APPENDIX F-2

Dreissenid Response Strategies at Lower Columbia River Basin Hydroelectric Fish Facilities

By Gregory Kovalchuk
Pacific States Marine Fisheries Commission
205 SE Spokane Street
Suite 100
Portland, Oregon 97202

May 2007

ACRONYMS

AWS	auxiliary water supply or auxiliary water system
BiOp	Biological Opinion
Corps	Corps of Engineers
CRB	Columbia River Basin
ESA	Endangered Species Act
DO	dissolved oxygen
ESBSs	extended-length submersible bar screens
FCRPS	Federal Columbia River Power System
FDS	Fish and Debris Separator
FPOM	Fish Passage Operations and Maintenance Coordination Team
FPP	Fish Passage Plan
JBS	juvenile bypass systems
PIT	passive integrated transponder
PA	pre-anesthetizing
PDS	primary dewatering structure
ROV	remotely operated vehicle
SDS	secondary dewatering system
SMF	smolt monitoring facilities
SMP	Smolt Monitoring Program
STSs	submersible traveling screens
VBSs	vertical barrier screens

I. Introduction

The purpose of this document is to evaluate the potential impacts of a zebra mussel (*Dreissena polymorpha*) or quagga mussel (*Dreissena bugensis*) infestation on the Federal Columbia River Power System's (FCRPS) hydroelectric juvenile fish passage facilities and adult fishways and determine potential impacts and appropriate rapid responses should an infestation occur. Although this response plan is specific to the Corps of Engineer's (Corps) projects at John Day Dam and Bonneville dams on the lower Columbia River mainstem, sections may apply to the other six Corps projects, privately owned Public Utilities District, or Bureau of Reclamation hydroelectric projects which maintain similar adult and juvenile fishways in the Columbia River Basin (CRB). Many projects have unique fish passage operations and components that would require site specific knowledge and evaluation to assess risk from invasive dreissenid mussels (Four of the other Corps projects have juvenile fish transportation facilities).

II. Background

The mainstem Columbia River Basin hydroelectric projects provide power, flood control, irrigation, navigation, and recreational opportunities throughout the Pacific Northwest and are vulnerable to potential impacts from an invasive mussel infestation. An overview of Bonneville Lock and Dam Project components that may be at risk of colonization can be found in Section C, Appendix H (Athearn and Darland 2006). In addition, a review of the risks to Corps project fish facilities such as Juvenile Bypass Systems (JBS), Smolt Monitoring Facilities (SMF), and adult fishways can be found in Athearn (1999). Salmon and steelhead pass through numerous dams on the mainstem Columbia and Snake Rivers. The fish passage facilities must function properly to allow both upstream and downstream migration of salmon and steelhead, many of which are listed for protection under the Endangered Species Act (ESA). An invasive mussel infestation impact on fish passage facilities are of particular concern because hydroelectric project operations (i.e. power generation) are often determined by federal regulations regarding salmonids passage. Surface fouling created by attached dreissenid mussel on structures such as fish ladders, as well as clogging inflows, drainages, and screened areas, could create hazardous passage conditions for fish.

Even small fluctuations in flow due to debris accumulation or changes in river flow can cause weirs, valves, and screens to operate out of fish passage criteria which may cause delay or injury. At John Day Dam, approximately 90% of the spring and summer juvenile salmonid out-migrants use the bypass facility between April 1 and June 2 and the majority of the fall out-migrants (80%) pass between June 14 and August 2 (Martinson, et al, 2006). Any unnecessary facility outages due to additional cleaning or maintenance associated with a mussel infestation should be avoided during this period. Unscheduled generation unit outages can cause increased, involuntary spill which might lead to unsafe levels of atmospheric gas supersaturation for aquatic organisms, unsafe flood control conditions in reservoirs, and lost generating revenue for BPA.

A Corps document called the Fish Passage Plan (FPP) is part of the current strategy to reduce conflicts between various river users and fish passage. The FPP is updated annually by the Corps in coordination with regional fish agencies, Indian tribes, the Bonneville Power Administration, and other participants through the Fish Passage Operations and Maintenance Coordination Team (FPOM). The plan is incorporated in the most current NOAA Fisheries and U.S. Fish and Wildlife Biological Opinions (BiOp) and contains a comprehensive list of criteria, by project, that are intended to comply with BiOp performance standards. Increased duration of maintenance periods or other emergency deviations during fish passage seasons caused by a mussel infestation would require coordination with FPOM and the Technical Management Team and consultation with NOAA Fisheries.

Invasive Bivalve Populations and Assessing the Risk for Bypass Components: The significance of any impact caused by dreissenids in the CRB will depend on their colonization potential and level(s) of infestation. Seasonal growth rates and mussel density will be determined by water quality, water quantity, and fluctuations in plankton density. Some risks at the bypass facilities associated with a mussel infestation are more easily imagined and obvious while other risks are difficult to qualify due the uncertainty surrounding how equipment and mussels will interact. Almost all risk is related to:

1. the amount of time components are submerged in raw water,
2. the level of accessibility for inspection and cleaning or replacement of key components,
3. the amount of redundancy built into the design of the system, and
4. the level of interaction between a component and fish.

In many cases submerged components are dewatered for regularly scheduled winter maintenance but good accessibility and maintenance opportunities are limited to these periods. Any built in redundancies, such as the installation of a second auxiliary water supply (AWS) pipe, would be very costly and require additional planning and funding (Phillips et al. 2005). Components such as dewatering screens, porosity plates, and separator bars have near constant interaction with fish and would need increased monitoring and more frequent maintenance and cleaning.

Asian Clam *(Corbicula fluminea.),* an Indicator Bivalve: Regional hydropower projects have been interacting with and working around an introduced bivalve, the Asian clam for decades. The Asian clam is believed to have been introduced into the Pacific Northwest in the early 1930's (Burch 1944) and has since become one of the most common bivalves in the CRB (Newell 2003). Due to the clam's prolific nature and ubiquitous distribution in the Pacific Northwest, it is found in abundance at most mainstem dams. In fact, this non-native bivalve is the predominant bivalve mollusk in many of the aquatic environments at projects and large piles of clam shells can accumulate in the collection channels, fishways, under diffuser grating, inside water lines or behind valves, and behind dewatering screens. Asian clams have been found living in some drain galleries inside the dams. They also cause direct physical injury to fish when they become lodged in dewatering screens or on separator bars. Although

Asian clams differ from dreissenids in many ways, they are similar aquatic organisms and lessons and observations regarding clams may aide in predicting the impact of dreissenids. One significant difference is the encrusting nature of dreissenids (up to several inches thick) and their ability to attach to vertical surfaces through the use of byssal threads. It is unknown how *Corbicula* might interact with introduced mussels, but clam shells do provide suitable attachment sites for juvenile mussel colonization. Larval *Corbicula* complete most of their development inside the female clam whereas dreissenids have free living, veliger larvae. It is unknown which group of bivalves would have any competitive advantage regarding reproduction or colonization, but the encrusting nature and feeding behavior of dreissenids has been shown to be a serious threat to native bivalves in other parts of North America. Of course, the site specific nature of aquatic environments, unique construction materials and flow situations at dams, and the unpredictable nature of invasive biological organisms challenge the amount of certainty in any assessment of future risk.

III. Potential Impacts and Responses - John Day Dam and Bonneville Dam Juvenile Bypass System Components

Juvenile Bypass Facilities: The juvenile facilities at John Day and Bonneville dams consist of two major components, the juvenile bypass system (JBS) (Figure 1) and the smolt monitoring facilities. At John Day Dam, both parts of the system operate together April 1 through September 15, passing fish through a passive integrated transponder (PIT) tag detector, sample gate, and the SMF. The smolt sampling season at Bonneville Dam operates March 1 through October 31. The primary risk to both parts of the bypass is that they utilize raw river water and very few components or supply lines have built in redundancies which would be beneficial should a mussel invasion occur. From September 16 through December 15, submersible traveling screens (STSs) remain in operation to prevent adult salmonids from falling back through turbine units. At this time, fish, water, and debris are routed out of the JBS, down the ogee ramp, and out to tailrace through the juvenile outfall structure. After December 16 and until the start of fish passage season in April, the STSs are stored in their respective gatewell slots and non-guided fish and debris continue to passively use the bypass system for the remainder of the year except for a short period when it is dewatered for an annual inspection. In general, the operation and shut down dates are important because they represent well established maintenance periods which usually do not conflict with juvenile or adult fish passage. Similar details and schedules specific to each Corps project can be found in the current year FPP and in Table 2.

In many cases, equipment vulnerability and associated risk may require the modification of maintenance schedules, increased inspection and maintenance, improved cleaning techniques, installation of higher capacity pipes and redundant supply lines, and purchase of spare parts or backup equipment (Table 3, Appendix F-1.).

An upstream to downstream list of components and their associated vulnerability to dreissenids follow in the text and are listed in Table 1, and a schematic showing the project layout for John Day Dam can be found in Figure 2.

1. Powerhouse and Auxiliary Water Supply Trashracks: The trashracks prevent most large woody debris from entering the turbine intake or auxiliary water supplies for the adult fish ladders and juvenile facilities. The spacing of the bars on the trashracks varies from 3/4 inch on fish turbine intakes to 6 inches for main generator units. River debris is removed by lowering a large rake to the bottom of the trashrack which then collects debris as it is pulled back up to the surface. Units must be turned off during the raking process which is performed as needed during the juvenile passage season, often coinciding with the some of the season's highest in-river flows and debris loads. The main auxiliary water supply at John Day Dam provides add-in water for the adult fishways, flushing water for the main components of the juvenile bypass system downstream of the tainter gate, and irrigation water. No duplicate water source is currently available for these locations.

Potential Impacts: These structures are permanently submerged and at high risk of colonization by mussels. Although most trashracks have relatively large openings (approx. 1 ft^2), severe fouling with mussel shells may cause more tumbleweeds and willows to accumulate which would contribute to elevated descaling and injury of fish. Any increase in the frequency of trashrack raking could pose limitations on power production by having units shut down that could be generating power. Inoperable units during high flow periods would require extra spill, amount to lost power generating revenue, and create potentially hazardous river conditions for fish. The extra weight or associated difficulty of removing debris encrusted with zebra mussels would have to be considered among the potential elevated costs of increased maintenance. The AWS and penstock area is susceptible to mussel accumulation which could cause malfunctioning adjustments to water volume or inefficient delivery to fishways or the SMF.

Response: Periodic (weekly or monthly) inspection for and hand clearing of mussel debris from sensitive guide slots or cables associated with trashrack raking may be needed. More frequent cleaning of trashracks may be necessary due to mussel shells that can catch and hold more debris than non-encrusted surfaces. Consider providing backup equipment which can be used to while trashracks are periodically removed and cleaned. Design, manufacture, test, and deploy a mussel removing brush for use with current trashrack raking structures. Duplicate auxiliary water supply pipes do not currently exist but may be required if an infestation becomes extreme and mussel growth limits the current pipe capacity.

2. Bypass Screens (STS, ESBS, and VBS): These screens are so essential to safe fish passage that units are shut down if screens are damaged or clogged with debris (USACE 2006). At least three types of bypass screens are utilized in the Columbia and Snake River mainstem dams, submersible traveling screens (STSs), extended-length submersible bar screens (ESBSs), and vertical barrier screens (VBSs). Both STSs and VBSs are made of a fine plastic screen mesh (approx. 2mm opening, or 40% minimum porosity) whereas ESBSs are made of wedge wire with a 2 mm gap width (Johnson or Hendrix wedge wire screen) backed by perforated metal plates with of various diameter holes. These bypass screens work in tandem with the bypass channel to move out-migrating juvenile and adult salmonids from the forebay to the tailrace with minimum injury or delay. Bypass screens vastly improve turbine unit fish guidance efficiency and help determine orifice passage efficiency. John Day Dam is equipped with three STSs for each main unit in service April 1 through December 15. These screens are about 20’ long and the plastic screen mesh surface rotates when deployed so that any debris caught on the upstream surface is carried to the downstream side and into the turbine intake or up into the gatewell towards the VBS and orifice. At John Day Dam, a total of three ESBSs were installed in Unit 7 for research purposes by the Corps and NOAA. These bypass screens are used successfully at other mainstem dams (e.g. McNary Dam), but were not deemed successful for use at JDA. The ESBSs are about 40’ long and do not rotate for cleaning but utilize a traveling brush to remove debris. Both types of screens are deployed through bulkhead (upstream) gatewell slots, lowered down through the gatewell, and positioned into the flow of the turbine intake area. The screens direct flow, fish, and debris up through the gatewell slot towards the 14” orifices and into the bypass channel or back toward the turbine through the VBS. At most projects the upstream and downstream gatewells are separated by a VBS to confine migrating fish in the vicinity of a bypass orifice and to keep them from re-entering the turbine intake via the downstream gatewell. The VBSs are a critical component of the fish bypass system and are susceptible to debris accumulation. Too much debris disturbs the gatewell environment and creates turbulent conditions for migrating fish. Units with STS bypass screens have 3 VBS screens per gatewell and units with ESBSs are fitted with 9 VBSs per gatewell. The VBSs are currently left in place, fully submerged, during the fish passage season and during the winter. The STSs at John Day Dam are generally raised and stored in the gatewell slot between December 16 and April 1.

Potential Impacts: Both types of bypass screens and the VBS screens are at high risk and susceptible to zebra mussel attachment and fouling. The screens are submerged and in use during the most active period of the year for dreissenid reproduction, veliger dispersal, and colonization (Table 1). Although flows through and around these screens are generally fast (3-5 fps), several irregular angles and crevices would provide suitable attachment conditions for mussels, particularly on the backside of ESBS screens. The STS screen mesh could be damaged by impacts from druses that may break off the trashrack or face of the dam just upstream. Mussel encrusted river debris could become more difficult to remove by brushing or rotating mesh and lead to increased fish injury. Ongoing maintenance and repair to the drive units, seals and other components of the bypass screens may increase in frequency.

Response: Increased camera or manual inspection of bypass screens and VBSs for mussel accumulations would be likely. The STSs must currently be inspected once per month and VBS screens once every two months (Fish Passage Plan, USACE - March, 2006). Any increases to inspections would require more coordination between fisheries and reduced operations. Most inspections are possible only when a unit is out of service. If screens were found fouled with juvenile mussels, a rotating schedule of in-service and out-of-service would have to be developed. In the “off” season, STSs are routinely stored in a gatewell slot, with the lower portion submerged in river water. The water in this environment below the screen and above the gatewell is relatively slow and conducive to zebra mussel attachment. Although veliger presence would likely be lower during colder water temperatures in the winter months, juvenile and adult mussels may detach themselves and move to more favorable conditions. Thus, a new location or improved storing technique would have to be developed to keep zebra mussels from attaching to STSs and ESBSs. If screens continue to be stored in gatewell slots, more time should be scheduled to include cleaning any mussels which may have attached during the winter months. Currently, VBS screens are left in place between the upstream and downstream gatewell slots year round, leaving them susceptible to mussel accumulation. Even minor blockage of flow through a VBS has the potential to create a turbulent gatewell environment for fish and unfavorable conditions for power generation due to excessive flow. A rotating schedule for periodic removal and cleaning of VBSs would help prevent an overabundance of mussels that could cause screen failure or poor gatewell conditions. Based on average daily air temperatures in Rufus, Oregon, approximately 79 days a year have an average below freezing and would be available if lethal temperatures for mussels are needed. Considerable time, effort, and equipment would be saved if storage or cleaning station location could be established out of the water on site.

3. Gatewells, Orifices and Juvenile Collection Channel: These three components of the JBS are interconnected and work together to move fish through the inside of the dam. The bypass screens divert water, fish, and debris from the turbine intake area, past a flow vein, and up gatewells towards the orifices and collection channel or through a VBS. The gatewell slots allow an operating gate or bulkhead gate to be lowered from the intake deck into the turbine intake for maintenance or emergency shutoff procedures. At John Day Dam, there are three bulkhead (upstream) gatewell slots and three roller gate (downstream) slots per unit and one 14 inch orifice in each upstream slot (some projects have 12 inch orifices). Orifices are fitted with pneumatic knife gates, cycled regularly to reduce the risk of debris plugs, and are fitted with an orifice light which helps attract juvenile out-migrants through the orifice into the collection channel. The collection channel flows are variable depending on the location in the channel because the overall height, width, and shape of the channel vary. Flows are generally in excess of 10 fps, but slower flow areas exist along the lower edge of the channel and near irregularities in the walls.

Potential Impacts: All of these components are at moderate risk due to the fact that they are submerged for the entire year under normal operating situations. Adult mussels would probably find the gatewell environment favorable due to the large amount of cement surfaces for attachment, moderate flows, and constant exposure to aquatic nutrients. A typical gatewell environment has gaps and crevices that may provide a starting point for veliger growth. Gatewell dip-netting or ROV inspections of STS or VBSs could be affected if mussels colonize guide rails or cables and prohibit deployment. Other methods of inspection are time consuming and costly and require dewatering of the unit. Cleaning would have to be done during any routine maintenance or repairs, probably in the winter months during annual inspections. Currently, dewatering, fish salvage, and water up occur in the same day. Periodic cleaning would require more time out of service. Water velocity through the orifices is too high for mussel attachment, but there is some risk to the knife valve armature due to the lower flow conditions just before the orifice. The main collection channel is usually operated with flows approximately 10-15 fps, but the irregular contours, rough cement surfaces, orifice entrance recesses, and access portals (orifice light holes and drainage holes from the forebay deck) create slow flow areas that would be favorable for mussel colonization. Extremely slow flow areas exist along the floor and wall of the collection channel towards the tainter gate and would provide suitable conditions for mussel growth (personal observation, Jan. 2007). Fluctuating water levels throughout the season could create areas along the waterline or near leaks that would be susceptible to druse formation.

Response: Increased frequency of orifice cycling during the fish passage season may be required to decrease the chance of mussels collecting in valve guides or other sensitive areas associated with the orifices. Increased cycling during the winter months may also help deter colonization, but the current method of having two out of three orifices closed during the winter months to conserve water would have to be reconsidered or modified because orifices closed or open for any extended period of time may allow mussels the opportunity to attach. Orifice light recesses would have to be inspected and cleaned if mussel growth is observed so accumulations would not block attraction light. Inspection and removal of druse or individual mussel accumulations along the lower edge of channel should occur during annual dewatering.

4. Tainter gate, Elevated Chute, and Crest Gate: The tainter gate regulates the amount of water flowing out of the JBS and over the crest gate into the elevated chute. The total volume ranges between 450 to 600 cfs and depends upon forebay elevation and the number of generating turbine units. In general, flow through the chute is very fast, approximately 15-20 fps and depth varies, approximately 4-18 ft. The crest gate is made mostly of concrete and weighs several tons. When lowered, synthetic gaskets along the edges seal the gap between the gate and the wall inhibit leakage into the ogee. At the end of the smolt monitoring season, the crest gate is raised and the elevated chute is subsequently dewatered. Water flows into the elevated chute April 1 through September 15.

Potential Impacts: The tainter gate has a low risk of being affected by zebra mussels due to its associated high flows and frequent movement. Submerged sensors may be affected by mussel growth and severe accumulation would require a re-design or modifications which allow access for cleaning or replacement. If mussels were to become established in a low flow area behind the gate or in the gate guide, they would probably not have the opportunity to grow very large before being scraped off by the tainter gate motion. The crest gate is also at low risk due to very high flows and the fact that it is dogged off completely out of the water after the fish passage period and has sufficient time to dry out and freeze before the next seasons use. The majority of the surface area of the inside of the elevated chute would dry out and be exposed to freezing air temperatures in winter. One exception could be the expansion joints, many of which have gaps and holes that could be colonized by mussels. Irregular contours in the floor trap some water after the dewatering, but it is not known if that water freezes in winter. In addition, the grated walkway on top of the structure allows precipitation to enter and accumulate.

Response: Routine inspection and cleaning of sensors for mussel accumulation would be recommended during the winter maintenance dewatering. Determine if the amount of water remaining in the elevated chute after dewatering freezes in winter or if it is enough to provide a refuge for mussels. Periodically check for and brush out any water that accumulates in the floor of the elevated chute. Check all expansion joints and crest gate seal for mussels and remove.

5. Ogee Ramp and Tailrace Outfall Flume: The ogee ramp carries all the fish, water, and debris from the juvenile collection channel to the tailrace outfall flume when the crest gate is in bypass mode. These components are dewatered during the smolt monitoring season, April 1 through September 15. The flow out of the collection channel into the ogee and outfall flume travels at approximately 10-15 fps, and usually enters the tailrace above the surface of the water except during high river flow periods, typically in the spring.

Potential Impacts: The ogee and outfall flume have a low to moderate risk of impact from mussel colonization due to normal high flow situations. Leakage from the crest gate into the ogee during the smolt monitoring season may promote mussel growth which would then pose a risk to bypassed fish when the main passage season ends. The outfall flume exit may be susceptible to mussel growth if high tailrace water levels persist for long periods.

Response: Inspect the crest gate seal for wear to prevent leakage into the ogee. If leaking persists, it may be necessary to devise a method of diverting the leaking water away from the ogee and outfall flume during the smolt monitoring season. Inspect outfall flume during the winter maintenance dewatering and remove mussels as needed.

6. Primary Dewatering Structure (PDS), Modulating Weirs, and Adult Drain: The PDS removes about 95% of the water routed down the elevated chute from the JBS. This excess water, approximately 500 cfs, flows through a series of dewatering screens and returns to the river via a 6 ft diameter underground conduit. The dewatering screens are made of stainless steel wedge wire panels with a gap width of 2 mm and are backed by perforated plates. They are lowered into guide slots on the inside walls of the bypass channel which runs the length of the structure. Dewatering screens placed vertically help minimize the velocity through the screens and reduce debris accumulation. They also help satisfy safe fish passage criteria by making it easier to maintain constant, laminar flow, to help minimize juvenile and adult fish delay. The screens are fitted with screen cleaning brushes which can be run in manually or in auto depending on debris loads. Automatic modulating weirs situated behind the dewatering screens regulate the amount of water removed from the structure. The adult drain is situated near the floor of the structure and is activated by raising a large pneumatic knife gate. Typically, it is opened at the end of the annual dewatering process in September and allows fish that become trapped in the PDS to exit and return to river without being netted, transported, and released by hand. After the initial surge of flushing water from the PDS, a 3-inch flushing water supply valve pushes fish downstream where they dump into the corrugated transport flume. The PDS is dewatered September 16 through April 1.

Potential Impacts: These components are at low to moderate risk of colonization by zebra mussels. All the screen surfaces, perforated plates, drains, and valves associated with the PDS dry out and are exposed to freezing winter temperatures. In season accumulation of mussel shells would be hampered by periodic use of the screen cleaning brushes, although brushing may not be effective in removing all mussels. Access to the PDS channel is possible during the winter and hand cleaning with pressurized water to remove mussels after they are dried and frozen would be possible, although providing water to this remote location is difficult. Sediment, clam shells, and other debris currently collect between the wedge wire dewatering screen and the perforated plate directly behind the screens. Even heavy accumulation of shells would have a limited impact due to the nature of the modulating weir functions which is that they would just “modulate” lower to compensate for any inefficiency caused by clogging. The adult drain is located in a recess about 2’ deep into the wall of the elevated chute and may provide a slow flow area where zebra mussels could attach and grow or accumulate after dying. Any leakage from this valve into the adult transport pipe during fish passage season could possibly sustain juvenile mussels which could injure fish during dewatering as they slide through the pipe.

Response: Check for areas of shell accumulation and remove as needed to prevent clogging and inefficiency of modulating weirs. Inspect screen cleaner brushes for wear and replace regularly so brushes can continue to deter mussel growth. Clear mussels from any knife valve guides or channels before winterizing procedures. There is currently no method of clearing mussels from the adult drain valve recess area before the adult drain is used during dewatering and mussels could cause serious damage to fish as they are forced to pass by this route. Modifications designed to eliminate this recess or retrofitting a type of plug or barrier to prevent mussel access to this area should be considered. In addition, the adult drain flushing water valve would also need to be purged periodically to remove any mussels.

7. Corrugated Transport Flume and Conveyance Pipe: The corrugated transport flume (JDA bypass only) and conveyance pipe (Bonneville PH2 bypass only) move water and fish from the PDS to the secondary dewatering structure (SDS) and porosity unit. Approximately 30 cfs of water flows down the transport flume at about 9 fps. A continual series of ½-inch corrugations on the floor and sides slows the water as it flows downstream and helps maintain safe passage conditions for fish. The length of the flume is approximately 1,000 feet long and is covered by sun shading grated panels, most of which can be removed to provide access for inspections or cleaning. The transport flume is dewatered September 15 through April 1.

The conveyance pipe at Bonneville contains about 33-38 cfs and flows at 4-5 fps. It is approximately 9,000 feet long and has a smooth high density polyethylene surface with minor irregularities occurring at the seams between sections of pipe. The majority of the pipe is buried underground and a series of inspection ports exist about every 1,000 feet to provide access between the powerhouse and the smolt monitoring facility. The conveyance pipe is dewatered approximately December 15 through February 28.

Potential Impacts: In general, the corrugated transport flume at John Day is at low risk of impact from zebra mussels due to the high flows experienced during the passage season (in excess of 6 fps). In addition, the flume is dewatered for most of the winter months and dries out almost completely. However, the degree to which juvenile mussels may be able to colonize the slow flow areas between the corrugations is unknown. Unfortunately, Asian clams are not a helpful surrogate bivalve in this situation because, unlike mussels, they are unable to attach to the substrate with byssal threads and cannot attach to the vertical surfaces of the flume.

The conveyance pipe at Bonneville Dam is probably a low to moderate risk area, although uncertainty exists regarding potential mussel colonization along the waterline and inside seams. Mussel growth on the smooth surface of the pipe could slow water and fish passage and seriously injury fish.

Response: These two fish passage routes should be inspected following their respective dewaterings. Seasonal cleaning may be required if mussels are able to attach and grow in the slow flow areas between corrugations, at the waterline, or inside seams. Accumulations left in place could break off during fish passage season and cause injury to fish at the separator bars, inside distribution flumes, or in sample holding tanks. Difficulty in gaining access to certain areas should be figured into any cleaning schedule. The conveyance pipe is a permit requiring confined space and presents a very difficult area to enter and clean. Should it be needed for mussel removal, providing water or electricity to these relatively remote work sites could be a major challenge. In addition, the surfaces are slippery, the environment is moist, and it is completely dark making complete removal of small mussels unlikely. Freezing air temperatures could not be relied upon to help kill mussels in the conveyance pipe because it is underground and somewhat insulated from outside temperatures.

8. Switch Gates and Flushing Valves: The switch gate is a large pivoting blade that directs the flow in the corrugated transport flume or conveyance pipe to either the bypass (back to river) or sample (to monitoring facility) flumes. A series of neoprene gaskets on the underside of the gate inhibit leakage between flumes and a perforated plate under the gate provides access for flushing water. At John Day Dam, the switch gate is dewatered and completely dry September 15 to April 1. The switch gate at Bonneville Dam continues to have water passing one side after the fish passage season until the conveyance pipe is dewatered in December.

Potential Impacts: The switch gate and associated flushing water valves have a low risk of being affected by zebra mussels because both components are dewatered during the winter months and are exposed to freezing air temperatures. In season accumulation of mussels under the gate could abrade or cut the neoprene gasket, but the gate is moved by a pneumatic cylinder set at 80 psi or greater and mussel shells would not likely inhibit gate movement. The flushing water valves could be more sensitive to mussel shell accumulation due to their location on the floor of the flume. Clearing mussel shells from behind the perforated plates could pose a challenge if a significant numbers of juvenile mussels grow inside flushing water supply lines. Seasonal growth rates will determine whether mussels grow large enough to be trapped behind the plates or if they will remain small enough to pass through. Also, some water may remain after dewatering in the hopper under the switch gate and could provide a winter refuge for mussels. Multi-season shell accumulations could clog the inflow and render the flushing water useless, making the seasonal dewatering experience less optimal for fish.

Response: Inspection and cleaning should take place during the winter maintenance months when the switchgate is dewatered. Mussel shells should be manually cleared from any surfaces on or near the gasket under the switch gate blade. The perforated plate below the gate should be cleaned annually and a larger diameter drain valve should be installed below the switch gate flushing water hopper to insure efficient evacuation of any seasonal buildup of mussels. Increased maintenance efforts and costs would be incurred if seasonal shell accumulations pose a clogging threat and require removal, cleaning, and reinstallation of perforate plates.

9. Fish and Debris Separator (FDS) - Secondary Dewatering System (SDS), Porosity Unit, Wetted Separator Bars, Juvenile Collection Hopper, and Distribution Flumes: These four components remove most of the remaining 30 cfs of flow in the corrugated transport flume and separate juvenile and adult fish and debris. The SDS and Porosity Unit are regulated with a series of manually adjusted weirs that discharge screened water into the head tank. The wetted separator bars have a gap width of ¾" and allow juvenile fish to fall through the bars into the juvenile collection hopper and adult fish to slide over and return to the river. Smaller debris typically falls through the bars and larger debris is usually stranded on top and requires periodic manual removal. The separator bars are continually sprayed and wetted with river water to provide a slick, slippery surface for fish. The juvenile collection hopper is directly below the bars and serves to route approximately 1 cfs and all juvenile fish into the distribution flumes. The distribution flume is the final stage before fish are routed towards the PIT tag detectors and rotating sample gates. These components are dewatered September 16 through April 1.

Potential Impacts: These components exhibit a moderate risk of impact from a zebra mussel invasion due to their intimate interaction with bypassed fish and the fact that they are watered up during the most active period of zebra mussel reproduction and dispersal. All bypassed fish would be susceptible to irregular flows and subsequent poor passage conditions such as flooding of the collection hopper or drying of the porosity unit perforated plate that can be caused by mussel shell accumulation under the screens. Fish could sustain direct physical injuries if the dewatering wedge wire or perforated plates become clogged or trap shells. In addition, the separator bars can be a very dangerous place for fish if they are forced to be separated when river debris such as chunks of wood, tumble weeds, plastic, dead fish, or druses get stranded and prevent separation. Fish forced at high velocity into debris can sustain fatal injuries to their head, gills, and body. The slick, wet surfaces of the separator bars are maintained by continual spraying and could be compromised by the accumulation of mussel shells inside the bars. The dryer, rougher surfaces that would be exposed if spray water is inhibited could contribute to elevated levels of descaling and poor fish condition. Currently, juvenile Asian clams accumulate in the separator bars and are purged several times per season by removing neoprene plugs screwed into the end of the bars. It is likely that mussels would also find these water supply lines as suitable habitat and increase the risk of plugging. Removal of the plugs can be done without any major impact to fish, but access is very difficult. The final distribution flume utilizes add-in water to help stabilize velocities and could be susceptible to mussel shell accumulation behind regulating valves.

Response: It is essential that flow conditions remain within fish passage criteria at this stage in the bypass system. Routine brushing and scraping of the FDS dewatering wedge wire and perforated plate at the porosity unit would need to be continued and potentially increased. Currently, cleaning and brushing of the FDS occurs at least every 30 minutes and more frequent monitoring prompted by mussel accumulation would limit the time used for other inspection duties. The rate of mussel shell accumulation would help determine an appropriate schedule for regular purging of the spray water system. Regular inspection and purging of add-in water valves would prevent unwanted blockage.

10. Tertiary Dewatering Units, Passive Integrated Transponder (PIT) Tag Detectors, and Rotating Sample Gates: Flow velocities through these components range about 8-10 fps. In general, the flume surfaces are smooth but small crevices between the transitional sections of pipe create some flow irregularities. The tertiary dewatering units were designed to allow flows exiting the juvenile collection hopper to be “fine tuned” in the distribution flumes. At John Day Dam, the wedge wire dewatering screens have been modified by inserting solid PVC pipes inside to prevent these units from loosing any flow. The modifications were prompted by the seasonal accumulation of sediment and Asian clams inside the dewatering baffles which was extremely difficult to remove during the winter maintenance period. The PIT tag detectors automatically record tag data when tagged fish pass an electromagnetic field created by an antenna coiled around the PVC pipe. Two antenna coils upstream of the 3-way sample gate help ensure complete code detections and data is downloaded several times a day to a database. Just downstream of the PIT tag detectors, the 3-way rotating gate is used to obtain the smolt monitoring sample and research fish (Figure 3). When rotated west, all fish and debris are diverted into the sample holding tank; when rotated east, all fish are routed to the research flume; and in the center or default position, all fish go to the tailrace outfall.   Sample gate activity varies but operates at least 2 to 6 times per hour during April 1 through September 15. The gate is pneumatically operated (90 psi) and, when activated, moves extremely fast and powerfully.

Potential Impacts: This section of the bypass system is at low to moderate risk and impact due to mussel colonization. The components become very dry when it is dewatered from September 16 through April 1 and are exposed to freezing air temperatures in winter. Several sections of the distribution flume and PIT tag detectors do not have access ports near pipe junctions so cleaning any accumulation of mussels would be difficult. Add-in water ball valves and supply lines could be vulnerable to mussel accumulations which would restrict flow and potentially effect PIT tag detection efficiency by slowing water velocities.

Response: Tertiary dewatering units would continue to be cleaned as needed. Even heavy buildup inside the baffles would not affect fish passage. New access ports near transition seams could be installed for easier cleaning or perhaps a method of scouring interior surfaces from the ends of the pipes could be devised. Periodic purging of add-in water valves during scheduled inspections would help reduce mussel accumulations during fish passage seasons.

IV. Potential Impacts and Responses - Smolt Monitoring Facility - Laboratory at John Day Dam and Bonneville Dam

1. Holding Tank, Inflow Butterfly Valves, and Crowder Panels: These components are all located inside the SMF and are routinely cleaned using water and brushes throughout the fish passage season by Smolt Monitoring Program (SMP) staff. The sample holding tank contains about 1,795 gal (6,795 L) of water and holds fish that were diverted by the sample gate throughout the day and night until they are anesthetized, sorted, and tallied by SMP personnel each morning. Fresh river water constantly flows in and out of the tank through perforated plates located in the front and the back of the tank. The total volume of water in the tank is exchanged every few minutes to remove fish waste, increase dissolved oxygen (DO) levels, and sustain suitable water temperatures for fish. This inflow water supply is delivered through a 12-inch diameter pipe on the upstream end of the tank and is regulated by a butterfly valve. The crowder panel separates groups of fish sampled at different rates or on different days. It also serves to move or crowd fish toward the pre-anesthetic (PA) chambers without causing too much stress. It is made of perforated plate and is pushed or pulled through the tank either manually or with the aide of a winch. A flexible neoprene flap is installed along the edges and bottom of the crowder panel to provide a tight seal between the crowder and tank so small fish cannot pass through or get stuck. These components are dewatered September 16 to April 1.

Potential Impacts: These components are at low risk of colonization by mussels due to the fact that they become dry during the winter months when the facility is dewatered, but in-season mussel shell accumulation in sensitive areas could injure fish. Any mussel growth associated with the perforated plate on the crowder will make it more difficult to move through the sample tank and potentially injure fish. Shells stuck to the neoprene flap could cause increased wear or tearing and cause descaling or mortality if fish try to squeeze through. Currently the butterfly valve that regulates flow into the holding tank is periodically purged to release any clam shell accumulations and mussel shell accumulations or growth could add to the current problem involving clams.

Response: Appropriate responses to a mussel infestation may include increased maintenance and cleaning by fisheries staff, scheduled purging of inflow butterfly valves, and more frequent replacement of the neoprene seal. In-season pressure washing to periodically remove any mussel buildup on the perforated plates would be difficult because fish are always in the tank and the cleaning process would cause increased stress. A method of temporarily hoisting the crowder out of the tank and washing it on the side of the holding tank might have to be developed if mussels become too difficult to remove by hand and prohibit movement of the crowder or injure fish.

2. Pre-anesthetizing (PA) Chambers, Fish Lifts, Drainage Pipes, and Flushing Water: Fish are hand maneuvered into the PA chambers using a panel net and a metal slide gate is lowered behind the fish to separate them from the holding tank. Two chambers exist at the upstream side of the holding tank and can be used alternatively if a problem with one occurs. Water drains out of the chamber to a prescribed level dictated by the height of the valve in the side of the chamber. At John Day Dam, this drain consists of a 2-inch PVC supply line and ball valve and drains directly back to the return to river flume. At the Bonneville juvenile facility, fish lifts raise the PA chamber from the holding tank in the basement to the sample laboratory on the main floor. Fish anesthetic (Finquel, MS-222) is added to the remaining volume of water (48 liters) and fish become sufficiently anesthetized in 2-3 minutes. A pneumatic knife gate is activated and fish and water are then flushed through a 6-inch diameter PVC pipe, across a final dewatering perforated plate, and into the sorting trough for examination. Flushing water is supplied through a 2-inch supply line and regulated by a ball valve which is currently susceptible to sediment and clam buildup even though it is operated several times daily.

Potential Impacts: These components are at low risk of colonization by mussels due to the fact that they become dry when the facility is dewatered, but at moderate risk in-season because mussel shell accumulation in sensitive areas could injure fish or restrict flow. Mussels could interfere with the slide gate if they accumulate in the guide and could cause leakage into the PA chamber. The guides are made of Delrin and are particularly difficult to clean due to their position at the end of the tank and partly under water. Any irregular seal and subsequent leakage would impact the sampling effort by increasing the time it takes to anesthetize fish and process samples. Severe leaks could hamper processing and even halt sampling if anesthetizing fish becomes impossible. The drain line and ball valve are continually submerged during fish passage seasons and are susceptible to mussel growth. Blockage or constriction of flow would increase PA chamber time for fish which increases stress. The upstream side of the knife gate and bottom surface of the flushing pipe into the sorting trough is also susceptible to mussel growth.

Response: The PA chambers, slide gates, and Delrin slide gate guides may have to be cleaned more frequently than the 2-3 times per week they currently experience. Use of the existing PA chambers could be alternated every week or so which would allow the non-used chamber to be dried and or cleaned. Flushing water supply lines may need isolation and drain valves so that they could be dried out between active periods. The knife gate and 6-inch transport pipe are extremely difficult to access and may require installation of access portals or the development of a "brush on a pole" scouring method of cleaning if mussels accumulate in this area.

3. Sorting Trough, Return Pipe, and Recovery Tanks: The sorting trough receives anesthetized fish from the PA chamber and is the location for all fish identification, data collection, counting, and condition examinations. Excess water in the trough is automatically drained and flows into the anesthetic reservoir tank in the basement of the SMF. Following the data collection process, fish are released into the return pipe and transported to one of two available recovery tanks. The return pipe is supplied with raw water from a 1-inch hose and operates throughout the smolt monitoring season. Recovery tanks allow anesthetized fish to recover and become more alert before being returned to the river. Both tanks receive a constant inflow of fresh river water regulated by a 9-inch butterfly valve. A minimum of 25 minutes is required before release, so alternating between the two tanks allows sampling to continue uninterrupted. Water exits through a perforated plate and down standpipes back to the river. Fish are flushed to the exit when the perforated plate and standpipes are removed.

Potential Impacts: These components are at low risk of mussel colonization due to the fact that they become dry when the facility is dewatered. In-season risks include mussel accumulation behind the return pipe hose valve or inside the return pipe itself. Mussels may also collect behind the butterfly valves that provide fresh water to the recovery tanks.

Response: In-season cleaning of the recovery tank return pipe water is difficult but could be accomplished if it is found that mussels grow inside the pipe. Periodic shut down and temporary removal of this pipe would increase maintenance time but probably not incur much extra cost. Replacement hoses and valves should be kept on hand so serious clogs to the return pipe flushing water would not stop sampling. Inflow butterfly valves to the recovery tanks should be regularly purged to prevent excess mussel buildup. At least weekly inspections of the interior of the tanks should be performed so that any mussel growth could be brushed or scraped away before posing a threat to fish condition. Devise a scouring method for cleaning inaccessible areas.

4. Release Pipes and Exit to River Flume: The release pipes are made of PVC and convey fish from the recovery tank in the laboratory to the exit to river flume outside. Water is released through two standpipes and all fish are usually evacuated within 4-5 minutes. The exit to river flume flows at about 8-10 fps, it is constructed of concrete, and directs fish into the outfall flume which empties into the tailrace. They are both dewatered during the winter maintenance period.

Potential Impacts: These two components are at moderate risk of mussel colonization. In-season mussel growth on the inside surface of the release pipes could injure fish as they are being released to river. Upon release, fish are forced at high velocity into contact with this pipe and even small mussels could cause cuts and scrapes which could increase mortality. The injuries could be difficult to detect because monitoring for fish condition does not occur after this point on project. The exit to river flume is also vulnerable to mussel growth in-season although consistently higher flows would be less suitable for juvenile mussel attachment and the relatively wide flume would allow fish to avoid contact with the walls.

Response: The main portion of the release pipe currently provides limited access or no access for inspection purposes. Both ends of the release pipe can be accessed however, and it may be possible to clean by scouring or hot water treatment. The exit flume is more easily inspected, but a heavy grating covers the entire length of the flume and prevents in-season cleaning. In addition, the flume is exposed to precipitation during the winter and may not become completely dry or frozen.

5. Recirculation Pump, Water Chiller, and MS-222 Filters: The recirculating system at the smolt monitoring facilities allows reuse of water containing MS-222. Because these systems have the unintended potential to grow and transfer fish pathogens such as bacterial kidney disease, they are generally not used for more than one day at a time. The recirculating tank contains a water chiller that helps monitoring personnel maintain river water temperatures which reduces fish stress during handling. Water is regularly drained from the sorting trough to keep DO, temperature, and waste levels safe for fish. This water is temporarily held in a storage tank in the basement of the facility until it is pumped through a series of 55-gallon Calgon brand activated charcoal filters. The filters are replaced annually or semi-annually depending on the condition of the metal drums and filtering ability of the charcoal. The filters remove some or all of the MS-222 before it is discharged to the soil outside the facility for further breakdown.

Potential Impacts: The recirculation pump and water chiller are at low risk of impact from a mussel infestation because they are not usually used for an extended period of time and are completely dewatered September 16 to April 1. Periodic inspection and cleaning of the main line debris trap may be needed if mussels build up during the season. Drain lines leading to the filter tank in the basement are at moderate risk because they are not easily accessed or cleaned and remain wet during the most active period for dreissenids. The storage tank in the basement is at moderate risk because it remains partially full of water all year and has a small, 2-inch discharge valve that is susceptible to mussel accumulation and blockage. The filter pump, water lines between filter canisters, canister interiors, and final discharge hose are also vulnerable to clogging which could cause the storage tank to overflow.

Response: The recirculating pump and chiller can be drained thoroughly after use to avoid any mussel accumulation. Pump components should be inspected annually to check for extra wear potentially caused by mussel shells. The storage tank can be vacuumed out or flushed clean at the end of the sampling season so debris does not accumulate and impact the pump and filters. Cleaning of the discharge lines could be accomplished using high-pressure water, compressed air, or by capping for chemical or hot water treatment. Consider installing a backup system in case of heavy shell buildup and blockage.

6. Research Activities - Temporary Holding Tanks, Degassing Columns, and Transportation Tanks: Research tagging activities focusing on juvenile salmonid behavior at the SMF often use temporary or semi-permanent components that are connected to raw water supplies. After sorting and identification, fish are held in temporary holding tanks for up to several days before being transported off-site for release to the river. The tanks are made of plastic or fiberglass and water is delivered through either 2-inch or 4-inch lines regulated with ball valves. Degassing columns made of 12-inch PVC pipes have been installed just upstream of the research holding tanks to help limit the potential risk to fish caused by supersaturated river water. Water is forced to flow through the medium inside the columns and allows any supersaturated gasses to come out of solution. If tagging occurs on-site, fish to be released at another location are held in transportation tanks designed with wheels to facilitate loading onto a vehicle. These components are dewatered during the same time frame as the smolt monitoring facilities, September 15 to April 1.

Potential Impacts: The research holding tanks are at moderate risk to impact from mussels because even small fluctuations in water flows can be lethal for fish by limiting DO or causing tanks to over flow. Their water supply lines and valves are susceptible to clogging and access for cleaning is limited. Degassing columns are at risk because they would probably provide suitable mussel attachment sites inside on the degassing medium. Too much debris accumulation in the columns could cause them to overflow and malfunction. Transportation tanks are at low risk because they are regularly cleaned and dewatered after each fish holding event to decrease the chance of transferring pathogens.

Response: These SMF components are dewatered during the winter and become completely dry. All valves are opened and drained for winter so most of the risk is associated with mussel accumulation occurring during the fish passage season by restricting flow. In-season risk can be reduced by maintaining the current routine cleaning protocol for holding and transportation tanks to reduce the chance of pathogen transfer. The tanks could be regularly inspected for mussel growth and mussels could be manually removed. Degassing columns should be taken down and cleaned as needed depending on the rate of mussel accumulation. Water supply lines that can be easily isolated and cleaned should be maintained and installation of a redundant supply system should be considered. Current transportation tank cleaning and dewatering protocols should continue.

7. Avian Hydrocannons: The avian hydro-cannons help deter avian predators such as gulls, cormorants, and terns from targeting temporarily disoriented fish at the outfall exit. The cannons are positioned at the very end of the structure and spray water in a large arc over the tailrace surface. The hydro-cannon at John Day Dam have not been used in recent years. The cannons at Bonneville are typically used throughout the juvenile spill passage season (April 1- August 31). The water for the hydro-cannon comes from the AWS and is dewatered some time after September 1. The supply line is isolated and purged of water using compressed air during the winter maintenance period.

Potential Impacts: The hydro-cannons are at low risk of impact from mussel colonization because the water supply line is dewatered and purged annually. Accelerated wear to the nozzle may occur due to mussel shells. There is also a risk of blockage to the isolation valve from in-season mussel accumulation, which could hamper the purging process.

Response: Continue purging the hydro-cannon water supply line after seasonal use and determine if any mussel or clam accumulation can be noticed. If mussels are found to restrict flow, a redundant supply line could be installed to provide a backup. Inspect the nozzle for wear and replace as needed.

V. Potential Impacts and Responses - Adult Fishway Components - John Day Dam

1. Adult Collection Channel: The adult collection channel runs the length of the powerhouse below the tailrace deck and increases the number of locations an adult salmonid may encounter attraction water leading to a fish ladder entrance. A series of floating orifice gates can be used to provide fish access into this channel at various locations. These orifices can automatically move up and down to allow the collection channel differential and velocity to constantly adjust with changing tailrace elevations. A series of diffuser pools provide supplemental water throughout the length of the channel. Standard diffuser gratings consist of one-inch gaps with ¼-inch width galvanized metal bars. The collection channel can be dewatered in sections using cross channel bulkheads and is usually dewatered during the winter maintenance period (see FPP for project specifics).

Potential Impacts: The adult collection channel is at low to moderate risk of impact due to a dreissenid infestation. Although large amounts of surface area would be susceptible to fouling, the relatively large height and width of the channel does not force fish into contact with the channel surfaces. In addition, the floating orifices are large and heavy enough that they would probably not be affected by the presence of mussel shells. The pressure sensitive transducers used to measure the tailrace and collection channel differentials may not work correctly if mussel accumulations interfere with their measurements. Incorrect readings would lead to changes in velocities in the collection channel potentially delay upstream migrants. The gratings over the diffuser pools would be susceptible to mussel accumulation because any restriction to flow in this area can force the grating to blow out which would allow fish access into the auxiliary water supply system. In addition, fish ladders are taken out of service until diffuser gratings can be repaired and, depending on the time of year, could disrupt adult fish passage.

Response: The gratings covering the diffuser pools may have to be cleaned during the winter maintenance period to keep mussel accumulations from restricting flow during the fish passage season. In addition, in-season scheduled transducer sensor cleaning may be required if mussel accumulations cause the sensors to malfunction. If fouling is severe, in-season cleaning and maintenance may be needed and this would require installation of a removable sensor that could be cleaned without dewatering the channel.

2. South Fishway Entrance: This fishway entrance is a transitional area between the adult collection channel, the fish ladder entrance, and the fish ladder weirs. Large amounts of water are added diffuser pools with grating located on the floor of the structure. This add-in water attracts adult fish into the ladders and is regulated with a series of valves. It is possible to dewater the fish ladder entrance separately from the collection channel and it is usually dewatered during the winter maintenance period (see FPP for project specifics).

Potential Impacts: This area is relatively large and easily accessible although it is only accessible when dewatered during the winter maintenance period. Mussel growth on the walls or floor would pose a low threat to fish because they are not forced into contact with the edges of the structure. The diffuser pool grating and regulating valves are at moderate risk of impact due to mussel accumulation because any flow restriction through the 1-inch gaps could loosen the gratings and allow upstream migrants access to the diffusion chambers under the gratings where they would be trapped and, unless removed, would eventually die.

Response: Regular inspections for mussels in this area may need to occur during the annual dewaterings. If mussels accumulate on the grating surfaces, cleaning and removal may be necessary to minimize flow restrictions. Currently, many diffuser pools have large amounts of *Corbicula* shells, rocks, sand, and woody debris that accumulate under the gratings and affect the amount of flow passing through the gratings. It is likely that a mussel infestation would add to the existing problem and substantially increase the amount of time necessary for maintenance. Debris removal from this area is difficult because the grating has to be moved out of position and then the debris has to be lifted up and out of the entrance area. Furthermore, some areas under the gratings are difficult or impossible to access by hand using rakes or shovels and may require use of a debris vacuum or hose.

3. Fish Pump Intake Basin: Water from this area comes from the tailrace and is pumped back up into the lower section of the fish ladders to provide auxiliary water for fish attraction. Tailrace water entering the basin passes through a trashrack to prevent large fish and debris from entering the basin. The fish pumps then push the water into various diffuser pools through chimney style conduits.

Potential Impacts: In general, this area is at low risk of impact from dreissenids because it is very large and does not usually contain fish. A slight risk of fish injury in the tailrace may occur if mussels accumulate on the trashrack and create high flow areas that could entrain fish as they pass by or capture debris that would then injure fish. The chimney style supply conduits are very large and their flow would probably not be affected by fouling.

Response: Inspections of the differential between the basin and the tailrace may be needed to determine the severity of mussel accumulations on the trashrack. Periodic removal and cleaning of the trashrack may be needed if mussels or debris are found to restrict flow or if dead fish are noted in the intake basin.

4. Francis Wheel Fish Turbines: The south fish ladder at John Day Dam has three Francis wheel fish turbines that are used to supplement flow in the lower section of the fish ladder. The penstock (approx. 36-inch diameter pipe) takes water from the forebay and provides each turbine with up to 100 cfs of water. The turbine wheels spin through a gear box and power impellers which are able to push up to 300 cfs of tailrace water into the south fish ladder diffuser pools.

Potential Impacts: This area is at low level of risk from dreissenids, but an accumulation of mussels between the penstock and fish turbines could impede flow and reduce turbine and impeller operating efficiency. Although flows are potentially very fast, shells from dead mussels could collect in low areas of diffuser pools. These accumulations and any extra debris trapped due to the mussels' presence could impede flow into diffuser pools. Restrictions in flow may slow or impede fish passage and increase the number of times the fish ladder is out of criteria.

Response: The fish turbines can be dewatered and potentially isolated by closing the penstock intake located in the forebay. This procedure allows access to the fish turbine intake area and would allow cleaning of turbine blades and other exposed surfaces. There is no available access for manual cleaning into the pipe between the penstock and the turbines so a method of removing any mussel accumulations would have to be developed. Water is not available for the south fish ladder diffuser pools or SMF when the penstock is closed, so any dewaterings usually occur during the winter maintenance period or for emergency repairs.

5. Fish Ladder Weirs - Submerged Orifices, Overflow Weirs, and Serpentine Weirs: Several types of weirs are utilized in CRB fish ladders. Submerged orifices are rectangular openings in the weir walls that allow fish to pass into the next weir while staying submerged. Overflow weirs allow fish an alternate route over the top of the weir wall. The water depth at the overflow weir can vary throughout the season and is periodically adjusted depending on desired fish passage criteria. During the peak of the American shad migration, overflow weir depth is kept at approximately 1 foot to facilitate shad passage and help prevent delay of salmonids. The serpentine weirs, located at the upstream end of the ladders, move water through a tall slot in the weir wall which is not directly downstream of other slots. The resulting side to side motion of the water between weirs helps reduce velocities and dissipate energy before water moves into the overflow weir section of the ladder. Some serpentine weirs are fitted with short hydraulic adjustment weirs along the floor to help regulate flow.

Potential Impacts: Although the risk level to this area is probably low**,** the large amount of cement surface area on most weir types make them potentially susceptible to mussel fouling. Many lower flow areas in corners and on the upstream and downstream side of weir walls would create suitable areas for mussel attachment. Physical injury to fish could occur when they jump between weirs or if they contact walls or edges. Dead mussel shells or associated debris accumulation in the serpentine section of the ladder could change the flow dynamics between weirs and may cause upstream migrants to delay or fall back through the ladder.

Response: Depending on mussel accumulations, it may be necessary to inspect all weir surfaces during dewaterings and remove mussel accumulations as needed. Most vertical and horizontal surfaces inside the weirs are easily accessible during winter dewaterings although it would be difficult to provide electricity and water needed for cleaning equipment to most of these outside areas. Removal of mussel remains would also be challenging due to the elevated location of many of the fish ladder areas. Manual removal would be labor intensive, increase maintenance costs, and increase the number of days fish ladders are out of service.

6. Diffuser Pools: Diffusers pools provide access for the auxiliary water system (AWS) which supplements flow volumes in the fishways. These pools are covered by diffuser gratings and are located in the adult collection channel, at fish ladder entrances, and at several locations in the adult fish ladders. The AWS is approximately 36-inches in diameter and originates from the penstock in the forebay.

Potential Impacts: The gratings over the diffuser pools are one of the most susceptible components of the adult fishways to a dreissenid infestation. Even a small amount of fouling could restrict flow through the 1-inch grating gaps and cause them to dislodge. Even if mussel densities are low, their shells may increase the amount of debris that collects under the grating and amplify the restriction of flow. When gratings are out of position, adult migrants can be attracted to the inflow of auxiliary water and gain access to the diffuser chambers where they can become injured, trapped, or killed. Fish ladders are taken out of service until diffuser gratings can be repaired and, depending on the time of year, could disrupt adult fish passage.

Response: It will be necessary to inspect all diffuser grating surfaces during dewaterings and remove mussel accumulations as needed. Severe debris accumulations (mussel shells, rocks, woody debris, etc.) under intact gratings may have to be periodically removed to inhibit blow out potential while operating during fish passage season.

[Note: numbers 7 – 17 below are incomplete and will be finalized in the future]

7. Transition Pool, Counting Station Window, and Picketed Leads: The transition pool is located directly downstream of the adult fish counting window. This pool provides a resting and staging opportunity for fish before they move upstream through a constriction in the channel positioned in front of the counting station window. The picketed leads funnel flow and fish into the counting window area. They consist of a series of vertical metal bars spaced at about 1 inch and are designed to allow much of the flow to pass through. These components are very susceptible to debris accumulation and are usually cleaned once a day or as needed during daily inspections.

Potential Impacts:

Response:

8. Fish Ladder Exit, Trashrack, and Debris Boom: The fish ladder exit is a short area of transition from the serpentine weirs to the forebay. A trashrack with 1-foot gaps at the exit prevents most large woody debris from entering the adult fish ladder but still allows fish to exit. A floating log boom is installed upstream of the fish ladder exits to help prevent floating debris from reaching the trashrack.

Potential Impacts:

Response:

9. Upstream Migrant Channel (UMT) - Bonneville Dam:

10. Adult Fish Facility (AFF) - Bonneville Dam:

11. Sea Lion Exclusion Device (SLED):

12. Removable Spillway Weirs (RSW):

13 Temporary Spillway Weirs (TSW):

14. Juvenile Transportation Program (barges, holding raceways, loading and unloading facilities):

15. Behavioral Guidance Screens:

16. Ice and Trash Sluiceway - The Dalles Dam:

17. Spillway Guide Wall - The Dalles Dam:

Table 1. Juvenile Fish Facility Components, Potential Risk Due to a Dreissenid Infestation, Reason for Risk Level, and Response and Preventative Actions at John Day and Bonneville Dams *[Note: Information on Adult "Reason for Risk Level" and "Response and Preventative Actions" is incomplete and will be finalized in the future].*

Juvenile Fish Facility Component	Potential Risk	Reason for Risk Level	Response and Preventative Actions
Powerhouse and Auxiliary Water Supply Trashracks	High	Submerged all year, difficult to access and clean, excess debris accumulation can cause fish injury	More frequent maintenance and cleaning, design trashrack brush or backup equipment
Bypass Screens: -STS -ESBS -VBS	 High High High	Submerged during veliger season or all year (VBS), difficult access, mesh and wedge wire screens are susceptible to fouling, units must be shut down for cleaning/maintenance , storage slots in water	Increased camera or manual inspections, periodic removal of VBSs for cleaning, establish on-site cleaning station for screens
Gatewells, Orifices, and Juvenile Collection Channel	Moderate	Submerged almost all year, generally high flows, but slow flow areas may produce druses, difficult to access and clean	Increased orifice cycling, inspect and clean orifice light recesses, remove druse accumulation during annual dewatering
Tainter Gate, Elevated Chute, and Crest gate	Low	Generally high flows, dewatered after fish passage season, easy access, crest gate seal may experience excess wear, sensor fouling potential	Check and clean expansion joints and crest gate seal, remove water accumulation in winter if needed
Ogee Ramp and Tailrace Outfall Flume	Low to Moderate	Leakage from crest gate during fish passage season may promote mussel growth in ogee and flume	Inspect and maintain effective seal on crest gate, re-route leakage
Primary Dewatering Structure, Modulating Weirs, and Adult Drain	Low to Moderate	Submerged during fish passage season, slight risk of mussel growth on dewatering screens, adult drain leakage may promote mussel growth	Remove mussels during winter maintenance, inspect and clean adult drain, design plug for this area
Corrugated Transport Flume and Conveyance Pipe	Low to Moderate	Submerged during fish passage season, normal high flows, very difficult to access conveyance pipe	Seasonal inspection and cleaning after dewatering
Switch Gates and Flushing	Low	Normal high flows, leakage may allow mussel growth in bypass flumes, flushing water	Inspect and clean in winter, purge flushing water in-season, increase

Valves		blockage	drain diameter, inspect seal for wear
Fish and Debris Separator – Secondary Dewatering System, Porosity Unit, Wetted Separator Bars, Juvenile Collection Hopper, and Distribution Flumes	Moderate	Submerged during fish passage season, normal high flows, dewatering screen, perf plate, and separator bar fouling, difficult access to parts of distribution flumes	Frequent inspection and cleaning, periodically purge supply valves and separator bars, provide improved access to flumes
Tertiary Dewatering Units, PIT Tag Detectors and Rotating Sample Gates	Low to Moderate	Submerged during fish passage season, smooth surfaces, high flow areas, access possible but limited, flushing water supply valves vulnerable to fouling,	Clean units as needed, purge flushing water supply lines and valves, provide improved access to flumes, devise scouring method for cleaning inaccessible areas
SMF Laboratory: Holding Tank, Butterfly Valves, and Crowder Panels	Low	Submerged during fish passage season with periodic cleaning, discharge water perf plate fouling, inflow valve clogging potential	Increased cleaning, periodic purging of butterfly valves, inspect and replace crowder seal as needed
Pre-anesthetizing Chambers, Fish Lifts, Drainage Lines, and Flushing Water	Low to Moderate	Submerged during fish passage season, difficult to access, even small accumulations can cause problems for fish and smolt monitoring personnel	Increase cleaning, improve water supply line isolation capabilities, install access portals to drain lines, devise scouring method for cleaning inaccessible areas
Sorting Trough, Return Pipe, and Recovery Tanks	Low	Daily dewatering and cleaning, mostly easy access, water supply and valve clogging potential	Provide backup return pipe or devise scouring method for cleaning inaccessible areas
Release Pipes and Exit to River Flume	Moderate	Submerged during fish passage season, difficult to access, problems would be difficult to detect	Improve access for inspections, implement cleaning as needed
Recirculation Pump, Water Chiller, and MS-222 Filters	Low	Submerged during fish passage season, difficult to access, many small diameter supply lines, increased pump wear and charcoal filter replacement	Remove seasonal accumulation of debris from storage tank, purge or clean lines to filters, maintain pump
Research Activities - Temporary Holding Tanks, Degassing Columns, and Transportation Tanks	Low to Moderate	Submerged during fish passage season, inflow supply lines, valves, and degassing column clogging potential	Maintain tank cleaning protocols, purge supply valves daily, inspect and clean degassing columns as needed
Avian Hydro-cannons	Low	Uses raw water, supply line mostly buried and susceptible to clogging and wear, no backup	Purge water supply line after use, inspect nozzles for wear

Adult Fishway Components	Potential Risk		
Adult Collection Channel	Low to Moderate		
South Fishway Entrance	Low		
Fish Pump Intake Basin	Low		
Francis Wheel Fish Turbines	Low		
Fish Ladder Weirs, Submerged Orifices, Overflow Weirs, and Serpentine Weirs	Low		

Table 2. Fish Management Details for Some Hydro-electric Dams in the Columbia and Snake River Basins.

Mainstem Hydro-electric Project	Project Managed by	Juvenile Fish Passage Season	Bypass Screen Type and Material	Juvenil e Bypass Facility	Juvenile Fish Transportation	Operate for Adult Passage	Adult Fishway
Bonneville Dam-PH1	USACE - Portland District	3/1- 10/31	No screens	Out of service	No	3/1 – 11/30	1, Bradford Island
Bonneville Dam-PH2	USACE - Portland District	3/1- 10/31	STS/VBS	Yes	No	3/1 – 11/3	2, Cascades Is., WA shore
The Dalles Dam,	USACE - Portland District	4/1 – 11/30	VBS	No	No	3/1 – 11/3	2, North and East
Public Utility District	Northern Wasco County Public Utility District	April - July	Dewatering screens only	Yes	No	NA	NA
John Day Dam	USACE - Portland District	4/1 – 9/15	STS/VBS/ESBS	Yes	No	3/1 – 11/3	2, North and South
McNary Dam	USACE - Walla Walla District	4/1 – 9/20	ESBS/VBS	Yes	Yes	3/1 – 12/31	2, North and South
Public Utility District	Northern	No sampling	Dewatering	No	No	NA	NA

	Wasco and Klickitat Co.		Screens only				
Ice Harbor Dam	USACE - Walla Walla District	4/1 – 12/15	STS/VBS	Yes	No	3/1 – 12/31	2, North and South
Lower Monumental Dam	USACE - Walla Walla District	4/1 – 9/30	STS/VBS	Yes	Yes	10/1 – 12/15	2, North and South
Little Goose Dam	USACE - Walla Walla District	4/1 – 10/31	ESBS/VBS	Yes	Yes	11/1 – 12/15	1, South
Lower Granite Dam	USACE - Walla Walla District	3/26 – 10/31	ESBS/VBS	Yes	Yes	11/1 – 12/15	1, South
Rock Island Dam	Chelan County - Public Utility District No. 1	4/1 – 8/31	VBSs, but no bypass screens	Yes	No	?	3 total

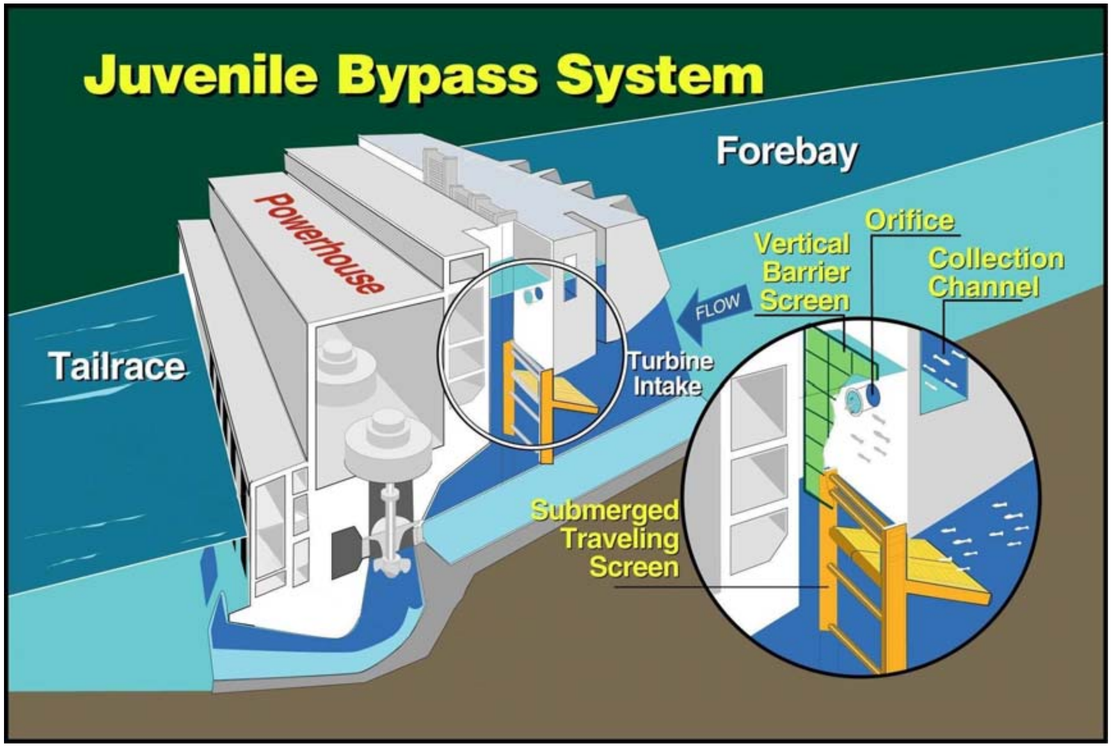

Figure 1. Generalized Juvenile Bypass System (Picture compliments USACE).

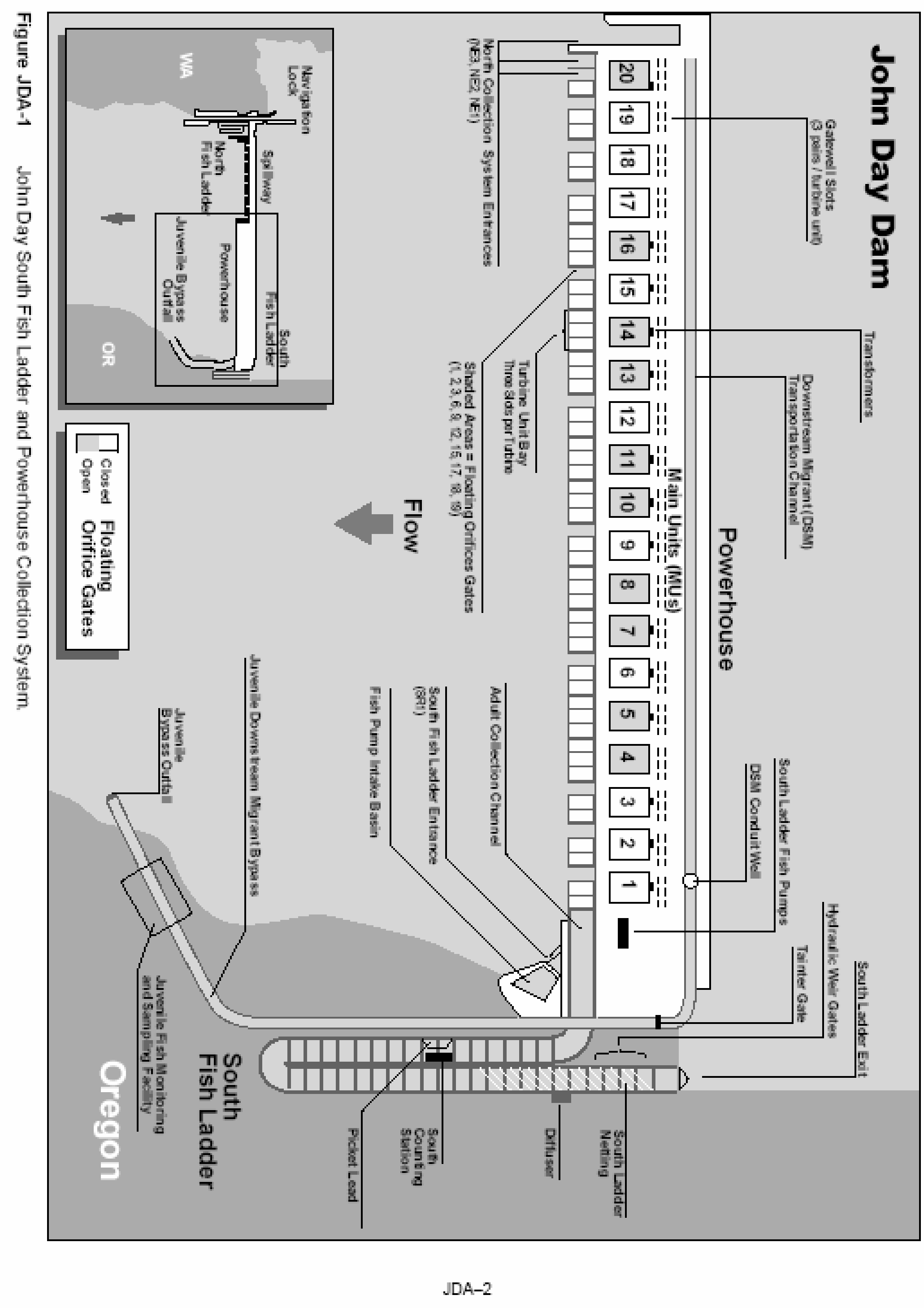

Figure 2. Project Plan of John Day Dam- South Fish Ladder and Powerhouse (Diagram compliments of the U.S. Army Corps of Engineer, Fish Passage Plan, 2006).

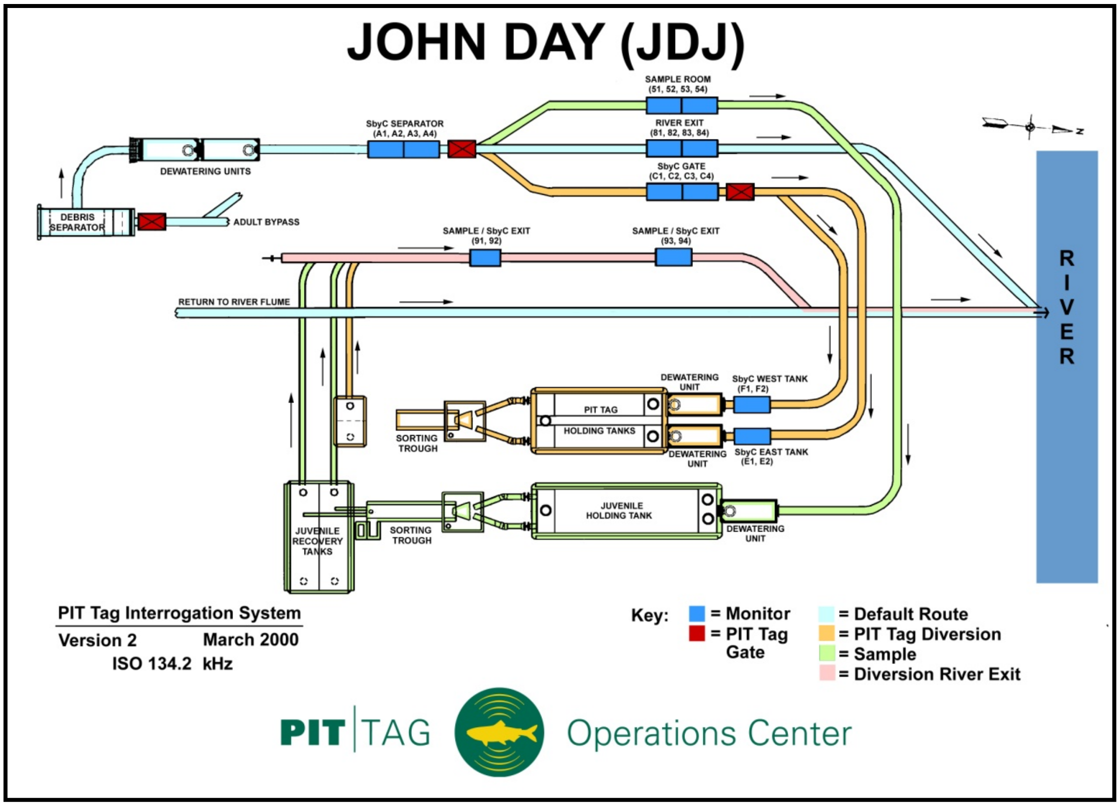

Figure 3. Passive Integrated Transponder (PIT) Tag Detection Schematic, John Day Dam Smolt Monitoring Facility (Diagram by PITAGIS, 2000).

VI. Project Specific Points of Contact

Smolt Monitoring Program staff-

Rick Martinson, John Day and Bonneville SMP Project Leader, Pacific States Marine Fisheries Commission. Phone: (541) 296-8989, email: rickdm@gorge.net.

Dean Ballinger, Bonneville Dam SMP Site Biologist, Pacific States Marine Fisheries Commission. Phone: (509) 427-2725., email: deanb@gorge.net.

Gregory Kovalchuk, John Day Dam SMP Site Biologist, Pacific States Marine Fisheries Commission. Phone: (541) 506-7863, email: gregkov@gorge.net.

Charles Morrill, Snake River SMP Project Leader, Washington Department of Fish and Wildlife. Phone: (360) 902-2747, email: cfwdfw@aol.com.

Rosanna Tudor, McNary Dam SMP Biologist, Pacific States Marine Fisheries Commission. Phone: (541) 922-3630, email: tudorrl@direcway.com.

Monty Price, Lower Monumental Dam SMP Biologist, Pacific States Marine Fisheries Commission. Phone: (509) 282-3332, email: montyp@televar.com.

Annie Dowdy, Little Goose Dam SMP, Oregon Department of Fish and Wildlife. Phone: (509) 399-2060.

Fred Mensik, Lower Granite Dam SMP Biologist, Pacific States Marine Fisheries Commission. Phone: (509) 843-3084, email: lgsmolt@hughes.net.

U.S. Army Corps of Engineers
Bonneville Dam Fisheries-

Ben Hausmann, Project Fisheries Biologist, USACE. Phone: (541) 374- , email: ben.j.hausmann@usace.army.mil.

Jonathan Rerecich, Fisheries Biologist, USACE. Phone: (541) 374-7984, email: jonathan.g.rerecich@usace.army.mil.

The Dalles Dam, John Day Dam, and Willow Creek Project –

Robert Cordie, Project Fisheries Biologist, USACE. Phone: (541) 298-7406, email: robert.p.cordie@usace.army.mil.

Miroslaw Zyndol, Project Research Coordinator, USACE. Phone: (541) 506-7823, email: miroslaw.a.zyndol@usace.army.mil.

Terry Hurd, Smolt Monitoring Facility Biologist, USACE. Phone: (541) 506-7860, email: terry.w.hurd@usace.army.mil.

Jeffrey Randall, ANS Coordinator for TD, JDA, USACE. Phone: (541) 506-7861, email: jeffrey.w.randall@usace.army.mil.

VII. References

1. Athearn, J. 1999. Risk Assessment for Adult and Juvenile Fish Facilities on the Mainstem Lower Snake and Lower Columbia Rivers Relative to a Potential Zebra Mussel Infestation. US Army Corps of Engineers, Northwest Division. Portland, Oregon.

2. Athearn, J and T Darland. 2006. Rapid Response Plan for Zebra Mussels in the Columbia River Basin. Appendix. H. Bonneville Hydroelectric Project Response Plan for Zebra Mussels *(Dreissena polymorpha)*.

3. Burch, J. Q. 1944. Checklist of west American mollusks. Minutes, Concological Club of southern California 38:18.

4. Martinson, R, Kovalchuk, G and D Ballinger. 2005. Monitoring of Downstream Salmon and Steelhead at federal Hydroelectric Facilities. Pacific States Marine Fisheries Commission for Bonneville Power Administration.

5. Ohio Sea Grant. 1997. Zebra Mussels in North America: The invasion and its implications. Fact Sheet 045. Columbus, Ohio.

6. Phillips, S., Darland, T. and M. Sytsma. 2005. Potential Economic Impacts of Zebra Mussels on the Hydropower Facilities in the Columbia River Basin. Pacific States Marine Fisheries Commission, US Army Corps of Engineers, Portland State University.

7. USACE (US Army Corps of Engineers). 2006. Fish Passage Plan. U.S. Army Corps of Engineers, Northwestern Division, Portland, Oregon.