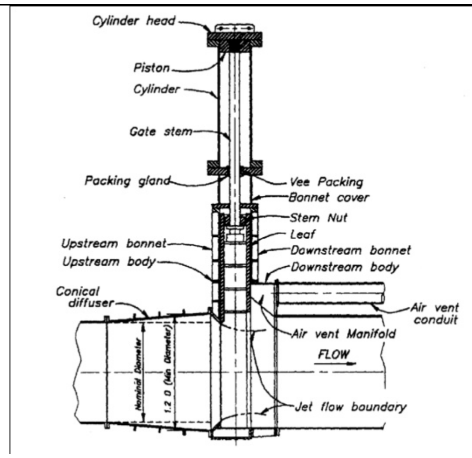
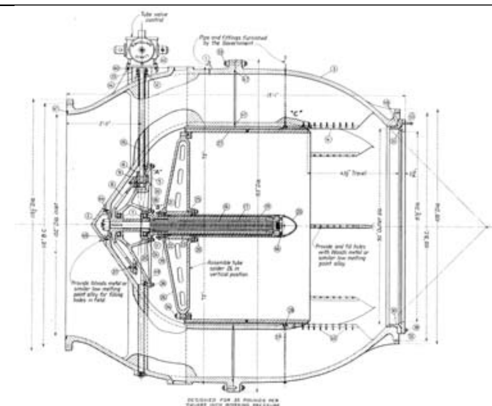
Species, and Seasonal Composition

Species composition data from entrainment studies show that the predominant species entrained through projects is highly variable. At Mason Dam, it seems reasonable to expect that the species composition of entrained fish would reflect the overall lake population, which is dominated by yellow perch. Walleye might be entrained at a higher rate than other species in Phillips Reservoir due to its habitat preference for deeper water. Perch, smallmouth bass, walleye and rainbow trout all spawn in the spring or early summer (Fisheries and Oceans Canada, 2010). Since spawning occurs in shallow water habitats, it is reasonable to expect that entrainment through the deep intake tower would be lower during the spawning period, when Phillips Reservoir is usually at or near its maximum water level. Similarly, entrainment may be higher in the late summer when reservoir levels are low and fish seek cooler, deeper water.

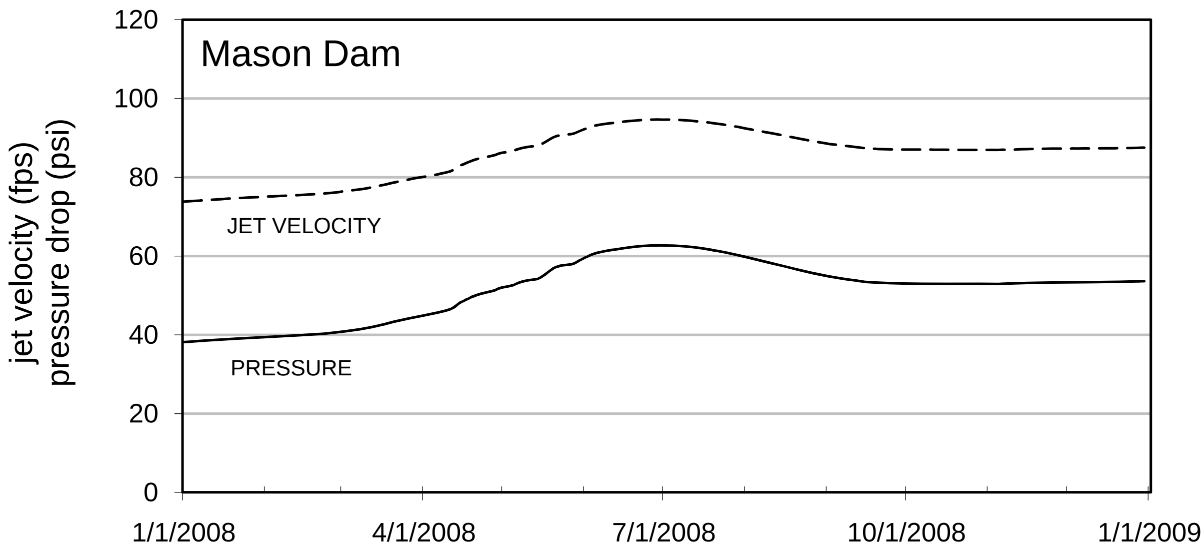
Valve Mortality

Currently, fish entrained through Mason Dam are ejected through two 2’ 9” slide gate valves into the tailrace below the dam. Fish mortality caused by passage through large release valves has not been extensively studied. However, mortality due to release valves has been previously studied at Tieton Dam on the Tieton River in Washington and at Wickiup Dam on the Deschutes River in Oregon. A comparison of the outlet works for these three dams is given in Table 6.

TABLE 6. COMPARISON OF OUTLET WORKS AT MASON DAM, WICKIUP DAM AND TIETON DAM.

PROJECT	VALVE TYPE	AVG MONTHLY FLOW (CFS)	HEAD (FT)	VALVE DRAWING
Mason Dam	2@ 33-in Slide Gate valve	10 – 270	68 - 157	
Tieton	2 @ 60-in Jet-Flow valve	90 – 1,600	46 – 210	
Wickiup	2 @ 90-in Fixed-cone (Tube) valve	160 - 1600	7 - 79	

Since jet-flow valves operate similarly to the slide gate valves used at Mason Dam, the mortality rate at Tieton Dam offers a first-order estimate of the mortality experienced by fish passing through Mason Dam. The FWS Biological Opinion for Tieton indicated that a conservative estimate of kokanee salmon direct mortality through the Tieton jet-flow valves is in the range of 60% to 80%, with mortality positively correlated with both head and flow (U. S. Fish and Wildlife Service, 2005). Mortality is likely caused by a combination of physical stresses and sudden pressure differences. Like Tieton, Mason Dam is a high head facility and water exiting the jet valves is expelled with great force. It is evident that passing through a valve causes physical stress to fish, which may strike hard surfaces at considerable speed. Entrained fish also experience a great pressure differential as they pass the outlet works because they experience the full head pressure of the reservoir just before they are suddenly ejected from the jet valve into the air, where the pressure is about 1 atmosphere (Figure 6). Due to the similarity in characteristics between Mason and Tieton dams, it is reasonable to expect a similar mortality rate for the existing jet valves at Mason Dam.



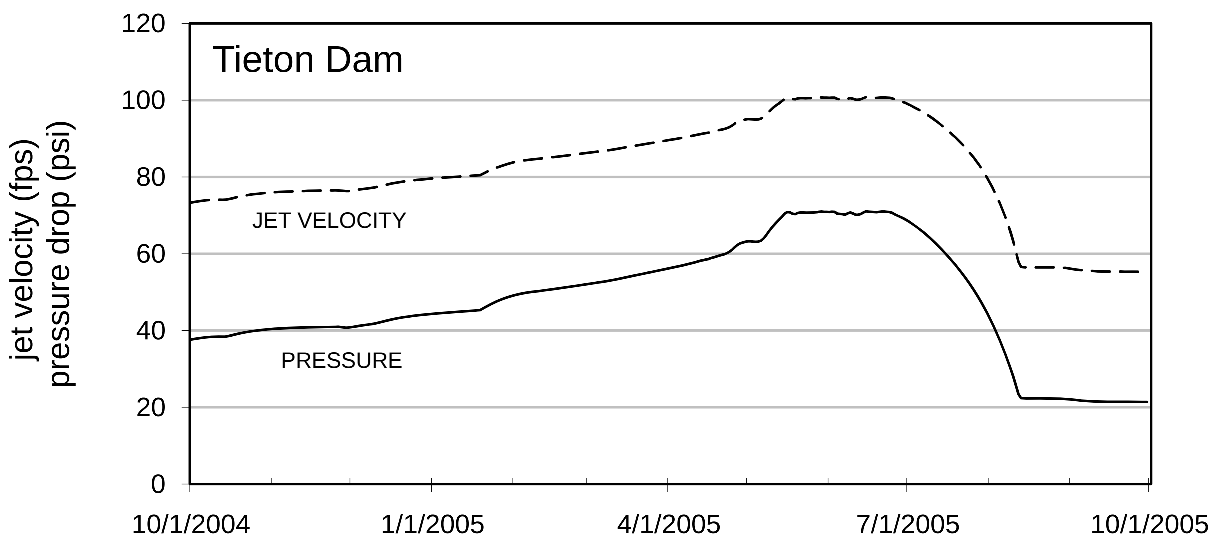


FIGURE 6. APPROXIMATE JET VELOCITY AND PRESSURE DROP EXPERIENCED BY FISH PASSING THROUGH VALVES AT MASON DAM (TOP) AND TIETON DAM (BOTTOM).

The overall direct mortality determined in the Wickiup Dam study was 81% (Symbiotics LLC, 2009). As in the Tieton study, mortality was positively correlated with head and flow. Although the Wickiup project employs cone valves rather than gate/jet-flow valves, cone valves are similar to the other valve types in the sense that they regulate flow by introducing a blockage into the flow path causing water to accelerate through the valve opening. Dead fish showed signs of both collision and pressure induced injuries.

The operator at Mason Dam has observed large numbers of yellow perch in the tailrace pool below Mason Dam during late fall, especially in low water years. The fish appear to be disoriented and unable to swim. The condition of these fish is consistent with the observations made at Tieton and Wickiup and it seems apparent that yellow perch experience at least some mortality passing through the gate valves at Mason Dam. Based on the similarity between Mason Dam and the dams where mortality studies have been conducted, it seems likely that the mortality rate at Mason Dam is probably also in the range of 60 – 80%.

Turbine Mortality

The study of turbine mortality was based on review and interpretation of the extensive literature on the subject. Mortality estimates for the proposed project are based on comparison to similar projects where mortality studies have been performed. Factors influencing turbine mortality include turbine type, project head, peripheral runner velocity, operating efficiency, and size of fish entrained.

Causes of Mortality

Known mechanisms of injury and mortality among fish passing through turbines (Cada 2001) include:

- rapid and extreme pressure changes
- cavitation - low water pressure causes the formation of vapor bubbles, which subsequently collapse
- shear stress
- turbulence
- strike (collision with structures including runner blades, stay vanes, wicket gates, and draft tube piers)
- grinding (squeezing through narrow gaps between fixed and moving structures).

Because the factors impacting fish in the turbine are complex and interrelated, it has been difficult for researchers to accurately identify and quantify which factors are having what impact. However, fish strike by the turbine blades is considered to be the major cause of fish mortality. Further, the size of fish is considered to be closely correlated to the probability of blade strike, and hence, to injury or death of the fish. That is, the smaller the fish, the greater the chance of survival, the larger the fish, the smaller the chance of survival.

In addition to blade strike, the most common mechanisms of injury or death are rapid changes in pressure and shear. A study by Mathur et al. (2000) estimated the proportion of injury caused by the various factors to be 50% due to blade strike/grinding, 19% due to pressure, 14% due to shear, and 17% due to a combination of other sources. Though cavitation is seen as a cause of fish injury, it is difficult to demonstrate and is highly dependent on the specifications of the particular turbine and how it is operated (i.e. efficiency and other technical attributes). Furthermore, most projects are designed to minimize cavitation to prevent turbine wear.

A Department of Energy publication (Odeh 1999) provides a general statement of mortality rates for Francis turbines. In studies since 1987, mortality rates of 16% and 4% were found for Francis and Kaplan turbines respectively. Basically, the number and speed of the turbine's runners are the main factors causing injury or death.

A review of 64 studies by Electric Power Research Institute (EPRI 1987) found that:

- Kaplan and Francis turbines present different challenges to safe fish passage. In Kaplan turbines, the primary injury mechanism is likely the crushing of fish between the blade tip and interior wall of the turbine. In Francis turbines, the main effect occurs at the entrance to the runner blade cage and is a function of the wicket gates, shape of the runner, and peripheral runner velocity.
- Head, a surrogate for force determined by the difference in elevation between forebay and tailwater, does not appear to be a significant independent determiner of mortality. However, head determines water velocity against the runner blades, and hence, the peripheral runner velocity.
- Subatmospheric pressures experienced by fish passing through the turbine appear to affect mortality rates.
- Difference in elevation between runner and tailwater seems to affect mortality, presumably because this difference results in subatmospheric pressure variations under the runner blades.
- Shear is assumed to be a factor in mortality but is a difficult mechanism to identify under test conditions.
- The average mortality for Francis turbines was 20%, vs. 12% for Kaplan turbines.

Comparison with Similar Projects

Though many factors contribute to fish mortality rates, peripheral runner velocity emerged in the EPRI review as the most critical:

> *Comparisons of turbine operational and design characteristics with mortalities in prototypes found few good cause-effect relationships. The best linkage with mortality was that of peripheral runner speed in the case of Francis units (EPRI 1987, p.iii).*

Table 7 presents the specifications for the turbines currently proposed for installation at the Mason Dam powerhouse. Oneida turbine specifications are also shown where available.

TABLE 7. TURBINE SPECIFICATIONS FOR THE MASON DAM HYDROELECTRIC PROJECT.

SPECIFICATION	**MASON DAM**
Number of turbines	1
Max flow per turbine (cfs)	300
Design Head (ft)	140
RPM	514
Peripheral velocity (ft/sec)	86
Runner diameter (ft)	3.2
Number of runner blades	13
Elevation of runner above tailwater (ft)	3.0
Average entrainment pressure (atm)	1.38

Table 8 lists projects utilizing Francis turbines where turbine mortality estimates have been performed and that have similar characteristics to the proposed project. Assuming that the principal mortality factor is peripheral velocity of the runner, with runner diameter, rpm, and head considered as important secondary factors, the Mason Dam project is most similar to the Glines, North Fork and Seton plants, which reported 36%, 26% and 9% average mortality respectively. Due to the comparatively high head at Glines, its mortality rate of 36% could be considered the upper limit of the estimated mortality for Mason Dam.

TABLE 8. AVAILABLE DATA ON FACTORS AFFECTING TURBINE MORTALITY FROM SPECIFIC SITES (ADAPTED FROM EPRI 1987).

PLANT	**HEAD (FT)**	**RPM**	**PERIPHERAL RUNNER VELOCITY (FT/S)**	**RUNNER DIAMETER (FT)**	**RUNNER ELEVATION ABOVE TAILWATER (FT)**	**AVERAGE PERCENT ESTIMATED MORTALITY**
Baker	250	300	80	5	-5	31
Cushman	450	300	108	6.9	11	41
Elwha	104	300	59	4.9	14	10
Faraday	120	360	62	3.3	10	4
Glines	194	225	86	7.7	7	36
Leaburg	89	225	88	7.5	11.9	17
Lequille	387	519	121	4.5	6.5	48
North Fork	136	139	82	9.7	5	26
Publishers	42	300	47	3	23	13
Puntledge	340	277	103	7.1	2	33
Ruskin	124	120	78	12.4	10	10
Seton	142	120	95	12	16	9
Shasta	410	138	111	13	3	39
Sullivan	42	240	64	6.2	23	20
Mason Dam	*140*	*514*	*86*	*3.2*	*3*	*24.8 (est.)*

Figure 7 shows the relationship of mortality vs. peripheral velocity for the 14 projects listed in Table 8. On the basis of peripheral runner velocity alone, the Mason Dam turbines are predicted to have a 24.8 percent mortality rate.

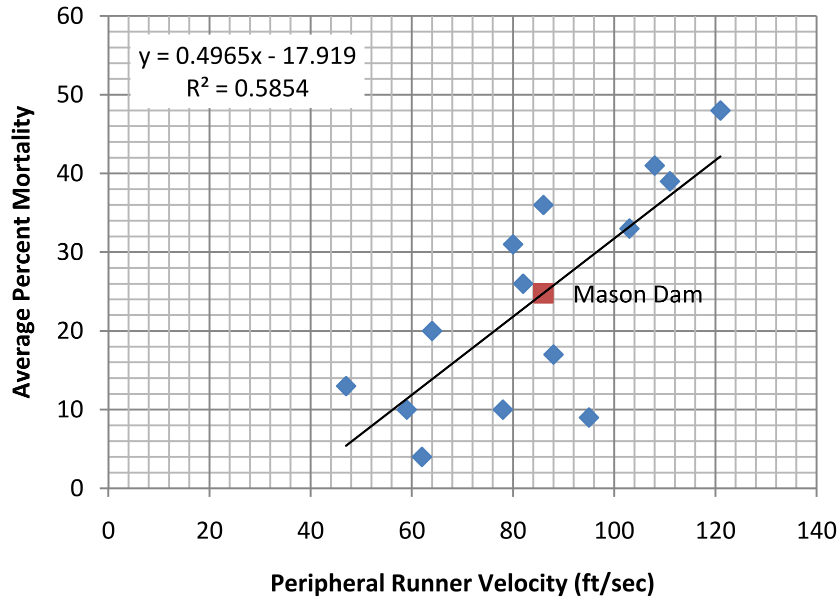


FIGURE 7. PLOT OF AVERAGE PERCENT MORTALITY VS. PERIPHERAL RUNNER VELOCITY FOR STUDIES LISTED IN TABLE 5.

Summary

The main results of this analysis may be summarized as follow:

The Caldron Falls/Peshtigo project, with an annual entrainment rate of 78,335 fish, was judged to be the best fit to the Mason Dam project with an emphasis on reservoir size and dam height. The Prickett/Sturgeon project, with an annual entrainment of 115,979 fish, was judged to be the best fit to the Mason Dam project with an emphasis on hydraulic capacity.

- The proposed project would not change the rate of fish entrainment at Mason Dam because the project would not alter the intake structure or change the amount or timing of water withdrawal.
- Entrainment rates at the two projects with the closest similarity in terms of hydraulic capacity and reservoir size/dam height to the proposed Mason Dam project were 115,979 fish/yr (Prickett/Sturgeon) and 78,335 fish/yr (Caldron Falls/Peshtigo).
- Using reservoir area and hydraulic capacity as the primary factors influencing entrainment, fish entrainment at the proposed Mason Dam project range from 74,000 to 250,000 fish per year.
- The entrainment rates estimated by comparison with other projects are probably conservative maximum values because Mason Dam has a high dam (153 ft) with a deep water intake structure, and the entrainment estimates were based on small dams (< 80 ft) with shallow water intake structures.

- Mortality due to passage through the Mason Dam slide gate valves is estimated to be in the range of 60% – 80%, based on comparison with two projects employing similar valves.
- Turbine mortality for 24 similar projects that utilize Francis turbines ranges from 4% to 48%.
- Mortality rates at the three projects with the closest similarity in terms of runner velocity and head to the proposed Mason Dam project were 36% (Glines), 26% (North Fork) and 9% (Seton).
- Based on peripheral runner velocity as the primary factor influencing mortality, the Mason Dam project is estimated to have a mortality rate of 24.8%

References

Abernathy, C.S., B.G. Amidan, C.F. Cada, 2001, Laboratory Studies of the Effects of Pressure and Dissolved Gas Supersaturation on Turbine-Passed Fish. U.S. Department of Energy, Idaho Operations Office, DOE/ID-10853.

Baker County, 2009, *Preliminary Licensing Proposal for Mason Dam Hydroelectric Project FERC No. P-12686.* Baker County, Baker City, OR.

Čada, G.F., 2001, Development of advanced hydroelectric turbines to improve fish passage survival. *Fisheries* 26:14-23.

CH2M Hill, 2003, Literature Based Characterization of Resident Fish Entrainment and Turbine-Induced Mortality, Klamath Hydroelectric Project (FERC No. 2082). Prepared for PacifiCorp during FERC relicensing for the Klamath Project.

Hardin, T., 2001, Comparison of Fish Mortality at Tieton Dam: Jet Valves vs. Turbines. Report by Hardin-Davis, Inc. prepared for Sorenson Engineering, Idaho Falls, ID.

Ecowest Consulting, 2009, *Combined Vegetation and Threatened, Endangered and Sensitive Species Assessment, Mason Dam Hydroelectric Project - Final Report.* Baker County, Baker City, OR.

Electric Power Research Institute, 1987, *Turbine-related Fish Mortality: Review and Evaluation of Studies*. EPRI Report No. AP-5480, Project 2694-4, prepared by Eicher Associates, Inc., Portland, OR.

Electric Power Research Institute, 1992, *Fish Entrainment and Turbine Mortality Review and Guidelines*. EPRI Report No. TR-101231, Project 2694-01, prepared by Stone and Webster Environmental Services, Boston, MA.

Federal Energy Regulatory Commission, 1995, Preliminary assessment of fish entrainment at hydropower projects, a report on studies and protective measures, volumes 1 and 2 (appendices). Paper No. DPR-10, FERC Office of Hydropower Licensing, Washington, D.C.

Federal Energy Regulatory Commission, 1996a, Final environmental impact statement, Wisconsin River basin, Wisconsin. FERC/EIS-0089F. Prepared in cooperation with the US Forest Service. FERC Office of Hydropower Licensing, Washington, D.C.

Federal Energy Regulatory Commission, 1996b, Menominee River multiple project final environmental impact statement, Little Quinnesec Falls Hydroelectric Project (FERC No. 2536), Chalk Hill Hydroelectric Project (FERC No. 2394), White Rapids Hydroelectric Project (FERC No. 2357), Grand Rapids Hydroelectric Project (FERC No. 2433). FERC Office of Hydropower Licensing, Washington, D.C.

Federal Energy Regulatory Commission, 1997, Final environmental impact statement for relicensing six existing hydroelectric projects in the Peshtigo River basin, FERC Project Nos. 2525 Caldron Falls, 2595 High Falls, 2522 Johnson Falls, 2546 Sandstone Rapids, 2560 Potato Rapids, 2581 Peshtigo. FERC Office of Hydropower Licensing, Washington, D.C.

Fenton, J., 2006, *Entrainment of Bull Trout at Agency Valley Dam 2005.* Bonneville Power Adminstration, Portland, OR.

Fisheries and Oceans Canada, 2010, *Ontario-Great Lakes Area Fact Sheets*. Retrieved Jan 2011, from Fisheries and Oceans Canada: http://www.dfo-mpo.gc.ca/regions/central/pub/factsheets-feuilletsinfos-ogla-rglo/index-eng.htm

Flatter, B., 2000, *Life History and Population Status of Migratory Bull Trout in Arrowrock Reservoir, Idaho.* Boise State University Master's Thesis, Boise, ID.

Mathur, D., P. G. Heisey, J.R. Skalski, and D.R. Kenney, 2000, Salmonid smolt survival relative to turbine efficiency and entrainment depth in hydroelectric power generation. *Journal of American Water Resources Association* 36:737-747.

Novak, M., 2004, *Powder River Subbasin Plan.* Northwest Power and Conservation Council, Portland, OR.

Odeh, M. 1999, A summary of environmentally friendly turbine design concepts. U.S. Department of Energy, Idaho Operations Office, DOE/ID-13741.

Reclamation, 2005, *Trap and Transport of Bull Trout From Lucky Peak Reservoir to Arrowrock Reservoir, Idaho.* U.S. Bureau of Recalamtion, Boise, ID.

Salow, T., & Hostettler, L., 2004, *Movement and Mortality Patterns of Adult Adfluvial Bull Trout in the Boise River Basin, Idaho.* U.S. Bureau of Reclamation, Boise, ID.

Symbiotics LLC, 2009, *Wickiup Dam Hydroelectric Project - FERC No. 12965 - Draft Study Report.* Symbiotics LLC, Portland, OR.

U. S. Fish and Wildlife Service, 2005, *Biological Opinion on the Effects of the Proposed Tietin Dam Hydroelectric Project on Bull Trout in the Yakima Basin.* U.S. Fish and Wildlife Service Reference 01-FC-E0396, Wenatchee, WA.