# CHIEF JOSEPH DAM

# PRELIMINARY INVESTIGATION OF

# FISH PASSAGE ALTERNATIVES

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US Army Corps of Engineers
Seattle District
Hydraulic Engineering Section

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## I. PROJECT DESCRIPTION AND SITE VISIT SUMMARY

Note - An overall reference for some of the material presented below is Chief Joseph Dam Periodic Inspection Report #12, 1999, available from USACOE.

### A. Dam Location and Water Levels:

Chief Joseph Dam, shown in the USGS Topographic map in Figure 1, is located 1.5 miles upstream of Bridgeport, Washington on the Columbia River. It is 545 river miles above the mouth of the Columbia and 51 miles downstream of Grand Coulee Dam. The reservoir created by Chief Joseph Dam, Rufus Woods Lake, has a maximum storage capacity of 593,000 acre feet with a water surface elevation of 956 feet. Minimum operating pool level is 930 feet (401,000 acre-ft of storage). The operating goal from February 15 through October 15 is 950 feet with summer levels varying between 950 and 956 feet. Elevation of the intake inverts is at 879 feet (about 75 feet below normal pool elevation) with a maximum tailwater elevation of 810 feet (top of training wall) and a design tailwater elevation of 787 feet.

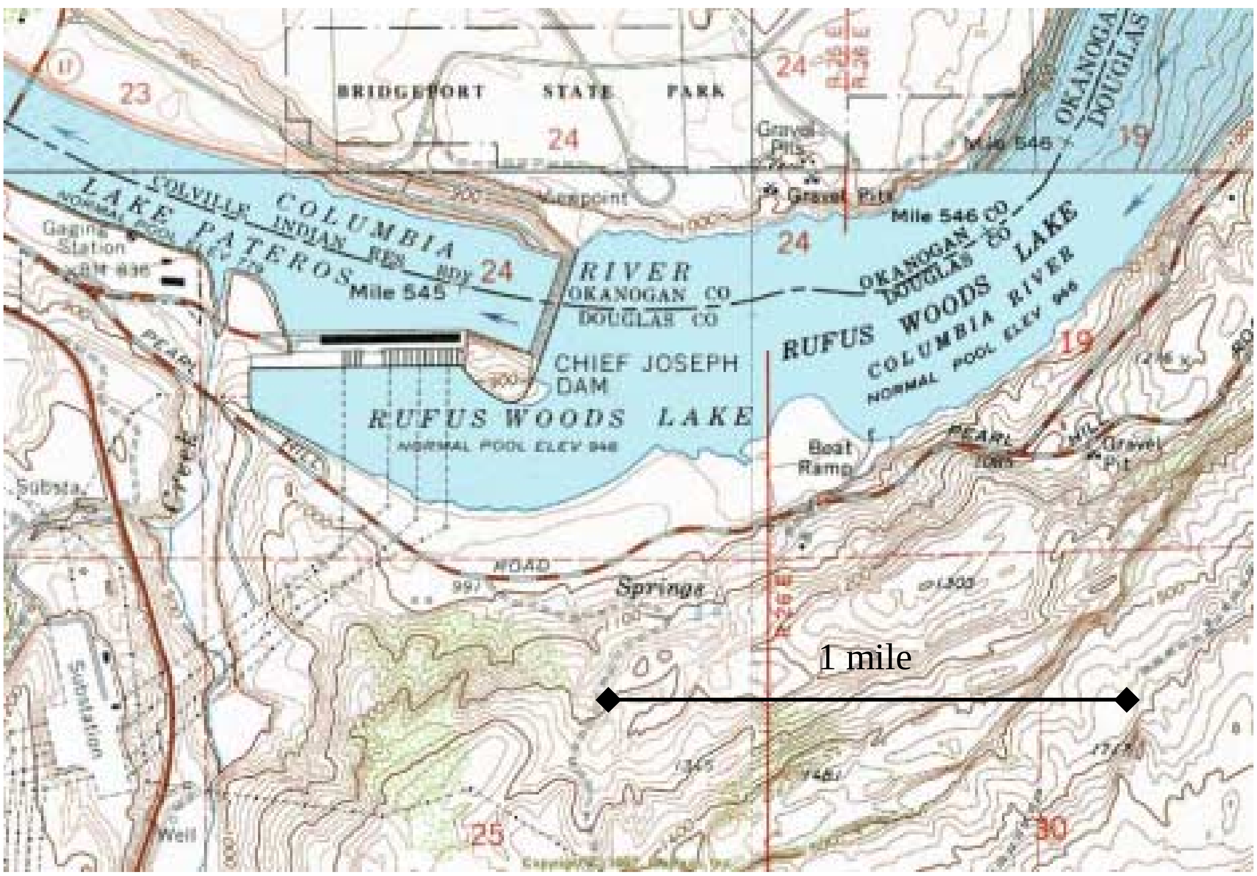


**Figure 1. USGS Topographic Map of Columbia River in the Area of Chief Joseph Dam and Bridgeport, WA.**

**B. Geologic Setting and Geotechnical Considerations:**

**1.** General Project Location - The project lies on the border between the locally granitic Okanogan Highlands to the north and the Columbia Basalt Plateau on the south. The Columbia River has cut a valley about 1,000 feet deep below the plateau surface into the granitic rocks. This valley has been modified by continental glaciation, and the irregular bedrock surface is overlain by a highly variable thickness of glacial outwash sand and gravel, glacial lake silts, and till. The present river has cut down through the glacial sediments into the granitic bedrock leaving a terraced, inner stream valley within the larger old valley.

Downstream of the south (left) dam abutment is the mouth of Foster Creek (see Figure 2), which drains an area on the order of 250 square miles. The three forks of the creek (West, Middle and East) join about two miles above the junction of Foster Creek with the Columbia River. Of these, East Foster Creek extends the furthest with its headwaters within about 3 miles of Banks Lake. The northern end of Banks Lake is near Electric City and the Grand Coulee Dam. Between Chief Joseph Dam and Grand Coulee Dam, the Columbia River has a number of creeks and tributaries as well as smaller local inflows. Some of the larger inflows include the Nespelem and Little Nespelem Rivers, as well as Tumwater, Coyote, Strahl Canyon and Sanderson Creeks.

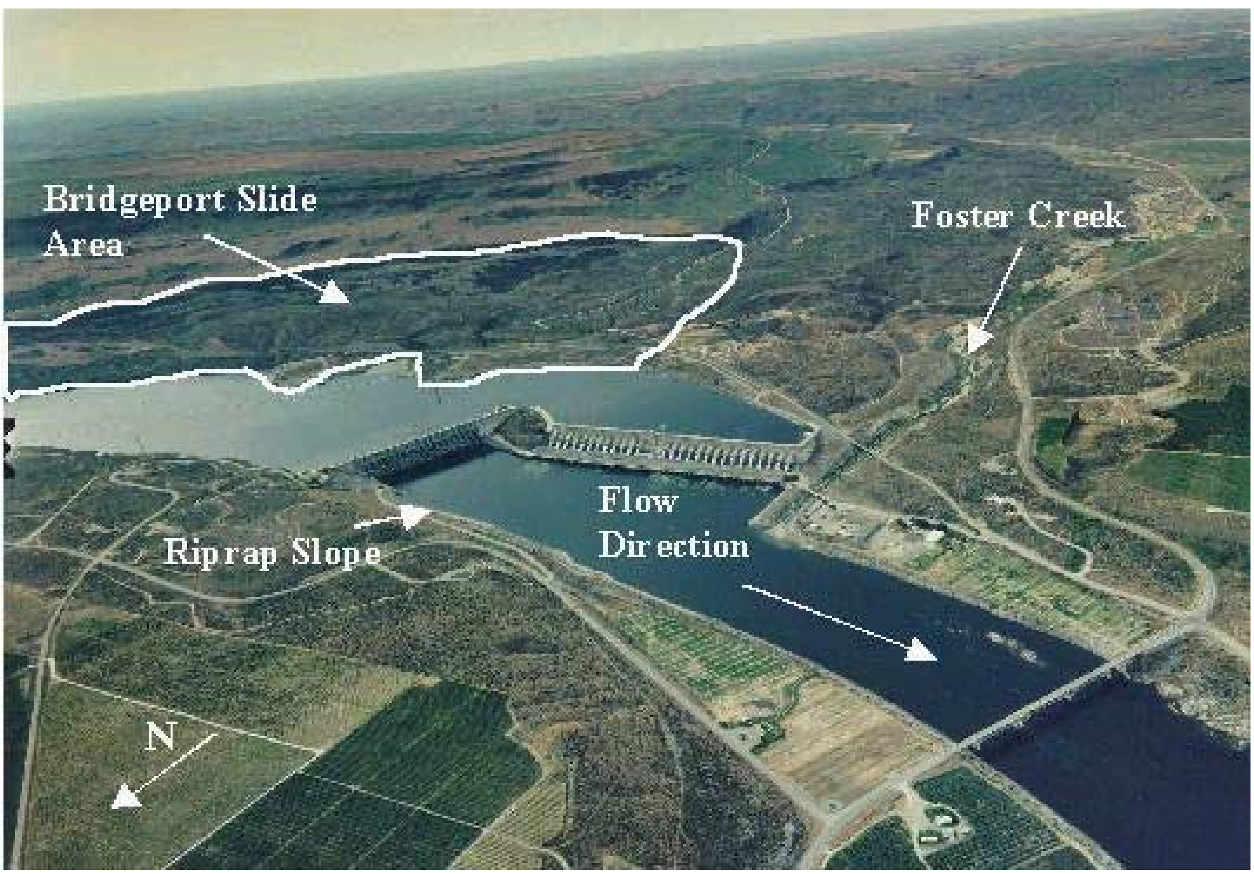


**Figure 2. Aerial View of Project Area.**

**2.** South (Left) Bank - The south side of the inner valley consists of an assemblage of glacial till, a variety of morainal material, and a large quantity of glacio-fluvial and glacio-lacustrine sediments and outcrops of granitic bedrock. The older valley rises above this assemblage and is composed of basalt flows. Colluvium derived from all of the above sources mantles most of the ground surface.

A short distance upstream from the south dam abutment begins an extensive, Pliocene to Holocene age landslide (Bridgeport Slide, see Figure 2). The Bridgeport Slide extends upstream for about 2.5 miles and is approximately 3,000 feet wide spanning from the reservoir to the basalt plateau. The slide involves basalt and glacial sediments and apparently the slide plane is along the granite-sediment contact. The slide is instrumented with inclinometers and periodically inspected by Project and by Seattle District Office personnel. The slide has had an average movement of ¼ inch per year during recent inspections. In the slide area upstream of the dam, the portions of banks above the waterline generally have slopes ranging from 1:50 to 1:10 and are largely unreveted. Below the dam, the banks as well as the mouth of Foster Creek are reveted with stone. The revetment extends down to the Route 17 bridge. Bank slopes are moderate at ratios of approximately 1:3 to 1:5.

**3.** North (Right) Bank - The right abutment is composed of a compact glacial till, morainal material, and openwork gravels overlying bedrock. Of predominant interest are the openwork gravels, which provide an aquifer in the abutment in which a relief tunnel is located. The issue of groundwater seepage is of some concern on the north bank and it is actively monitored and managed. Slope areas upstream of the dam have experienced small local slumping failures and erosion. Upstream of the dam the banks are quite steep, occasionally nearly vertical. Bank protection is limited to areas around equipment. Portions of the slope above the north bank are irrigated for use as orchards, and seepage and drainage issues exist both upstream and downstream of the spillway. Downstream of the dam, the banks are reveted with stone. This revetment extends to the Route 17 bridge just like on the south bank. Bank slopes are moderate with ratios similar to the south bank. The riprap slope downstream of the training wall (see Figure 2) has experienced some loss of material over the years and there is some concern about excessive loss of riprap and bank material. The area has been stabilized by avoiding non-uniform spillway use, but could become an issue if spills occur more often due to operational changes.

## C. Site Visit:

On October 31, 2000 Seattle District personnel Jeffrey Laufle and Catherine Petroff visited the Chief Joseph Project to view areas in the vicinity of the project. The visit was part of a reconnaissance level evaluation of possible fish passage concepts at Chief Joseph Dam. We met with Laura Beauregard, chief of the resource management section for the project with whom we toured the facilities. On the day of the site visit, the average water surface in Rufus Woods Lake was at an elevation of 953.5 feet.

**Figure 3. Rufus Woods Lake Looking Downstream toward Chief Joseph Dam, (10/31/00).**

**Figure 4. Rufus Woods Lake, View of North Bank (10/31/00).**

1. South Bank - We viewed the Chief Joseph Project in several locations, starting with the south bank upstream of the dam. Figure 3 shows a distorted composite panoramic view of the dam from the south bank of Rufus Woods Lake. The photograph was taken from the region of the Bridgeport Slide looking west (downstream) toward Chief Joseph Dam. The two protrusions into Rufus Woods Lake on the left bank are both within the slide zone. The nearer peninsula has a boat ramp and launch facility, and a white car parked to the left of the lower tree gives an idea of scale. The further peninsula serves as the southern anchor point for the debris (log) boom and as a base for the southern transmission line tower. A small marsh area has recently been revegetated in the northwest corner of the inlet between the two peninsulas.

   Figure 4 (distorted composite photo) was taken from the same location as Figure 3 and shows a continuation of the view across Rufus Woods Lake towards the north. The upstream northern anchor point of the debris boom is seen in the center of the photograph. The object in the center near the south bank is a small boat with an outboard motor and two people in it (for scale). It is evident that the north bank of Rufus Woods Lake upstream of Chief Joseph Dam is quite steep and subject to periodic sloughing of slope material. As seen in the photo, the steep bank continues a long distance upstream, in excess of 2 miles. The area of the north bank shown in the photo is occupied primarily by Bridgeport State Park.

   Figure 5 (composite photo) shows a close-up of the marsh area to the west (downstream) of the boat ramp. This marsh area has been replanted as part of the Chief Joseph Dam Project resource management activities. There is considerable reed and grass growth along the bank in the marsh and visible bird activity. It would be useful to know how attractive this area is for fish. Flows in the marsh are unknown.

**Figure 5. View of Marsh at South End of Debris (Log) Boom, Left Bank Looking Upstream (10/31/00).**

2. Foster Creek - Any fish passage measures associated with the south (left) bank would involve modifications on or around Foster Creek. There is anecdotal evidence of steelhead in the creek at high flows. We viewed several areas of the creek starting at the confluence with the Columbia River downstream of Chief Joseph Dam. Figure 6 shows a distorted composite photograph of Foster Creek just upstream of the confluence with the Columbia River. The left abutment of Chief Joseph Dam is in the central part of the photo. Passing in front of the abutment is the Pearl Hill Road, a two-lane road that skirts the south shore of Rufus Woods Lake.

**Figure 6. Foster Creek at South (Left) Dam Abutment and Pearl Hill Road Bridge (10/31/00).**

**Figure 7. Foster Creek Upstream of Pearl Hill Road Bridge (10/31/00).**

While Foster Creek has a fairly large drainage area, when there is no local storm activity the water is confined to a low flow channel seen on the far (eastern) side in Figure 6. The eastern side of the channel is reveted with rock, presumably to prevent erosion during high water events. It is possible that some anadromous fish activity occurs in this portion of Foster Creek.

Figure 7 shows Foster Creek from the left abutment of Chief Joseph Dam to a point approximately 0.7 mile upstream of its outlet to the Columbia River. Above the Pearl Hill Road, Foster Creek widens considerably and shows evidence of considerable sediment deposition in its valley. The channel has a lower gradient in this area than at the creek mouth. In Figure 7 the low flow channel can be seen as the green strip that runs through the valley. The western (near) side of the creek valley is somewhat milder in slope than the eastern (far) side, which seems to have fairly erosive slopes. If this area of Foster Creek is involved in the construction of fish passage facilities, we would need to determine to what extent the slopes are the result of natural erosion and what portion of the topography is the result of cut and fill operations or prior road building activities.

Approximately 0.9 miles upstream of the junction of Foster Creek with the Columbia River, is a small check dam about 20 feet high, shown in Figure 8. This structure may serve to impound water for upstream agricultural use. The heavy sediment load in Foster Creek has resulted in the formation of a sediment deposit, which is in most places at the same elevation as the dam crest. A small incised channel runs through the deposit to the location of the weir overflow seen in the center of Figure 8. The sides of the check dam are notched into a natural bedrock constriction in the creek. This site is a barrier to fish passage into upstream areas of Foster Creek and would be the upper limit of anadromous fish habitat for fish passing through the Columbia River. During the period 1957-1977, the USGS operated three gauging stations on Foster Creek, one on the East Fork near Leahy, WA (#12437930); one on the West Fork near Bridgeport, WA (#12437960); and one on an East Fork tributary (#12437950). All three stations were upstream of the check dam location.

**Figure 8. Check Dam / Weir on Foster Creek (10/31/00).**

**3.** North Bank - In order to investigate options for fish passage on the north (right) shore of the Chief Joseph Dam Project, we viewed locations at the north (right) abutment, near the visitor viewing / information area and we also descended to the level of Lake Rufus Woods on the north shore upstream of the spillway. Figures 9a and 9b show the spillway and the power generation station as seen from the north bank. The short section of island joining the two structures faces onto the spillway apron.

**(a)** **(b)**

**Figure 9. Views of Chief Joseph Dam from Downstream (10/31/00): (a) Spillway Face, (b) Penstocks.**

As mentioned previously, the north bank in the vicinity of the dam is quite steep. Upstream of the dam, the shoreline is generally unaltered with small areas of armoring or revetment in the vicinity of structures and at the level of normal reservoir fluctuations. Downstream of the spillway, because of the erosive power of the spilled water, the right bank has been reveted for some distance downstream of the training wall (Figure 10).

**Figure 10. View of North (Right) Spillway Training Wall, (from Periodic Inspection Report # 12, USACOE, 1999).**

Some loss of riprap at the junction of the training wall and the bank is seen in the upper center of Figure 10. This situation is monitored by Project and by Seattle District Office personnel and is assumed to be the result of unbalanced flows when the first two spillway bays are not used due to excessive spray and air entrainment during high flow events. Current plans for gas abatement on the spillway are focused on reducing water quality impacts due to spill. The gas abatement project will also investigate whether any changes will be needed to the right bank revetment once deflectors are installed and all bays are used for spill. Any fish passage facilities proposed for the north bank would have to take into account the steep slopes and seepage in this area as well as the high velocities and water quality changes that occur during spill periods.

At the conclusion of the site visit we met with Edward Reynolds, project manager of the Chief Joseph Dam project to discuss possible options and ideas for fish passage around the Chief Joseph Project.

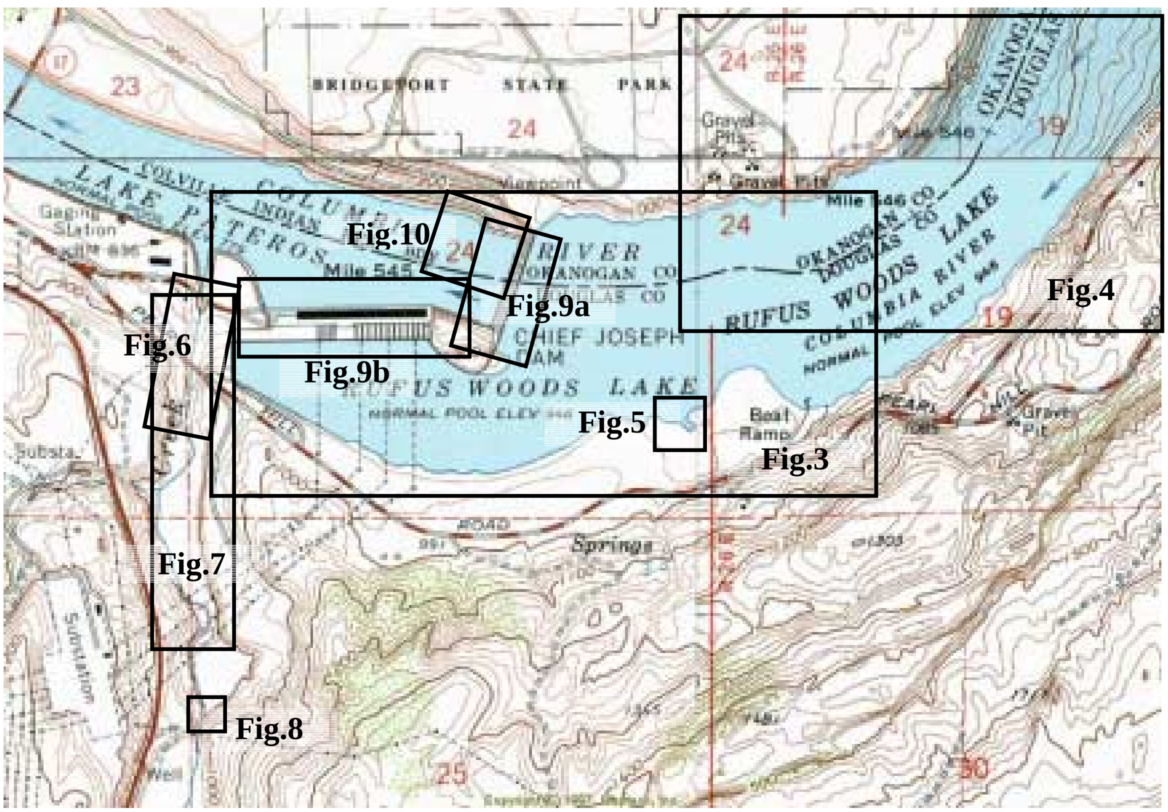


**Figure 11. Guide to Photograph Locations.**

## II. REVIEW OF FISH PASSAGE SYSTEMS:

### A. Upstream Passage (usually adult passage, possibly juvenile passage):

Current Systems in use on the Columbia, Snake and many other rivers include:

**1.** Fish Ladders – A number of different types of fish ladders or fishways have been designed to promote the upstream passage of adult fish. Currently, all of the dams on the Lower Columbia and Lower Snake Rivers have some sort of fish ladder. On the Upper Columbia River, Wanapum, Rock Island, Rocky Reach and Wells dams also have fish ladders. The term fishway is meant to encompass both the entrance and exit features of the passage facility as well as the ladder section. Actual dam crossing may occur near the dam crest or through a tunnel or floating orifice some distance below the upstream water surface. Fishways rely on a system of elements such as weirs, slots and baffles to provide attraction flows, head dissipation and the appropriate hydraulic conditions for the species of fish using the fishway. For example, depending on the fish species, a free surface flow may be required at control sections such as for upstream passage of shad. Certain salmonids do not tend to leap and may require continuous deep flows for passage.

- Pool style fishways (shown below), including pool and weir arrangements as well as pool and chute and vertical slot configurations, are one major type of passage structure. Many of the ladders on the Columbia and Lower Snake river make use of pool type fishways especially ones which use deep vertical slots and are self regulating over a wide range of flows. Ice Harbor Dam has a pool and weir fishway where the plunging jet over each weir section impinges on the backwatered pool from the next weir downstream. One item to note is that it is possible for a properly designed pool type fishway to allow for upstream passage of juvenile as well as adult fish. A fishway usually uses a single weir design for its entire length.

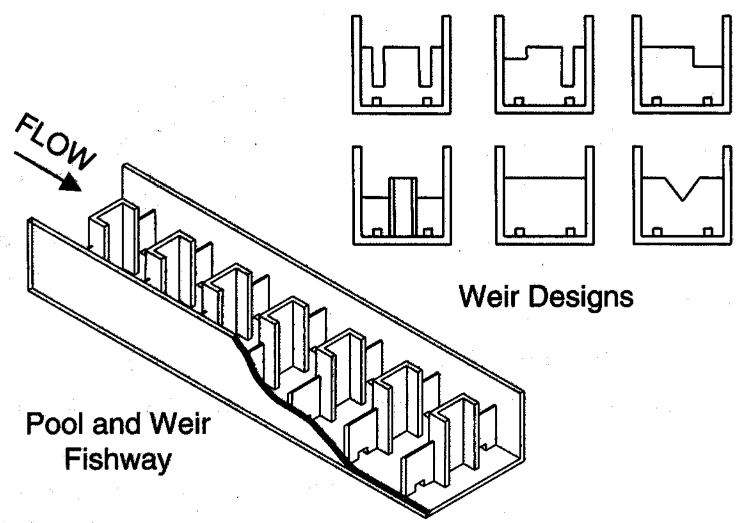


**Figure 12. Schematic of pool and weir fishway showing various possible weir designs. Weir design usually includes the option for floor level orifices to allow for different preferred passage methods for salmonids of different species and in different life stages, (from Odeh, 1999).**

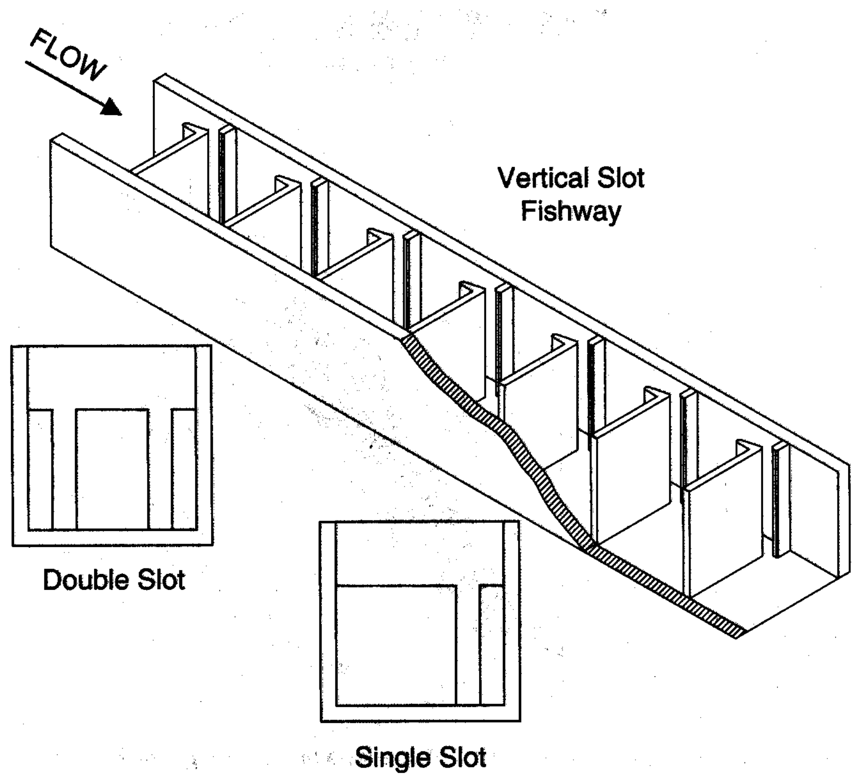


**Figure 13. Vertical slot fishway showing one or two slots within a weir between pools. Vertical slot fishways are self-regulating over a range of pool elevations, (from Odeh, 1999).**

- Roughened channel fishways such as the Denil style fishway or the Alaska Steep pass Channel make use of baffles to provide head dissipation along the channel and are probably not appropriate for high head, permanent installations.
- There are a number of hybrid fishway designs that make use of combinations of the pool and weir, vertical slot or roughened channel approaches. Often these structures transition from one hydraulic condition to another based on the hydraulic flow conditions.

**2.** Nature-like Fishways - A "nature-like" rough channel or rock ramp (shown below) can also be classified as a type of fish ladder or fishway. Although this type of passage method is not currently used along the Columbia and Snake Rivers, nature-mimicking channels have been used with some success in other, usually lower head drop, projects.
A key principle in the design of nature mimicking fishways is to provide a variety of flow conditions within the fishway cross section by using natural materials. They are characterized by a control sill and rough rock linings. Boulders can be placed in the channel to maintain the desired hydraulic conditions for fish passage. The boulders are anchored either in a cobble and gravel substrate or in concrete depending on the desired slope and flow velocities. One issue for such channels is that they often must also be capable of passing debris as well as fish. In high gradient areas, an alternative to the rock ramp is a simulated step-pool channel which is designed to mimic the dimensions of similar channels found in nature. The desired elevation drop is a result of a series of smaller drops over the steps in the step-pool system.

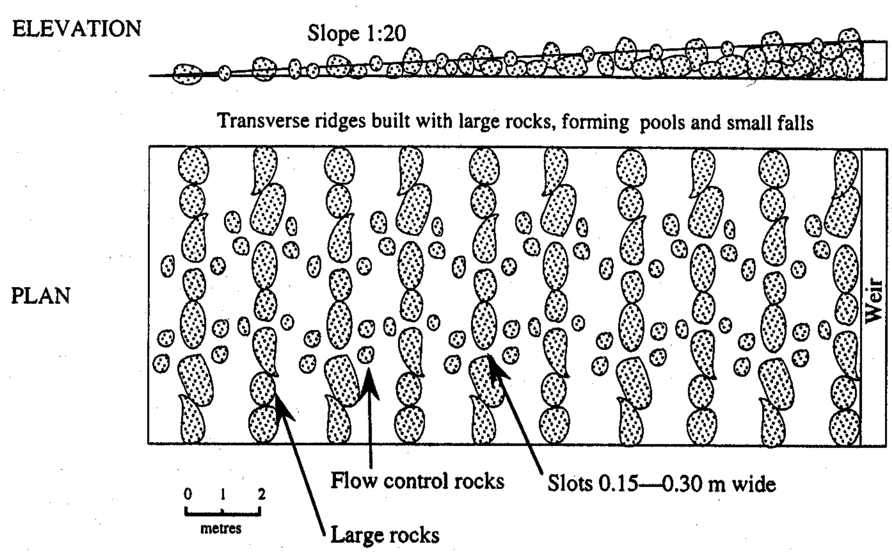


**Figure 14. General design layout of an experimental rock-ramp fishway in New South Wales, (from Harris et al, 1998).**

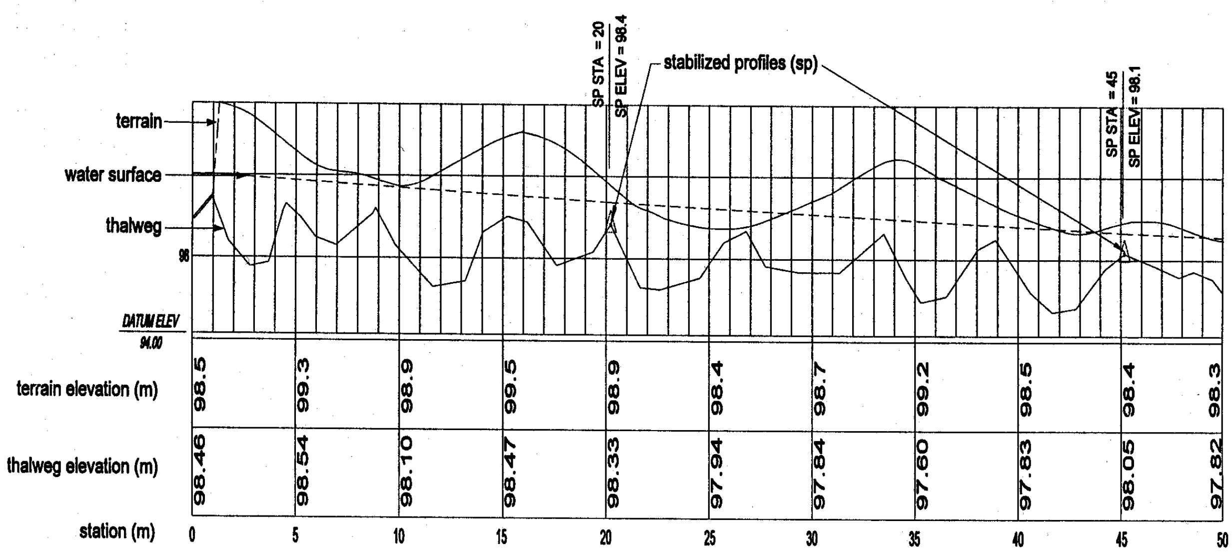


**Figure 15. Longitudinal profile of a bypass channel showing the location of pool drops and stabilized profiles used to insure the maintenance of slope during and after construction, (from Parasiewicz et al, 1998).**

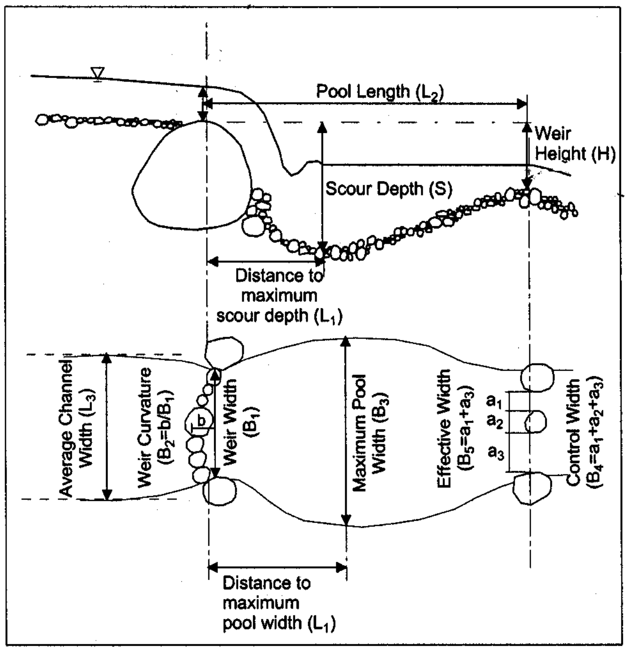


**Figure 16. Schematic of the dimensions of a step-pool unit, (from Thomas et al, 2000).**

The Mill Creek fishway on a tributary to the Bogachiel River is an example of a nature-mimicking channel. It has a net rise of 7.5 ft (2.3 m) in a length of 95 feet (29 m) with a 10 year design flow of 1200 cfs (34 cms). Besides use in the United States, nature-mimicking fishways have been installed and are under evaluation in many locations including Australia, Austria, Canada and Finland, Germany and Japan. One of the larger of such structures is a 800 m (2600 ft.) long branching bypass channel under construction at the Fredenau Dam on the Austrian Danube (shown below). It has a total elevation rise of 8 m (26 ft) and after initial establishment of the channel structure at flow rates of 7 cms (250 cfs) will operate at discharges between 1.8 cms and 3.6 cms (63 – 127 cfs). The bypass channel is predominantly a series of braided streams and incorporates a step pool pass structure at the upper end.

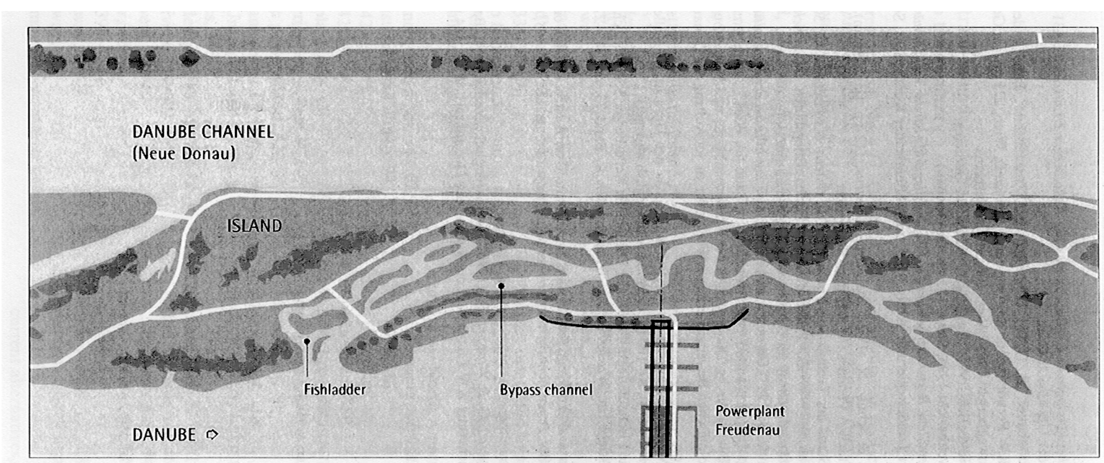


**Figure 17. Site plan of the bypass channel at Fredenau, (from Steiner, 1998).**

**3.** Fish Locks and Lifts – For passage over high head structures, fish locks and lifts can be employed in either the upstream and downstream directions provided that fish can be adequately attracted to the collection area. Bonneville Dam was built with a fish lock for upstream passage. The locks or lifts constructed at Bonneville, McNary and The Dalles were decommissioned when they were shown to be ineffective. A fish lock is currently in the design stage at the Howard Hanson Dam on the Green River near Seattle, WA for downstream passage of juvenile fish. In a lock chamber, the fish are collected and then the lock chamber is either filled or drained depending on the desired direction of passage.

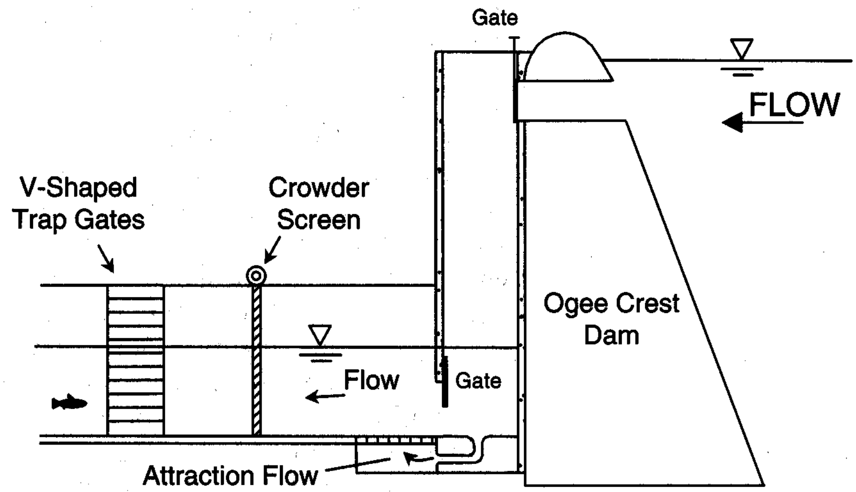


**Figure 18. Schematic of a fish lock. Navigation locks are known to allow some fish passage, (from Odeh, 1999).**

A variation of the fish lock concept is a pressure chamber fishway which connects the tailwater and headwater areas of a dam by means of a horizontal chamber which can be pressurized to pass fish upstream. Examples of pressure chamber fishways once existed at McNary Dam and are in place at the Rygene dam on the Nyldeva River in Norway (shown below).

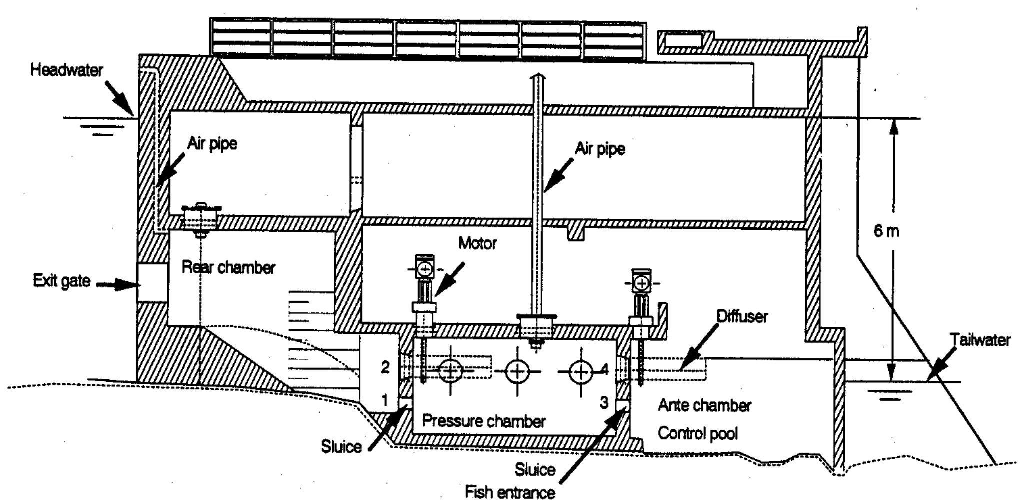


**Figure 19. Cross section of the Rygene dam and pressure chamber fishway, (from Grande and Matzow, 1998).**

For a fish lift, the fish ascend in baskets or bins by mechanical means. Among the issues for all these structures are the means of collection and the stress induced on the fish during collection and transit.

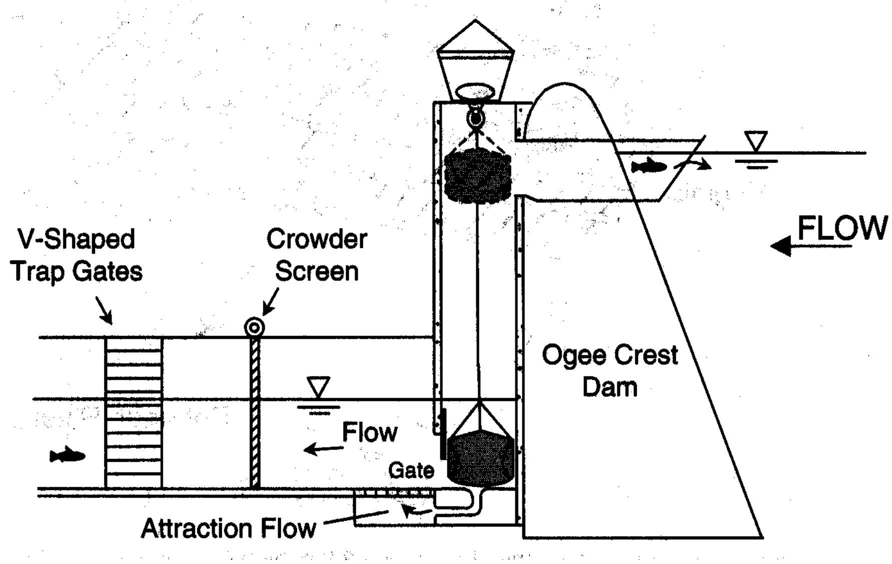


**Figure 20. Schematic of a fish lift at a dam. The attraction and discharge channels can take on many different designs, (from Odeh, 1999).**

**B. Downstream Passage (usually juvenile passage, possibly adult passage):**

Current systems in use include:

**1.** Passage through Turbines - This is affected by turbine design and turbine operating efficiency. Indications are that operating turbines within 1% of maximum efficiency leads to lowest mortality rates through the turbines. Other factors affect mortality including fish species and size, depth of release and specifics of the flow structure through the piping system. Iwamoto and Williams (1993) report that turbine survival per dam averages about 90% in the mainstem of the Columbia River (based on data through 1992). The turbines at Chief Joseph operate at generally higher power and with 60% more head than most of those in mainstem Columbia dams which would negatively affect this survival rate. In addition, the turbines at Chief Joseph Dam are Francis type turbines while the turbines along the mainstem of the Columbia are Kaplan type. Francis turbines run at somewhat lower specific speeds than Kaplan types. The two types have different internal geometries and it is expected that the impact and pressure damage to fish would consequently be different, though it is not clear whether survival rates would be better or worse as a result. If turbine passage is considered at Chief Joseph, this issue would require further study.

Passage over Spillways and Sluiceways – Success of passage during spillway flows is affected by the percentage of maximum spill capacity, absence or existence of flow deflectors and fish species and size. Reported ranges of survival fall between 87% and 100% depending on the above factors. Another issue, which affects survival during spillway passage, is gas entrainment and its subsequent effect on the fish. Special notched surface spill gates (SSGs, shown below)designed for fish passage have been tested at Rock Island Dam with some success. In general, depending on fish species, surface spill seems to be preferable over sub-surface release. Some projects, such as The Dalles have made use of ice and trash sluiceways to achieve surface entrainment and release of fish for downstream passage (for other issues regarding surface collection and bypass, see below). Other dams that make use of sluiceway passage include Bonneville, Ice Harbor, Priest Rapids and Wanapum Dams. The gas abatement project planned at Chief Joseph Dam would improve the water quality directly downstream of the spillway and possibly reduce the mechanical damage to fish passing over the spillway.

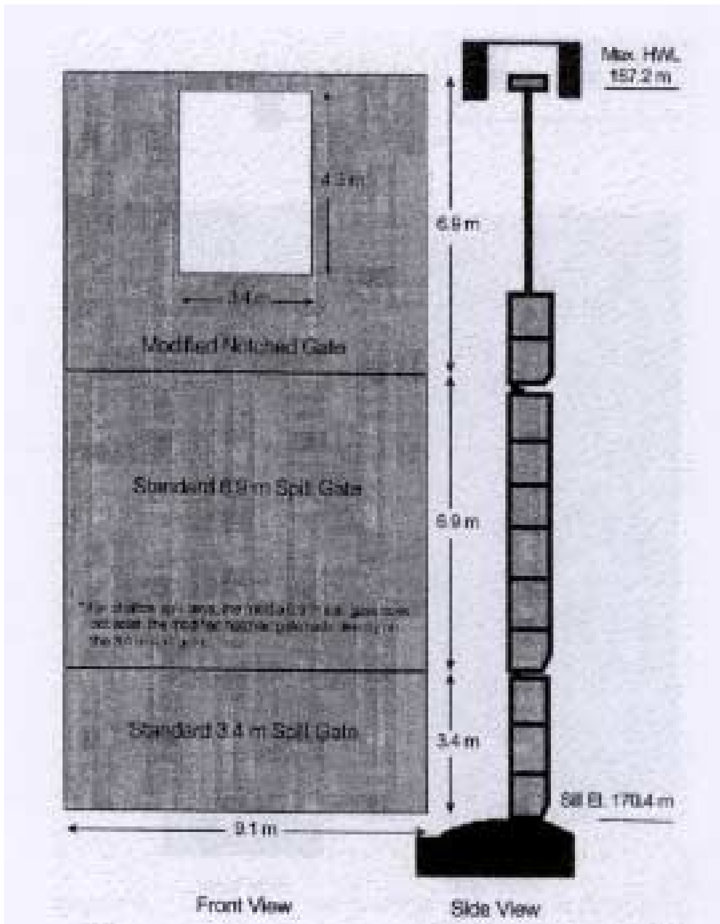


**Figure 21. Diagram of the notched surface spill gate used at Rock Island Dam in 1996, (from Iverson et al, 1998).**

**2.** Bypass Systems and/or Collection:

- Turbine Bypass - Traveling screens at turbine intakes have been implemented at most of the Lower Columbia and Lower Snake River dams with the exception of The Dalles Dam. These screens actively entrain fish away from the turbine intakes and deflect them into the gatewells and then into collection channels or pipes. Depending on the facility, the fish are then diverted to transportation facilities or to the tailrace area. Two designs are currently in use in the Columbia River: Submersible Traveling Screens (STS) which have a mesh surface and Extended Submersible Bar Screens (ESBS) which protrude further into the turbine forebay and have a wedgewire screen surface. Issues with these bypass systems include their efficiency in guiding fish away from the turbine intakes and the subsequent stress on fish during the collection and transport process. There is some data to support the idea that flume passage is preferable to pipe passage through the collection system. In addition, traveling screens induce a loss in the head available for power production on the order of 1-2 feet of hydraulic head. At Chief Joseph Dam, because of the 2.6 Megawatt capacity of the powerhouse, the power lost through screens is significant.

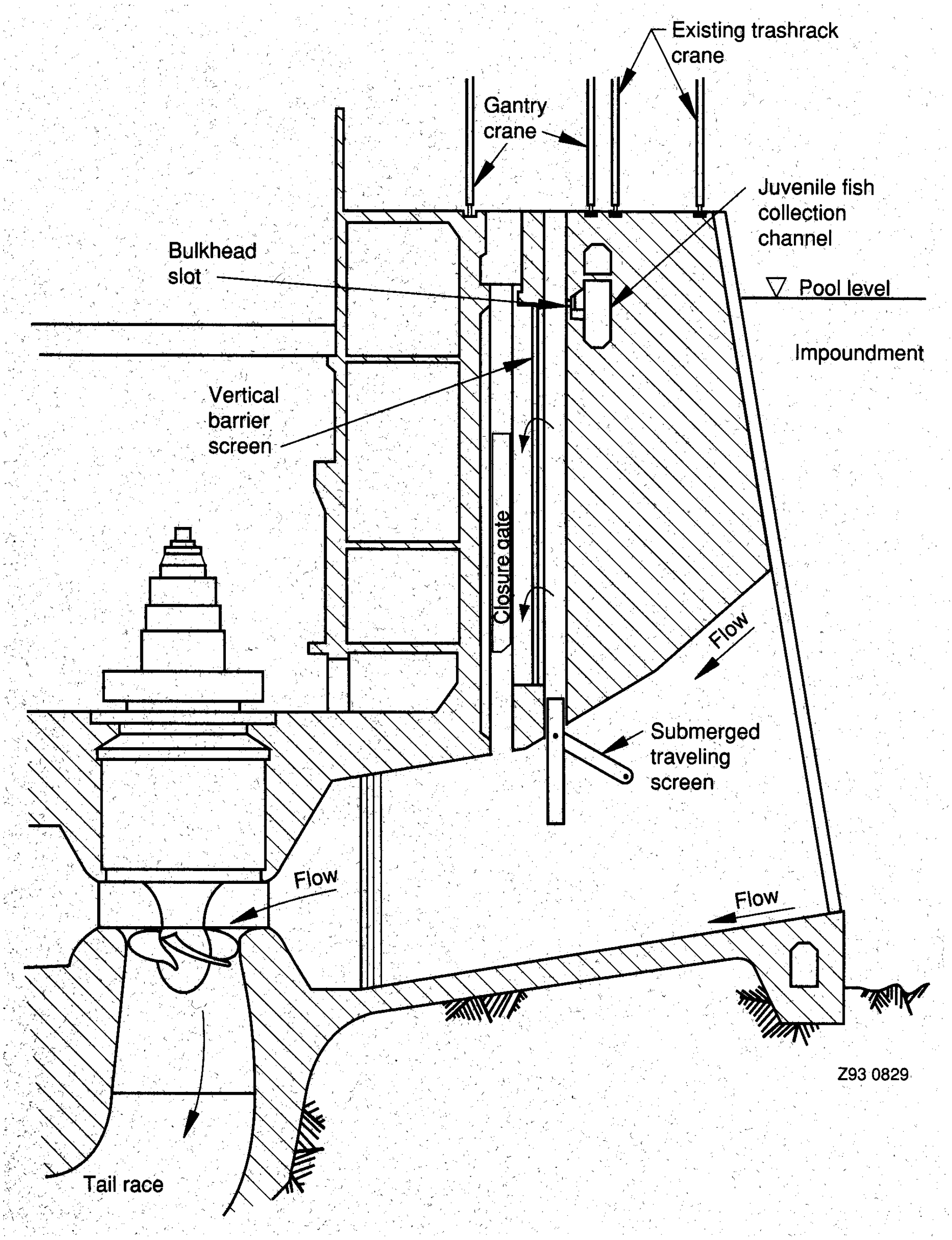


**Figure 22. Lower Monumental Dam fish collection and passage system. the submerged traveling screens direct the downstream migrants into the gatewell slot, to right of the vertical barrier screen and into the juvenile fish collection channel. (from Francfort et al, 1994).**

- Surface Bypass Collectors – Recent innovations in fish passage technology have focused on the collection and routing of juvenile fish from the surface waters where they are usually found. Subsequently, the fish may be directed to collection and transport facilities or to areas directly downstream of the dam usually in the tailrace. The National Marine Fisheries Service (NMFS) has outlined the following conceptual framework for application in surface bypass collection efforts (NMFS, 2000):
  - Smolts follow the bulk flow as they approach a dam: this is usually controlled by forebay hydraulic conditions.
  - Smolts can discover the surface bypass flow net: they must be able to find and react to the attracting surface flow field in the collector.
  - Surface bypass entrance conditions should not elicit an avoidance response.
  - Smolts must stay in and pass through the conveyance structure safely.
  - Smolts should enter the tailrace and migrate quickly downstream.

Surface bypass collection facilities exist or have been tested at Bonneville, Lower Granite, Brownlee, Wanapum, Rocky Reach, and Wells Dams in the Columbia / Snake system. Additionally, passage of fish through sluiceways as outlined above is also considered as surface bypass. The surface bypass system at Wells Dam was a particular motivator for use of surface collection systems since bypass efficiency (ratio of fish passing surface bypass to total passage at test units) during a three year testing period, 1990 to 1992, at Wells dam was nearly 90 percent. It is difficult to extend bypass performance at Wells Dam to other projects since the arrangement of spillways and power generation units at Wells dam is unusual and unique among dams on the Columbia.

Surface bypass systems have three major design types: Deep slot collectors, corner collectors and surface weirs. The schematics below show the deep slot collector configuration for the Lower Granite Dam on the Snake River as well as schematic examples of a corner collector and a surface weir. An example of a corner collector is the bypass system under development at Rocky Reach dam which takes advantage of natural fish accumulations at the southern end of the powerhouse forebay.

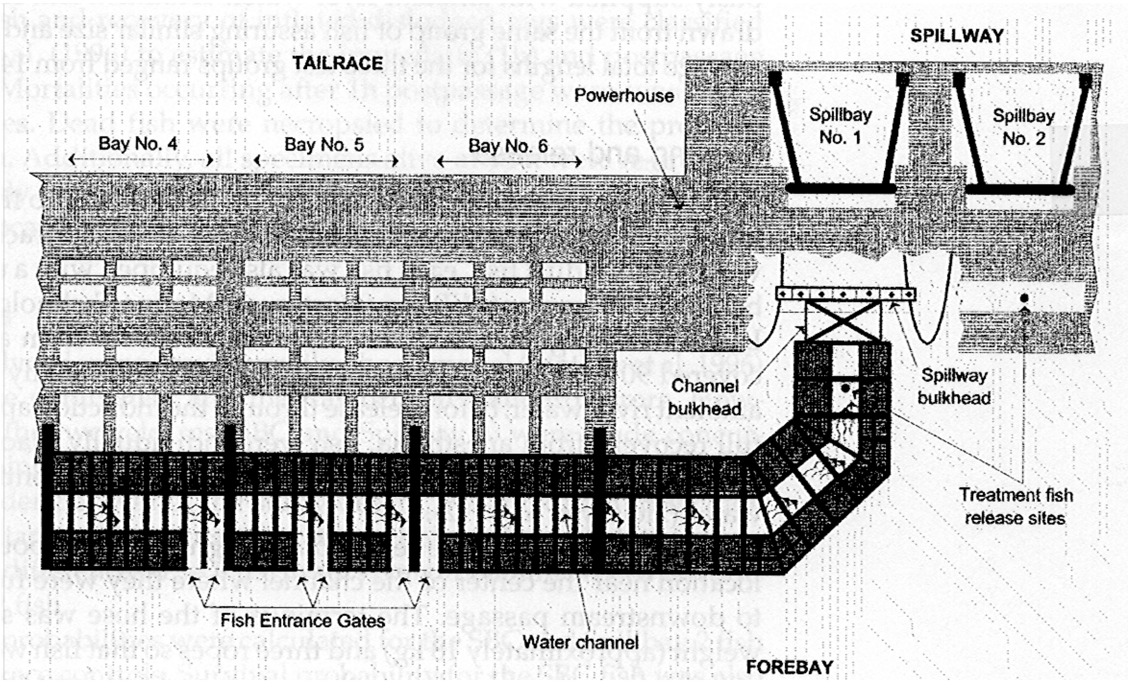


**Figure 23. Schematic Top view of the surface bypass collector (SBC) at Lower Granite Dam and fish release locations on the spillway bays, (from Mathur et al, 1999).**

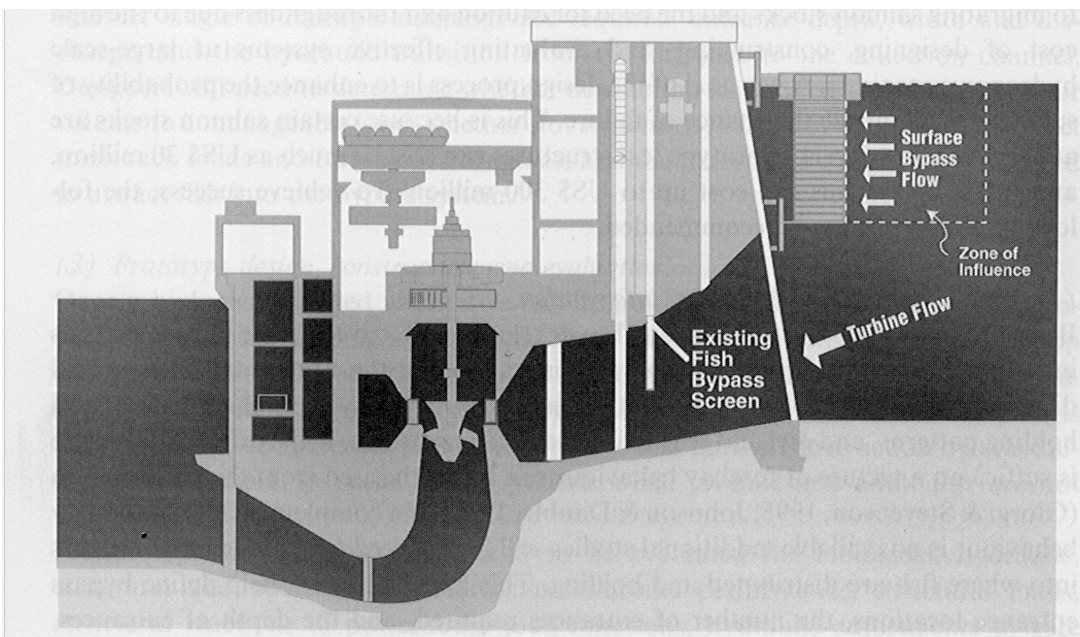


**Figure 24. Cross sectional view of the prototype deep-slot collector at Lower Granite Dam. Slot entrance velocities range from 0.6 to 1.8 m/s (2 – 5 ft/s), total bypass flow is 111 cms (4000 cfs) through two slots. Slot depth is 18.3 m (60 ft), (from Ferguson et al, 1998).**

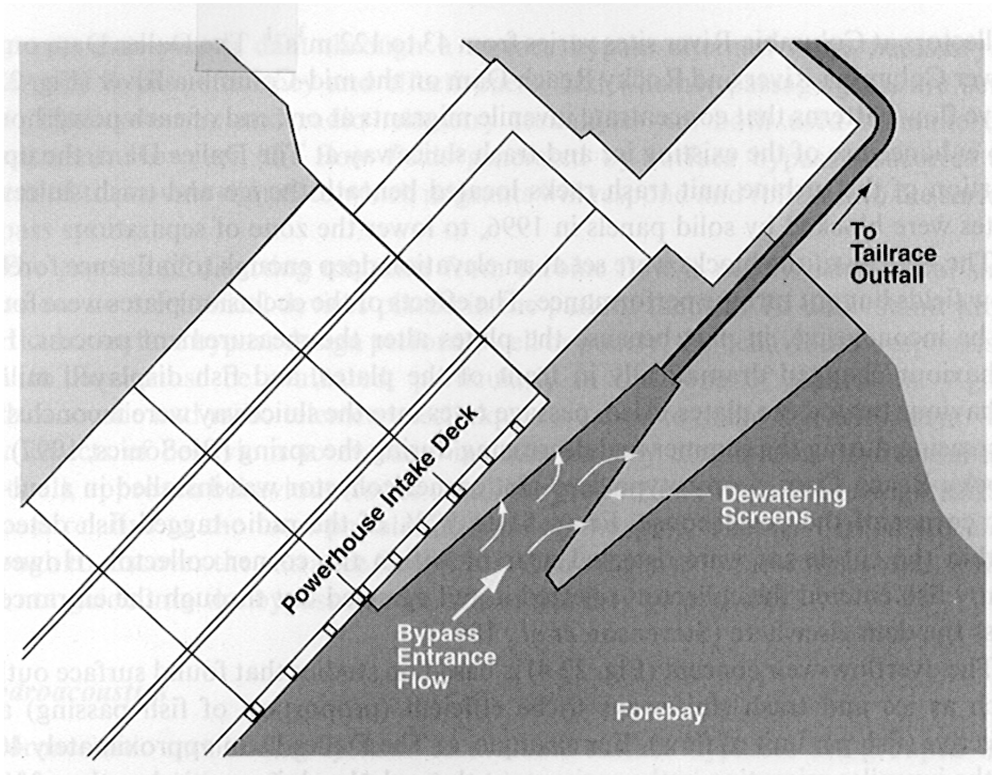


**Figure 25. Plan view of the corner collector concept, (from Ferguson et al, 1998).**

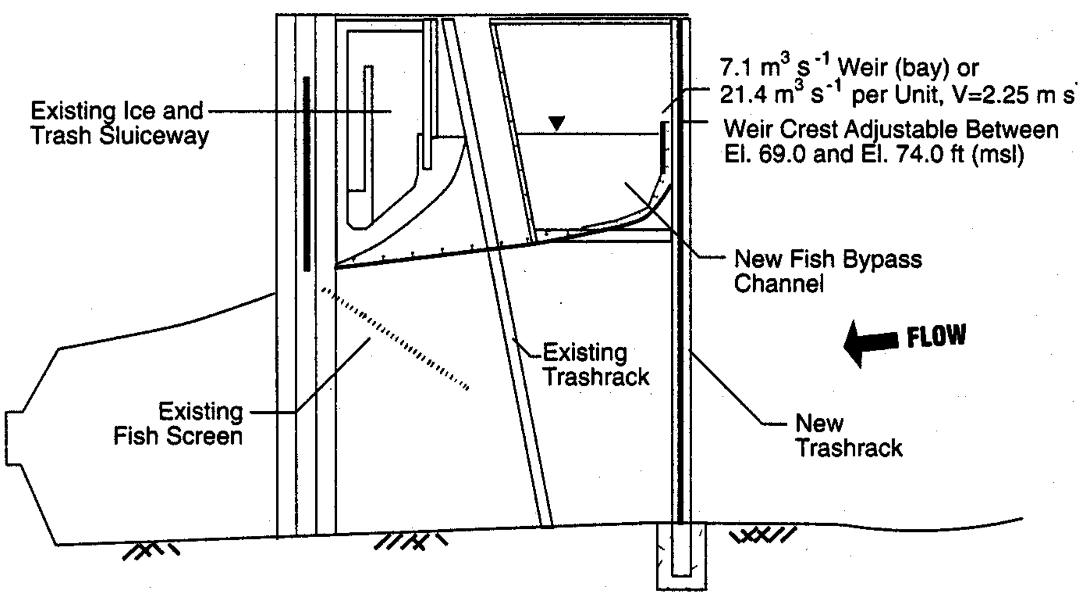


**Figure 26. Cross-sectional view of a conceptual surface weir, (from Ferguson et al, 1998).**

- Transportation – Once fish have been collected, whether by sub-surface or surface collection methods, they may be routed to a transport facility and then moved by truck or barge past one or more dams. Issues of concern in transportation include not only mortality during collection and transport, but also stress on the fish during the transport process and the subsequent effects of that stress on the ability of the fish to survive and reproduce. Concerns also arise over whether removal from the river promotes straying or confusion during upstream passage for spawning when the fish return as adults. Currently, juvenile salmon are transported downstream from Lower Granite, Little Goose, Lower Monumental, McNary and Priest Rapids Dams. During the period 1968 to 1988, NMFS conducted various studies using steelhead, chinook and sockeye salmon at the Columbia and Lower Snake River dams. Smolt to adult returns (SARs) observed during these studies generally exceeded SARs for in-river migrant fish but were still substantially lower than for pre-dam conditions.

## C. Summary Table of Columbia and Snake River Fish Passage:

Table 1 on the following page summarizes the fish passage facilities on the Columbia and Snake Rivers. The list of facilities which have been tested or are currently in use does not include gas abatement or operations modifications such as turbine efficiency, use of spillways, flow augmentation. Fish attraction or repulsion measures such as acoustics and lighting are also not specified in the table.

| | CONSTRUCTED BYPASS FACILITIES *** | | | | | | |
|---|---|---|---|---|---|---|---|
| DAM | Ladders (#) | Lock or Lift | Surface Bypass Collector | Use of Ice and Trash Sluiceway | Spillway Modification | Traveling screens at intakes + bypass channel | Transport by barge or truck |
| Lower Columbia: | | | | | | | |
| Bonneville | A (3) | X | J, d/s | J d/s | | J d/s (STS) | |
| The Dalles | A (2) | X | | J d/s | | | |
| John Day | A (2) | | | U/D | | J d/s (STS) | |
| McNary | A (2) | X | | | | J d/s (ESBS) | J d/s |
| Snake | | | | | | | |
| Ice Harbor | A (2) | | | J d/s | | J d/s (STS), F | |
| Lower Monumental | A (2) | | | | | J d/s (STS), F | J d/s |
| Little Goose | A (1) | | | | | J d/s (ESBS), F | J d/s |
| Lower Granite | A (1) | | J d/s, P | U/D | | J d/s (ESBS), P | J d/s |
| Hells Canyon | | | | | | | |
| Oxbow | | | | | | | |
| Brownlee | | | J d/s, T | | | | |
| Upper Columbia | | | | | | | |
| Priest Rapids | | | | J d/s | | | J d/s |
| Wanapum | A (1) | | J d/s | J d/s | | | |
| Rock Island | A (3) | | | | SSG | | |
| Rocky Reach | A (1) | | J d/s, P | | | J (d/s), P | |
| Wells | A (2) | | J d/s | | | | |
| Chief Joseph | | | | | | | |
| Grand Coulee | | | | | | | |

*** Does not include gas abatement or operations modifications such as turbine efficiency, use of spillways, flow augmentation, etc.
A = Adult, J d/s = Juvenile downstream, T = Experimental, U/D = Under Development, X= Out of service
STS = Standard Traveling Screen, ESBS = Extended Submersible Bar Screen, P = Pipe, F = Flume
SSG = Surface Spill Gate

**Table 1. Fish Passage Facilities used on Columbia and Snake Rivers.**

## III. EVALUATION CRITERIA FOR FISH PASSAGE:

The choice of an appropriate system for fish passage system should accommodate requirements for adult and juvenile fish, hydraulics, and land use. In addition, the choice of an appropriate passage system must take into account the costs and time required for implementation. Criteria for evaluating passage alternatives at Chief Joseph Dam are summarized below:

### A. Fish:

**1.** Sizes and Species – At Chief Joseph Dam, downstream passage flow depths and velocities should accommodate a wide range of fish sizes, from juvenile salmonids through adult steelhead. Upstream passage facilities should be able to pass adult steelhead, chinook, rainbow trout and whitefish.

**2.** Direction and Location of Passage – Both upstream and downstream passage are desired. Fish tend to follow the channel banks during migration so, if possible, a fish passage system should address fish presence at both right and left banks. Investigations of fish behavior and hydraulics near the Chief Joseph forebay and spillway would be necessary so that a facility could be designed to accommodate normal migration routes with an understanding of the velocity, temperature and water quality dynamics of the reservoir.

The following table lists passage alternatives along with some possible placement locations and direction of fish passage at Chief Joseph Dam.

| Fish Passage Method | Upstream | | | Downstream | | |
|---|---|---|---|---|---|---|
| | Right Bank | Mid Channel | Left Bank | Right Bank | Mid Channel | Left Bank |
| Bypass channel | | | X | | | X |
| Fish ladder | X | | X | | | |
| Fish lock | | X | | | X | |
| Collection and transport | | | X | | | X |
| Surface bypass collector / pipe | | | | | X | X |
| Gatewell bypass collector / pipe | | | | | X | X |
| Sluiceway passage | | | | X | | |
| Spillway passage | | | | X | | |
| Turbine passage | | | | | | X |

**Table 2. Possible location and direction of passage for fish passage alternatives.**

**3.** Migration timing for anadromous species (others may also use facilities) (from Bell 1986) is summarized in Table 3, below. Based on the species and runs of concern, upstream passage facilities need to operate year-round, while downstream passage is an issue from March through to the end of summer.

| Species / Run | Downstream Juvenile | Upstream Adult |
|---|---|---|
| Fall Chinook | April – June | August - December |
| Spring Chinook | Spring and Summer | May - June |
| Summer Chinook | Spring | July – September |
| Steelhead Summer Run | March - June | June – early August,<br>August - October |

**Table 3. Timing of Downstream Juvenile and Upstream Adult migration for chinook and steelhead in the vicinity of Chief Joseph Dam.**

**4.** Swimming capabilities for anadromous species (others may also use facilities) - Velocities in the designed facilities must allow for fish passage without undue stress or energy expenditure by the migrating fish. Table 4, below, summarizes assumptions for the species of interest at Chief Joseph Dam.

| | Swimming Speed | | |
|---|---|---|---|
| **Species / Run** | **Cruising (ft/s)** | **Sustained (ft/s)** | **Burst (ft/s)** |
| Adult Chinook | 0 – 3.4 | 3.4 – 10.8 | 10.8 – 22.4 |
| Adult Steelhead | 0 – 4.6 | 4.6 – 13.7 | 13.7 – 26.5 |
| Juvenile Fish 2” (based on rainbow and sockeye) | 0 – 0.5 | 0.15 – 0.7 | 0.5 – 2.0 |
| Juvenile Fish 4” (based on rainbow and sockeye) | 0 – 1.0 | 0.3 – 1.4 | 1.0 – 4.0 |

**Table 4. Swimming capabilities for anadromous species.**

**5.** Time in Transit – Fish passage methods should be designed to permit minimum times for waiting and passage to minimize stress and predation of the fish.

## B. Hydraulics:

**1.** Attraction flows – Entrance hydraulics need to be appropriate for attracting fish into the passage facility. For upstream passage the attraction flow must be strong enough that it can be differentiated from the main flow direction. For downstream passage adequate flow acceleration must occur.

**2.** Flow characteristics – Flow in fishways, channel and pipes should be optimized for fish survival and swimming capabilities. Entrance velocities of 4 to 8 feet per second are typically recommended for adult fish. Minimum depth of flow for chinook and steelhead is considered to be 1 foot.

**3.** Water usage – The quantity of flow in a passage facility should be easily and consistently deliverable by the project either through normal operations or by use of auxiliary water supply.

**4.** Extraction and injection points – Placement of entrances and exits should not adversely affect dam operations and should be designed to place the fish at least risk from predation and water quality issues. Entrance of debris into the fishway should be avoided. Entrances and exits must be functional over at least the normal range of river and reservoir levels.

**5.** Screening – Screens should be positioned to minimize avoidance and fish injury. Screens also need to be easily maintained and avoid collecting debris.

**C. Land Use:**

**1.** Geotechnical – Placement of the fish passage facility needs to take into account the stability of the site and surrounding soils and any foundations or revetments that will need to be placed.

**2.** Roads – Local road access needs to be maintained throughout construction and road modifications as a result of the facility need to be assessed. Public access to viewing areas may be an issue.

**3.** Ownership – Real estate issues will need to be addressed and will bear upon the cost of the final facility.

**4.** Fisheries – Tribal harvest site access may be a factor

**D. Costs and Schedules:**

**1.** Design – Where possible, design should make use of prior experience and design efforts for similar projects.

**2.** Construction – Timing and cost of construction will depend on Dam operations and how much work needs to be performed below normal waterline. Fish migration may impact in-stream work.

**3.** Monitoring / management – Fish passage facilities should include instrumentation, facilities and funding for monitoring the results of installing the facilities.

**4.** A benefit / cost analysis will not depend upon monetary (e.g. commercial fishing or recreational fishing) value of the fish.

**5.** The costs that need to be considered in estimating fish passage facilities are:

- Capital Costs – Cost of construction of the fish passage facilities including monitoring facilities and real estate acquisition.
- Operating Costs – This cost includes:
    - Operations and Maintenance Costs – Costs of pumps for water attraction flows, cleaning of passage facilities and facilities repair. The costs associated with collection and transport of fish should be included if applicable to the passage method.
    - Reporting and Monitoring Costs – Costs include fish counting, fish behavior and other studies after construction as well as the salaries of fish biologists and other personnel involved with monitoring of the facilities.

- Study Costs – Costs of the studies for selecting the facilities as well as studies for facility design and permitting. Costs for fish behavior studies prior to construction are also included in this category.
- Lost Generation Costs – Costs due to spillage of water that could otherwise be used for power generation.

**6.** Cost Estimates – The cost estimates in this document are based primarily on findings from Environmental Mitigation at Hydroelectric Projects, Volume 2. Benefits and Costs of Fish Passage Protection, January 1994, Idaho National Engineering Laboratory. This study examined the costs associated with fish passage at 16 hydroelectric projects ranging in capacity from 0.4 to 840 Megawatts. Three of the case studies in this document, Lower Monumental Dam, Wells Dam and Conowingo Dam were high head projects producing over 1 million Megawatt –hours of power annually. Fish passage costs from these three projects were used as a guide for developing the estimates for fish passage alternatives at Chief Joseph Dam.

**7.** Cost Assumptions – For estimating fish passage costs using information from other hydroelectric projects, facilities on the right and left banks of the river were scaled up or down using the total head drop of the facility. Facilities that were connected to or located in the powerhouse were scaled using the total generating capacity of the power station.

| Hydroelectric Project | Diversion Height (ft) | Average Site Flow (cfs) | Capacity (MW) | Estimated kW/cfs |
|---|---|---|---|---|
| Chief Joseph | 174 | 113,200 | 2600 | 12.6 |
| Wells | 67 | 80,000 | 840 | 4.5 |
| Lower Monumental | 100 | 48,950 | 810 | 5 |
| Conowingo | 105 | 45,000 | 512 | 6.8 |

**Table 5. Project statistics used in preparing cost estimates of fish passage alternatives.**

## IV. POSSIBLE PASSAGE SYSTEMS:

### A. Fish Ladder – Pool and Weir, Vertical Slot or Hybrid Fishway

**1.** Location / Direction – This passage method is most appropriate for use on the right bank but could also be used on the left bank. The center of channel island is not likely to have enough area for a fishway without many switchbacks or bends which lengthen the time required for passage. A fish ladder would be primarily for upstream migration of adult fish. Juvenile downstream migration would need to be addressed in a separate facility.

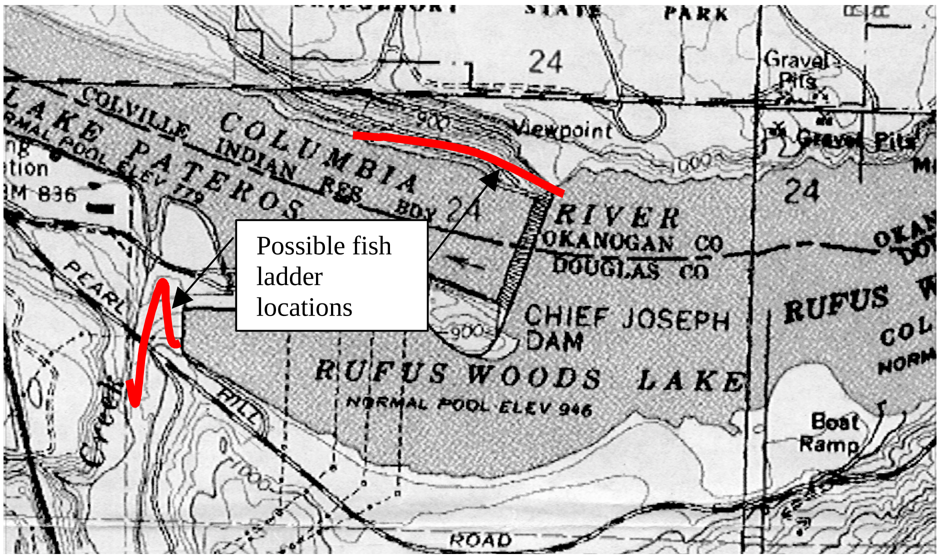


**Figure 27. Examples of possible fish ladder locations.**

**2.** Length and dimensions – At a slope of 1-on-10, the fish ladder(s) would be 1740 feet long and would require extra length for fishway bends if installed on the left bank. A pool and weir type ladder such as that used at Ice Harbor could be employed. Such a fishway is 16 feet wide with two 5-foot overflow weirs and orifices at the fishway floor. Depending on the orifice opening, flow over the weir portion of the fishway should vary from 1 to 1.2 feet in depth. The flow rate required for the Ice Harbor fishway is 70 cfs.

**3.** Attributes – Fish ladders are fairly established technology, so many previous designs have been tested at model and prototype scale. Hydraulic design studies for this type of structure should be minimal and adult fish response to the fish ladder should be fairly predictable.

**4.** Issues – Attraction flow needs to be adequate divert fish from the main channel and so supplementary flow may be needed to be provided. Predation is typically heavy at inlets to fishways since the fish congregate at the downstream entrance prior to beginning the ascent of the fishway. Depending on the final grade and length of the fishway, the fish may require resting pools. The foundation design for the ladder will have to take into account seepage issues in the soils around the dam abutments especially on the right bank.

**5.** Costs: Table 6 below shows a preliminary cost estimate for a single fish ladder at Chief Joseph Dam. The estimated costs are based on the costs associated with fish ladders at Wells Dam and Lower Monumental Dam which each have two ladders. The costs have been scaled with the total head drop at each dam. The lost generation due to flow in the ladder is given in kilowatts and includes the estimated base flow at the ladder.

| Fish Ladder: | Wells | Monumental | Average |
|---|---|---|---|
| **Capital Costs ($ million)** | **40** | **22** | |
| **Rise (feet)** | **67** | **100** | |
| **Lost Generation Flows (cfs)** | **300** | **495** | |
| **Number of Ladders** | **2** | **2** | |
| **Annual Operating Costs ($ thousands)** | **211** | **409** | |
| | | | |
| **Scaled Capital Cost (1993) ($ millions)** | **52** | **19** | **36** |
| **Scaled Capital Cost (2002) ($ millions)** | **65** | **24** | **45** |
| | | | |
| **Scaled Operating Costs (1993) ($ thousands)** | **141** | **165** | **153** |
| **Scaled Operating Costs (2002) ($ thousands)** | **175** | **206** | **191** |
| | | | |
| **Study Costs (1993) ($ millions)** | **7** | **1** | |
| **Study Costs (2002) ($ millions)** | **9** | **2** | **5** |
| | | | |
| **Estimated Lost Generation Flow (cfs)** | | | **200** |
| **Annual Lost Generation @ 12.6kw/cfs (MW-HR thousands)** | | | **22** |
| **Value of Lost Flow @ $40/ MW-HR ($ thousands)** | | | **883** |

**Table 6. Sample fish ladder estimate.**

## B. Surface Bypass Channel – Simulated Natural Channel

**1.** Location / Direction – A simulated natural channel could be located on the left bank with its entrance either upstream of log boom west of the boat ramp or from a surface collector at the powerhouse forebay. The channel could possibly be designed to accommodate both upstream and downstream passage. The example channel alignment shown in Figure 28, below, is comprised of two sections. The first, most upstream section is a low gradient channel excavated starting at the left bank boat ramp and running parallel to the left bank to minimize excavation volumes. The second section is a steeper step pool channel that empties into Foster Creek.

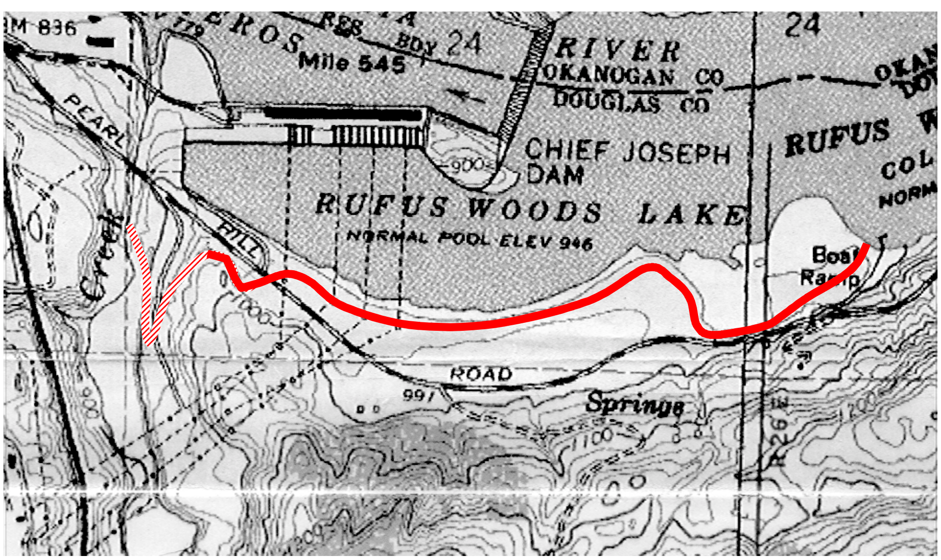


**Figure 28. Example of an alignment for a bypass channel.**

2. Length and Dimensions – The low gradient channel length as shown is approximately 6400 ft with a bed slope of 0.0008 ft/ft. At an inflow rate of 100 cfs, mean channel depth would average 3 ft with a mean velocity of 1.8 ft/s. This velocity was selected to allowed sustained swimming speed for adult fish while allowing juvenile fish to migrate in the slower flow regions near channel sidewalls. Fine sediments would remain in motion for this type of flow. The upstream channel entrance for this configuration could be self-regulating over the normal range of pool elevations (950 – 956 ft) but could not be operated at pool levels below 945 feet. Additional attraction flow may be required if flow velocity at the entrance is to exceed 6 ft/s. The downstream section of the channel descends into Foster Creek, has a slope between 0.02 and 0.03 ft/ft and a length of approximately 2440 feet. This second portion of channel would be designed as a series of steps and pools with a minimum depth of approximately 1.5 feet and a maximum velocity of 6.8 ft/s in the step sections and deeper depths and slower velocities in the pools at 100 cfs.
3. Attributes – The channel would be of low impact to fish since it would simulate a natural streambed. The channel would maintain a free surface throughout its length avoiding pressurization issues.
4. Issues – Channel design would need to incorporate a collection mechanism or sufficient attraction flow to bring fish into the channel, both for ascent and descent. There may also be a need for active upstream flow control to allow operation over a range of pool levels. The low gradient portion of the channel may have to use a flexible lining system because of motion of the Bridgeport slide.
5. Costs – Table 7 shows a preliminary estimate for the costs of a natural bypass channel. Since no comparable projects were available for comparison in this case, the estimate is split into two sections. The low gradient section is estimated using a preliminary cost of $12/ cubic yard of excavated material and an additional factor of 40% for the construction of the channel, entrance structure and road crossing. The high gradient section may need to constructed with a rigid lining, slope revetments and sections of retaining wall, so a per foot cost was assumed based on a lineal foot cost for fish ladders.

Natural Bypass Channel

| | |
|---|---|
| **Capital Costs ($ million)** | |
| **6400 feet of channel at 0.0007 Slope 3:1 sidewalls** | |
| **Excavation costs ($ millions) based $12/cu.yd.** | **6** |
| **Entrance & Channel construction @40% of excav ($ millions)** | **2** |
| **2440 feet of step pool structure at 0.02 - 0.03 Slope** | |
| **Scaled from average fish ladder cost** | **62** |
| **Scaled Capital Cost (2002) ($ millions)** | **71** |
| **Scaled Operating Costs (2002) ($ thousands)** | **191** |
| **Study Costs (2002) (assumed comparable to fish ladder, $ millions)** | **5** |
| **Estimated Lost Generation Flow (cfs)** | **150** |
| **Annual Lost Generation @ 12.6kw/cfs (MW-HR thousands)** | **17** |
| **Value of Lost Flow @ $40/ MW-HR ($ thousands)** | **662** |

**Table 7. Sample natural bypass channel estimate.**

## C. Fish Lock or Lift

**1.** Location / Direction – Could be used for both upstream and downstream passage. The structure could be located at either right or left bank or in the center of channel island.

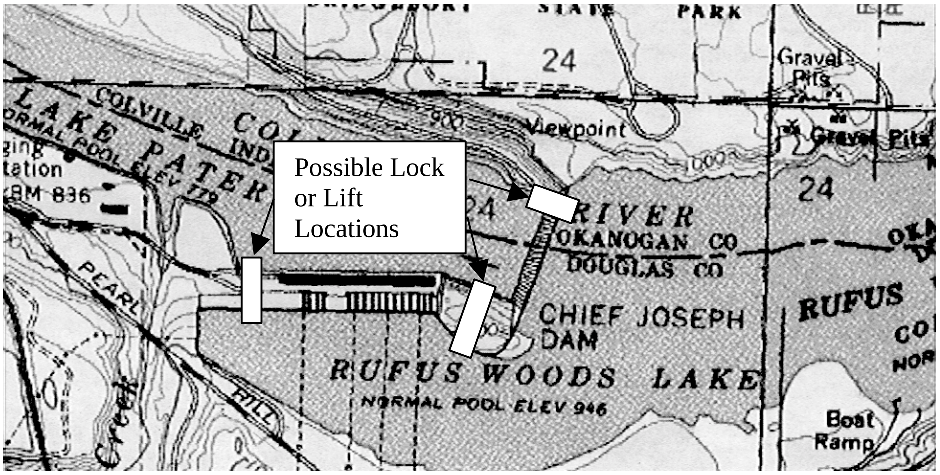


**Figure 29. Examples of possible lock locations.**

**2.** Attributes – Would have less mechanical damage and shorter transit time than piping/ collection / trucking methods.

**3.** Issues – Attraction of fish to the lock or lift is an issue. It might have to be coupled with a surface collection method and might only be feasible to operate in one direction (upstream or downstream). In addition, stress on fish during accumulation time between lockages is also an issue. A conventional lock system would probably not be feasible here because of the large head difference. A pressurized system may be feasible.

**4.** Costs – The costs presented below in Table 8 are for a fish lift. As such they probably present the lower cost end of a lift or lock system. The costs are based on the fish lift system in place at the Conowingo Dam on the Susquehanna River in Maryland. Costs are scaled by the total head difference across the dam. Flows are assumed to be needed all year long.

Fish Lift:

| | |
|---|---|
| **Capital Costs ($ million)** | 12 |
| **Rise** | 100 |
| **Lost Generation Flows (cfs)** | 300 |
| **Annual Operating Costs ($ thousands)** | 400 |
| **Scaled Capital Cost (1993) ($ millions)** | **24** |
| **Scaled Capital Cost (2002) ($ millions)** | **30** |
| **Scaled Operating Costs (1993) ($ thousands)** | **696** |
| **Scaled Operating Costs (2002) ($ thousands)** | **869** |
| **Study Costs (2002) (assumed comparable to fish ladder, $ millions)** | **5** |
| **Estimated Lost Generation Flow (cfs)** | **300** |
| **Annual Lost Generation @ 12.6kw/cfs (MW-HR thousands)** | **33** |
| **Value of Lost Flow @ $40/ MW-HR ($ thousands)** | **1325** |

**Table 8. Sample fish lift estimate.**

## D. Surface Collector at Forebay or Sluiceway or Other Channel / Pipe Bypass.

**1.** Location / Direction – Such a system would be located near the upstream face of the powerhouse, probably in the forebay area for a deep slot collector or near the left bank for a corner collector design. The system would be for downstream passage only.

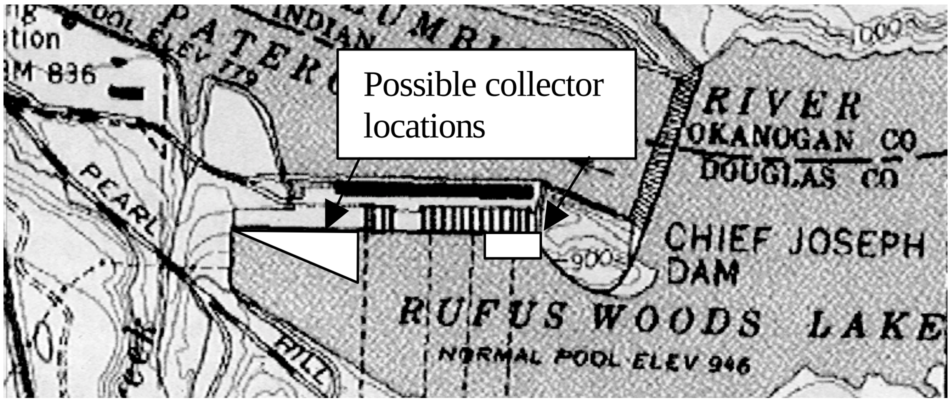


**Figure 30. Examples of possible surface collector locations.**

**2.** Attributes - The collector could be located to take advantage of existing fish migration patterns. Surface collection is a recognized alternative to collection in the turbine gatewells.

**3.** Issues -Screening and flow conditioning to attract fish could affect intake at the turbines. Transport of fish subsequent to collection would have to consider pressurization effects in the exit piping. Since surface collection is still a relatively new and developing method for fish passage, collection efficiencies are difficult to predict and optimal collector design has not been established.

| Surface Collector: | Wells | Monumental | Combined |
|---|---|---|---|
| **Capital Costs ($ million) (each partial)** | **1** | **8** | |
| **Generating Capacity (MW) (for Wells bypass portion)** | **840** | | |
| **Rise (ft) (for Monumental collector portion)** | | **100** | |
| **Lost Generation Flow (cfs)** | **2000** | | |
| **Annual Operating Costs ($ thousands)** | **406** | **275** | |
| | | | |
| **Scaled Capital Cost (1993) ($ millions)** | **4** | **13** | **17** |
| **Scaled Capital Cost (2002) ($ millions)** | **5** | **17** | **21** |
| | | | |
| **Scaled Operating Costs (1993) ($ thousands)** | **406** | **478** | **884** |
| **Scaled Operating Costs (2002) ($ thousands)** | **507** | **597** | **1104** |
| | | | |
| **Study Costs (1993) ($ millions)** | **7** | | **7** |
| **Study Costs (2002) ($ millions)** | | | **9** |
| | | | |
| **Estimated Lost Generation Flow (March - June only) (cfs)** | | | **2000** |
| **Annual Lost Generation @ 12.6kw/cfs (MW-HR thousands)** | | | **74** |
| **Value of Lost Flow @ $40/ MW-HR ($ thousands)** | | | **2943** |

**Table 9. Sample surface bypass collector estimate.**

**4.** Costs – The costs presented above represent an estimate for a bypass and collection / piping system. The bypass screens are estimated based on values from Wells Dam while the collection system uses values from Lower Monumental Dam. This combined estimating method was used because of the unique construction of Wells Dam, which integrates powerhouse and spillways and so obviates the need for collection channels and piping.

## E. Gatewell Turbine Bypass -Traveling Screens

**1.** Location / Direction – Traveling screens would be located at turbine intakes approximately 70 feet below normal pool elevation and are for downstream passage only.

**2.** Attributes - Traveling screen systems have been extensively tested and developed for use on Lower Snake and Lower Columbia River dams so the technology is well established.

**3.** Issues - The high head at Chief Joseph would require the downstream migrating juveniles to descend 70 feet to the intakes when their preferred behavior is to stay near the surface. Transport of fish from the gatewells would have to consider pressurization effects in the exit piping.

**4.** Costs – The costs estimate for turbine bypass is based on STS (submerged traveling screens) installed at Lower Monumental Dam. Since the installation of these screens extended versions of these screens (ESTS) have been tested and installed on Columbia River dams, however, costs of the ESTS were not used for this estimate. Since Chief Joseph has 27 turbines as opposed to Lower Monumental which has 6 turbines, the cost estimate has been scaled by the relative power generation capabilities of Chief Joseph and Lower Monumental Dams.

| Traveling Screens | |
|---|---|
| **Capital Costs (Lower Monumental) ($ million)** | **13** |
| **Generating Capacity (Lower Monumental) (MW)** | **810** |
| **Annual Operating Costs (Lower Mon.) ($ thousands)** | **275** |
| | |
| **Scaled Capital Cost (1993) ($ millions)** | **40** |
| **Scaled Capital Cost (2002) ($ millions)** | **51** |
| | |
| **Scaled Operating Costs (1993) ($ thousands)** | **882** |
| **Scaled Operating Costs (2002) ($ thousands)** | **1101** |
| | |
| **Study Costs (1993) ($ millions)** | **1** |
| **Scaled Study Costs ($ millions)** | **3** |
| **Study Costs (2002) ($ millions)** | **4** |
| | |
| **Lost Generation based on 1.5% loss in Power due to head loss at screens = 720 MW-HR /day** | |
| **Annual Lost Generation (MW-HR thousands)** | **263** |

**Table 10. Sample traveling screens estimate.**

## F. Collection and Transport Facility

**1.** Location / Direction – A collection facility could probably be located on the left bank or near Foster Creek. The direction of transport could be either upstream or downstream, possibly both. The collection and transport facility would need to be associated with one of the other fish passage systems detailed above such as a surface collector for downstream passage or a fish ladder for upstream passage. As such, the cost for such a facility is additive to the facility being used to attract the migrating fish.

**2.** Attributes - Fish could be collected for transport to other parts of the Columbia River system.

**3.** Issues - Would have the same issues as fishways, surface collectors and channels in terms of attraction flows and screening for collection. Would also have to address predation at entrance and release locations as well as stress in transit.

**4.** Costs – The costs for holding and transport represent an added cost to a surface or subsurface collection system. The estimate for this facility is based on similar costs at Lower Monumental Dam. The costs are not scaled since they are assumed to be independent of facility size but depend more on the expected volume and numbers of fish to be collected.

<u>Collection and Transport Facility</u>

| | |
|---|---|
| **Monumental example (1993) ($ millions)** | **6** |
| **Monumental example (2002) ($ millions)** | **7** |

**Table 11. Sample collection and transport facility estimate.**

## G. Spillway and Turbine Passage

**1.** Location / Direction – These operations changes provide transport in the downstream direction only.

**2.** Attributes - Passage depends on operations and management of current facilities without additional construction. Flow deflectors installed for gas abatement on the spillway are not likely to adversely impact fish passed by spilling.

**3.** Issues – Operations changes would possibly have to consider modifying turbine operations and would have to consider pressurization effects in the exit piping from turbines.

**4.** Costs – The costs associated with passage over spillways are usually estimated by assessing the lost generation capability of the water. Spill value estimates from Wells and Lower Monumental Dams have been averaged to provide an estimate of these costs. The estimate did not take into account changes in power generation caused by modifying turbine operations or turbine efficiency. In addition, at Chief Joseph Dam, any capital costs associated with spillway modifications for fish would depend on whether the project occurred before, after or in concert with the gas abatement project and have not been estimated for this option.

<u>Spillway Passage</u>

| | Wells | Monumental | Average |
|---|---|---|---|
| **Annual spill value estimates (1993) ($ millions)** | **1** | **5** | **3** |
| **Annual spill value estimates (2002) ($ millions)** | | | **4** |

**Table 12. Sample spillway passage estimate.**

## H. SUMMARY OF PASSAGE OPTION COSTS:

(Current Year, 2002, Dollars)

| **Passage Option** | **U/S** | **D/S** | **Capital Costs** ($ millions) | **Annual Operating Costs** ($ thousands) | **Annual Generation Loss** ($ thousands) | **Study Costs** ($ millions) |
|---|---|---|---|---|---|---|
| 1. Fish Ladder | √ | | $45 | $191 | $883 | $5 |
| 2. Bypass Channel | √ | √ | $71 | $191 | $662 | $5 |
| 3. Fish Lift | √ | √ | $30 | $869 | $1325 | $5 |
| 4. Surface Collector | | √ | $21 | $1,104 | $2943 | $9 |
| 5. Traveling Screens | | √ | $51 | $1,101 | $263 | $4 |
| 6. Collection and Transport Facility | √ | √ | $7 | NR | NR | NR |
| 7. Spillway Passage | | √ | NR | NR | $4000 | NR |

Source: Wells, Monumental, Conowingo case studies (Francfort, 1994)

N/R – Not Reported

(Low, Medium, High rankings)

| Passage Option | U/S | D/S | Capital Costs | Annual Operating Costs | Annual Generation Loss | Study Costs |
|---|---|---|---|---|---|---|
| 1. Fish Ladder | √ | | M | L | L - M | M |
| 2. Bypass Channel | √ | √ | M - H | L | L - M | M |
| 3. Fish Lift | √ | √ | M | M - H | M | M |
| 4. Surface Collector | | √ | L - M | H | H | H |
| 5. Traveling Screens | | √ | M | H | L | L |
| 6. Collection and Transport Facility (add-on to other facility) | √ | √ | L - M | L | L | L |
| 7. Spillway Passage | | √ | L - M | M | H | L |

L – Low
M – Moderate
H – High

Sources: Francfort (1994), J. Athearn – NWD, pers. comm.

## V. CONCLUSION:

The fish passage options presented in this document represent a wide sampling of mitigation systems currently used at hydroelectric projects. In order to better understand the advantages, impacts and costs of the individual options, a detailed feasibility study would be useful. Such a study should address fish behavior and reservoir hydraulics specific to Chief Joseph Dam for both adult and juvenile fish. Based on the preliminary cost criteria, it appears that the surface collectors, fish lift and traveling screen options may entail higher operating and / or power generation losses. A successful fish passage system is likely to combine several options to achieve both upstream and downstream passage.

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