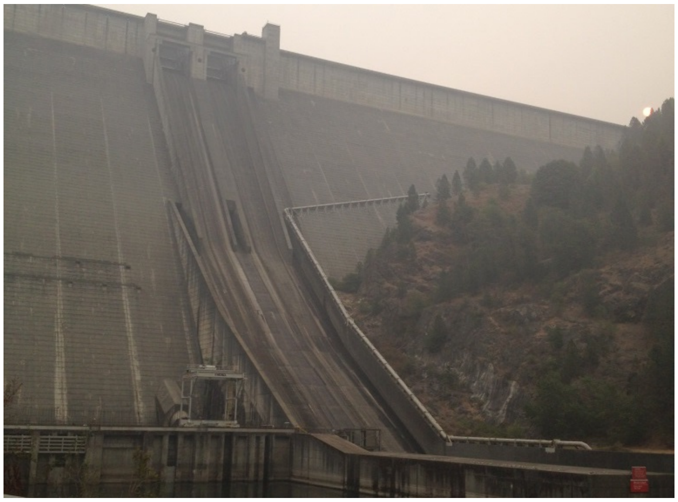
RECLAMATION
Managing Water in the West

Facility Assessment for Dworshak Dam

Invasive Quagga and Zebra Mussels

U.S. Army Corps of Engineers
Walla Walla District



U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

August 2015

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Invasive Quagga and Zebra Mussels

Prepared for U.S. Army Corps of Engineers Walla Walla District and Dworshak Dam Project Office

U.S. Department of the Interior
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The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Cover Photo: Photo of Dworshak Dam and Spillway.

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Executive Summary

The purpose of this assessment is to provide U.S. Army Corps of Engineers (USACE) management and project staff with information regarding the vulnerability of facility features to invasive mussel impacts. This report is not intended to be a risk assessment or prediction of the potential for a future mussel infestation. Instead it is intended to assist in anticipating and planning for impacts should a future infestation occur.

Findings

The facilities at Dworshak Dam are relatively complex and a heavy invasive mussel infestation would likely significantly impact facility operations and maintenance. However, from limited available water quality information, conditions at Dworshak may not be suitable for supporting an infestation. Low calcium levels (<8 mg/L) combined with persistently low temperatures (<45°F) at depth would limit or preclude mussel establishment. Nevertheless, the facilities were assessed for potential impacts should an invasive mussel infestation occur.

Recommendations

The following recommendations are provided for consideration:

- In conjunction with this assessment, consideration should be given to development of site-specific response actions that build upon the Columbia River Basin response plan to address a future infestation (if not already in place). While there is no accurate way to predict whether Dworshak will become infested, planning ahead will allow time for budgeting and implementation of response actions if needed. Management options have been included in Appendix B along with links to other response plans and response planning guidelines developed by the National Parks Service.

- An analysis of available water quality data with consideration for seasonal variations in calcium, pH, dissolved oxygen, and temperature would be worthwhile to further assess whether conditions are suitable for supporting an invasive mussel infestation. Doing so would help considerably in prioritizing planning efforts.

Introduction

Purpose and Objectives

The purpose of this assessment is to provide U.S. Army Corps of Engineers (USACE) management and project staff with information regarding the vulnerability of facility features to invasive mussel impacts. This report is not intended to be a risk assessment or prediction of the potential for future mussel infestation. Instead, it is intended to assist in anticipating and planning for impacts should a future infestation occur.

Brief Project Description

Dworshak Dam is a concrete gravity dam with a structural height of 717 ft. The dam is located on the north fork of the Clearwater River in Idaho and is equipped with a spillway section, outlet works, and powerhouse. The project provides flood control, hydroelectric generation, navigation, and irrigation.

The spillway is controlled by two 50 by 56.4-ft tainter gates with a maximum capacity of 150,000 ft^3/s. The spillway section also contains an outlet works with three 12 by 17-ft outlets regulated by three tainter gates.

The powerplant is adjacent to the spillway and consists of three Francis turbine and generator units, two rated at 90 MW and the third rated at 220 MW. The powerplant operates year round with varying number of operating units as needed to meet demand. The dam and powerplant are owned, operated, and maintained by the U.S. Army Corps of Engineers.

Background on Potential Invasive Mussel Impacts

Quagga and zebra mussels (adult lengths typically average about 1 in) are unique in that they can firmly attach to the underwater surfaces using byssal threads. They begin spawning by emitting eggs and sperm into the water column when water temperatures reach about 10ºC (50ºF); though spawning has been observed at slightly lower temperatures in some cases. On a population-wide basis, egg production occurs in astronomical levels (on the order of 30,000 eggs/female/reproductive cycle). Depending on temperature and environmental suitability, multiple reproductive cycles may occur in a single year. Fertilized eggs develop into freely swimming larvae or veligers (ranging in sizes from 60 to 250 micron) which may be transported by water currents for many miles. Within a few weeks and if water conditions are suitable, the veligers will settle (i.e., attach to hard surfaces) and continue growth to adulthood.

Successful settlement is mediated by a number of environmental conditions inherent in the natural water system. These include calcium, alkalinity/hardness, pH, nutrients, dissolved oxygen, temperature and conductivity. It should be noted that some of these parameters are indirect measures of others. For example, alkalinity/hardness is presumptive for calcium and magnesium. It is generally accepted that highly successful mussel colonization occurs when calcium levels exceed about 24 mg/L. Successful establishment is more in question when calcium values fall below about 10 mg/L. With the possible exception of nutrients (implied indicators of food supply) in high mountain lakes, the remainder of listed parameters seems fairly well represented as having adequate levels in most Western waters where data are available. Table 1 provides water quality parameters suitability criteria for invasive mussels. It should be noted that this information may not be entirely applicable to all water bodies in the Western U.S. Nevertheless it provides an approximate indication of suitability requirements.

Table 1. Presumptive infestation-level suitability criteria for invasive mussels.

Parameter	Low Probability of Survival	**Infestation Levels**		
		Low	Moderate	High
Calcium (mg/L)	<10 (QM) <8 (ZM)	10-12 (QM) 8-15 (ZM)	12-30 (QM) 15-30 (ZM)	>30
Alkalinity/Total Hardness (mg $CaCO_3$/L)	<35 (QM) <30 (ZM)	35-42 (QM) 30-55 (ZM)	42-100 (QM) 55-100 (ZM)	>100
pH	<7.0 >9.5	7.0-7.8 9.0-9.5	7.8-8.2 8.8-9.0	8.2-8.8
Dissolved Oxygen (mg/L)	<3	5-7	7-8	>8
Dissolved Oxygen (% saturation)	<25%	25-50%	50-75%	>75%
Mean Summer Temperature (^{o}F)	<64 >86	64-68 83-86	68-72 77-83	72-75
Conductivity (µS/cm)	<30	30-60	60-110	>110
Salinity (g/L)	>10	8-10	5-8	<5
Secchi depth (m)	<0.1 >8	0.1-0.2 2.5-8	0.2-0.4	0.4-2.5
Chlorophyll a (µg/L)	<2.0 >25	2.0-2.5 20-25	8-20	2.5-8
Total phosphorous (µg/L)	<5 >50	5-10 35-50	10-25	25-35

It is also important to note that mean summer temperature does not imply temperature thresholds. Adult mussels have been observed to survive at temperatures near freezing. The low-temperature threshold for mussel growth is thought to be around 45 ºF. This would imply that mussels are more likely to colonize systems with raw water temperatures greater than about 45 ºF, with a lower probability of colonization for sustained temperatures below this threshold. On the upper end, temperatures greater than about 84-86 ºF for extended periods are not generally expected to support mussel survival. For additional information see Mackie G. & R. Claudi, Monitoring and Control of Macrofouling Mollusks, 2nd Ed., CRC Press, 2010.

Environmental and operational conditions of the structures themselves may also influence veliger settlement and subsequent colonization. Within a facility, veliger settlement is prohibited or greatly reduced in pipes where water velocities continuously exceed 6 feet per second (ft/s). However, intermittent operations or lower velocities may lead to successful settlement. Once attached, mussels can sustain that attachment even when flow velocities are well above 6 ft/s.

Ideal areas for mussel colonization are those areas with continuous flows of moderate velocities (<6 ft/s) and ample supplies of food and oxygen. Piped systems which are seldom utilized or idle for prolonged periods and which have depleted oxygen are not generally supportive of successful colonization. A major exception is a situation where leaking valves allow constant flows and replenishment to such seldom used systems.

Invasive mussels pose serious threats to water resources infrastructure and operations. Of major importance to facilities is the ability of mussels to rapidly colonize hard surfaces at densities of tens of thousands per square meter. Heavy accumulation can lead to costly operations and maintenance problems. Flow restriction is the foremost concern because mussels can clog water intake structures, such as trashracks, pipes and screens, thereby threatening water delivery to critical systems at hydropower plants and reducing pumping and conveyance capacities of water distribution systems.

Assessment Findings

Potential Infestation Levels

Water Quality

Of importance for estimating potential infestation levels are those parameters necessary for establishment and growth of mussel populations discussed above (namely calcium, pH, dissolved oxygen, temperature, and nutrients). Limited water quality information was available at the time of this assessment, but discussions with USACE staff suggested calcium levels and temperatures are very low which may limit or altogether preclude the possibility of an infestation.

Vulnerability of Features

Dam & Spillway

Although it is currently uncertain (i.e., hypothetical), structural drainage systems (under drains, formed drains, and toe drains), may be impacted by mussels depending on the design of the systems, size of seepage passages, and potential for backflooding of outlets. Typically flow passages to drain systems are extremely small, but if they are sufficiently large for larval mussels (> 60μm) to enter and the water chemistry is suitable for survival, then mussel colonization and clogging of portions of the drainage systems may be possible.

Spillway Gates

Impacts can range from increased friction along sealing surfaces and degraded seal performance to accelerated corrosion on submerged metallic surfaces (e.g., the gates themselves and embedded seal plates). Depending on the seats design, it may also be remotely possible for shell debris to accumulate in recesses which could make fully seating the gates difficult. However, project staff indicated the spillway radial gates are submerged for relatively short periods of time in any given year (i.e., the spillway operates during spring to early summer after which the gates are typically no longer submerged until the following spring). As such, long term impacts to the spillway gates would be expected to be minimal.

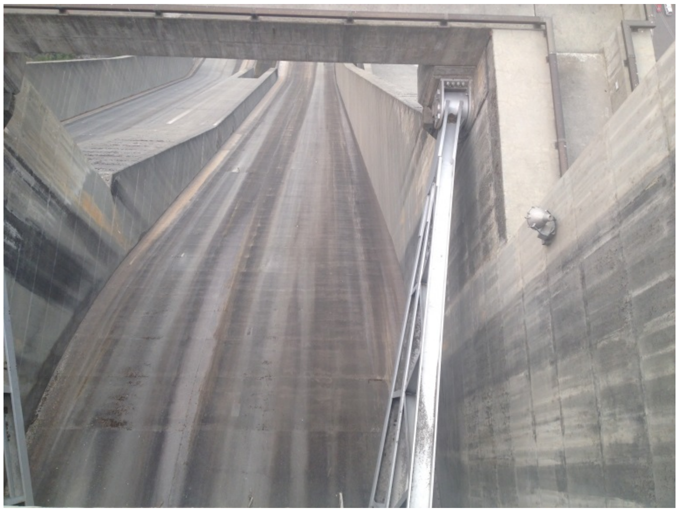

Figure 1. Spillway chute looking downstream

Figure 2. Spillway tainter gate viewed from downstream

Outlet Works

The trashracks and tainter gates for the outlet works may be susceptible to light fouling, but temperatures at depth would likely limit mussel growth. If heavy fouling were to occur, reductions in discharge capacity may be possible. Impacts to the gates can range from increased friction along sealing surfaces and degraded seal performance to accelerated corrosion on submerged metallic surfaces (e.g., the gates themselves and embedded seal plates). Depending on the seats design, it may also be remotely possible for shell debris to accumulate in recesses which could make fully seating the gates difficult.

Although not directly susceptible to impacts (since they are stored in the dry), the maintenance bulkhead guides and seats could be impacted by mussel shell debris, degrading seal performance and making seating difficult during installation.

Powerplant

Intake Trashracks

The powerplant intakes are equipped with trashracks which may be susceptible to mussel related impacts owing primarily to intermittent operations. Experience at Reclamation facilities that are heavily infested with quagga mussels suggests that portions of powerplant intake trashracks can become heavily fouled with significant reductions in open area resulting in increased headlosses. Furthermore, long term fouling on submerged metal work can accelerate corrosion if not adequately protected. However, project staff indicated that temperatures at depth rarely exceed 45°F which would significantly limit long-term growth of mussels depending on operation of the selective withdrawal system.

Selective Withdrawal System

Design or operational information on the selective withdrawal system were not provided at the time of this assessment, however based on knowledge of other selective withdrawal systems, the system at Dworshak would likely be susceptible to mussel related impacts if conditions are suitable for supporting an infestation. Impacts ranging from fouling of the structure itself to fouling of temperature instrumentation may be possible which could affect operation of the selector. Furthermore, if the system is operated to provide warmer release temperatures via withdrawal from the epilimnion, increased intake temperatures may be more suitable for mussel settlement and growth in downstream interconnected systems (e.g., cooling

Intake Gates & Bulkheads

Gates for the powerplant intakes are generally susceptible to mussel fouling since they remain submerged. Mussel fouling has the potential to damage seals and sealing surfaces leading to degraded seal performance. Although not likely to render the gates inoperable, mussel fouling of the mechanical components may cause abrasion damage to bearing surfaces with some potential for incomplete seating on closure depending on design, infestation levels and operating conditions. Again, impacts will likely be limited due to very low temperatures at the intakes elevation.

Bulkheads for the powerplant intakes are not likely susceptible to mussel fouling since it is stored in the dry. However, the bulkhead slots may be susceptible to varying degrees of mussel fouling which can indirectly impact rubber seals during installation. Like the intake gates, mussel fouling along the slots can damage seals and sealing surfaces with the possibility for incomplete seating during installation. If the bulkhead remains installed for extended periods of time (e.g., several months) then direct fouling is possible which can impact bypass fill lines may also occur and complicate removal unless other means of pressure balancing are available.

Cooling Water Systems

The cooling water systems at Dworshak Powerplant supply the bearing oil coolers, generator air coolers, packing, and HVAC system with raw water. The transformers are air cooled. Raw water is supplied via a single intake from the tailrace which is favorable for reducing shell debris and may have additional mitigating effects due to lower temperature. In general, cooling water systems are some of the most susceptible features to mussel related impacts due mainly to the small size of piping. Excessive shell debris drawn into the system can overwhelm strainers and filters if not adequately maintained. Strainers alone will not exclude mussel larvae (veligers) which can pass and settle in downstream portions of the system. Live mussels and dead mussel shell debris have the potential to clog small flow passages (i.e., heat exchangers) reducing or cutting off water flow at multiple points in the system. Clogging can cause increased operating temperatures and has the obvious potential for costly outages until cooling water flows can be restored.

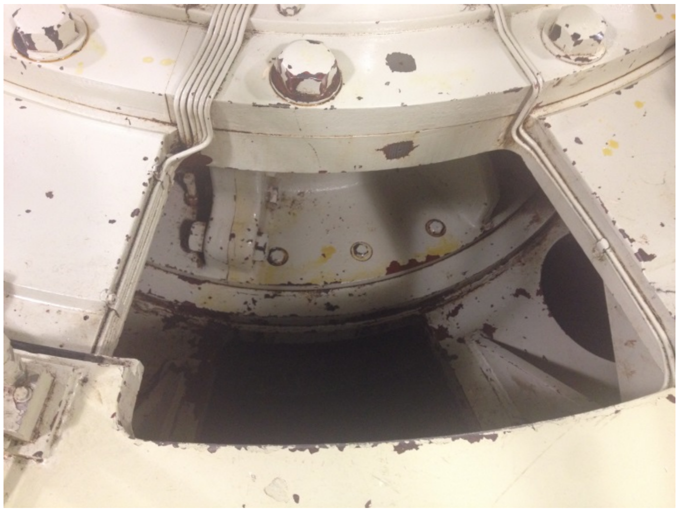

Figure 3. Turbine pit drain

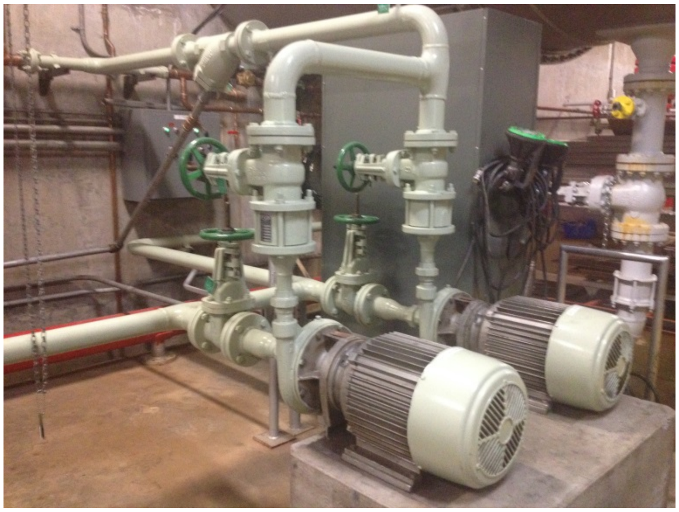

Figure 4. Cooling water pumps

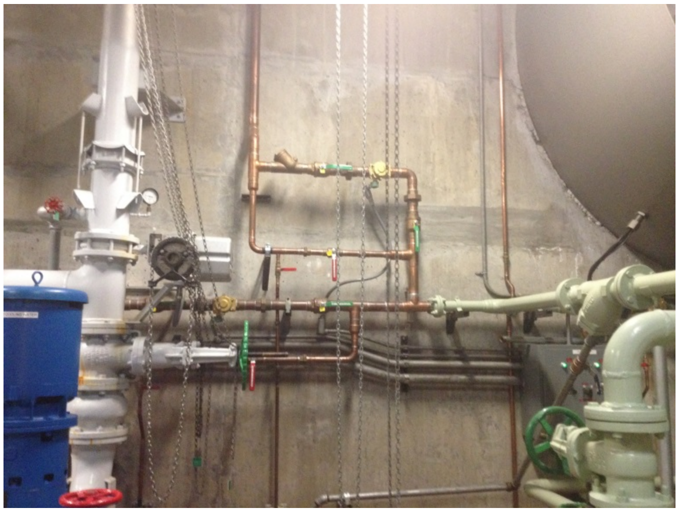

Figure 5. Cooling water distribution piping (copper)

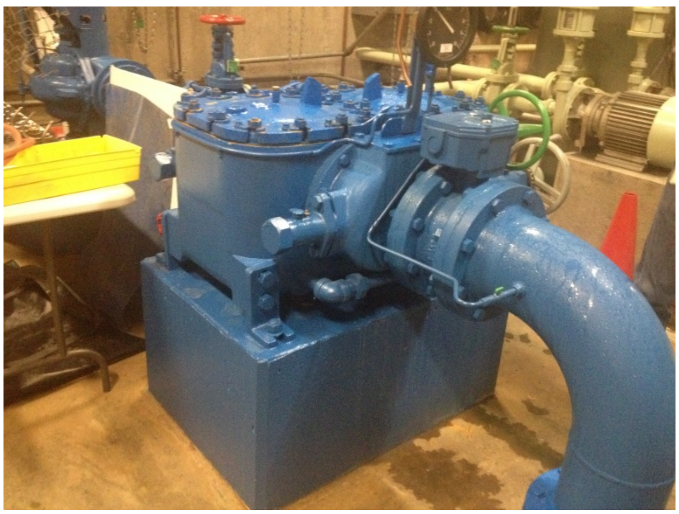

Figure 6. Cooling water supply strainer (duplex)

Waterways & Draft Tubes

The internal surfaces of the penstocks, casings, and draft tubes are not generally susceptible to mussel fouling during operation due mainly to high velocities and perhaps high turbulence intensities which is thought to be prohibitive for mussel settlement. However, units that operate intermittently (as most do) would allow for settlement during down times. Mussel fouling has been observed on portions of draft tubes (with excessive fouling on recesses in access hatches) at powerplants which are exposed to heavy quagga mussel infestations. Such limited settlement is not expected to significantly impact operation of the units. Conversely, draft tube drain lines and valves would be susceptible to clogging from live mussels or mussel shell debris. Furthermore, draining to the powerplant unwatering sump would be a source of live mussels and shell debris contamination which would adversely affect sump operations.

Draft Tube Bulkheads

Draft tube bulkheads are typically stored in the dry above the tailrace water surface elevation and used when needed to dewater for inspection and maintenance. As such they will generally not be directly susceptible to mussel fouling. However, the guides and seats are typically susceptible to some degree of mussel fouling or shell debris accumulation which could lead to seal damage and/or incomplete seating during installation. Like other bulkheads, if installed for extended periods of time, mussel fouling of drain holes in structural members can adversely affect hoisting and operability of bypass fill valves which could further complicate removal.

Drainage & Unwatering Sumps & Pumps

The powerplant sump system collects drainage and unwatering flows from appurtenant systems. Leakage from or draining of the powerplant waterways to the sump would expose the system to colonization by live mussels and contamination from dead mussel shell debris. Impacts would likely include mussel attachment on submerged surfaces and equipment which could affect sump pump performance or operability. Fouling of pump intake screens (if so equipped) would reduce capacity and may even lead to inoperability of the pumps under extreme conditions. Furthermore, fouling of the float switch arrangement in the drainage sump could render automatic system inoperable. However, the noncontact ultrasonic level sensor in the unwatering sump would not be impacted.

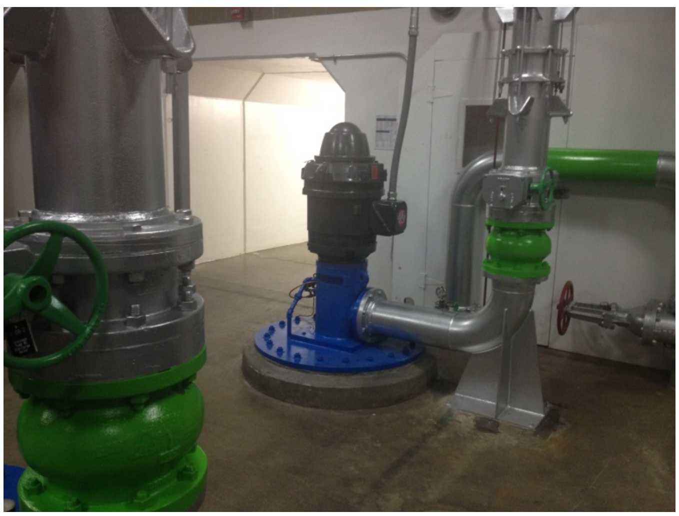

Figure 7. Station unwatering sump pumps

Air Vents

Air vents can be impacted by mussel fouling at connections resulting in blockage and reduction in vent capacities. Air vents typically serve multiple purposes including air release during filling, air admission during draining, prevention of negative pressures downstream of the gate to ensure smooth operation, or in certain cases to prevent downstream pipe collapse during an unbalanced gate closure. In some cases, venting is also required to prevent cavitation damage. Impacts will vary depending on operating conditions and levels of infestation, but are likely to be more prevalent for smaller diameter vent lines.

Service & Domestic Water Systems

Due to relatively small diameters, raw service water piping and hose taps are generally susceptible to clogging from live mussel settlement and/or mussel shell debris with the potential for inoperability depending on levels of infestation and associated shell debris loads.

Fire Protection Systems

The powerplant transformers are equipped with raw water fire protection systems. The oil storage room mist system is supplied via potable water from the on-site treatment plant and hence would not be directly susceptible other than impacts to the water treatment plant supply system. The transformer system is supplied via pumps which draw water from the tailrace and is comprised of distribution piping and spray nozzles at the transformers. Experience at Reclamation facilities exposed to heavy levels of infestation suggests that systems of this type can be rendered inoperable in a very short period of time. Although strainers afford some measure of protection from shell debris, they can be quickly overwhelmed by heavy debris load upon activation of the fire system. A measure of protection is however afforded by the fact that like the system draws raw water from the tailrace which tends to reduce shell debris.

Figure 8. Fire system supply piping and equipment

Figure 9. Transformers with fire system distribution piping and nozzles

Fish Hatcheries Water Supply

The fish hatcheries water supply intake grating, trashrack, or screen would be susceptible to partial occlusion, but the downstream piping would not likely be susceptible to complete blockage due to the relatively large size. Mussel fouling of the intake combined with mussel settlement along the piping could potentially reduce discharge capacities and shell debris for downstream systems that these pipelines serve would likely be the most significant impact. Furthermore, should an infestation occur, delivery of water from Dworshak would expose hatchery facilities to settlement of live mussels and associated impacts. It should also be noted that the supply piping feeds a small privately owned powerplant, which would also be susceptible to mussel related impacts, the degree to which would depend on design, operating conditions, and levels of infestation.

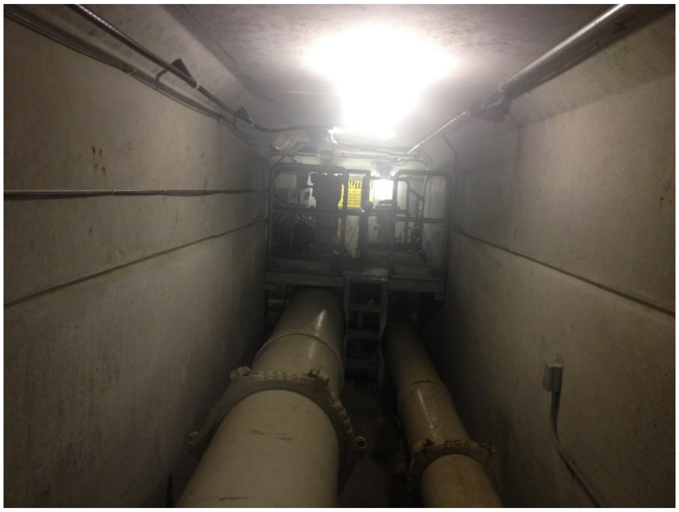

Figure 10. Fish hatcheries water supply piping

Instrumentation

Pressure, temperature, flow and level measurement instrumentation (including forebay and tailrace level sensors) in contact with raw water are susceptible to errors or inoperability due to mussel fouling. This also includes stilling wells, floats, piezometer rings, pressure transducers, pressure and temperature gauges and switches, and acoustic flowmeters.

Crane & Hoist Certification

If water weight bags are used for crane or hoist testing, the contract statement of work should include language for preventing the spread of invasive species from one site to another. Information about decontamination procedures can be found in Appendix B with a link to Reclamation's Equipment Inspection and Cleaning Manual.

Conclusions

The facilities at Dworshak Dam are relatively complex and a heavy invasive mussel infestation would likely significantly impact facility operations and maintenance. However, from limited available water quality information, conditions at Dworshak may not be suitable for supporting an infestation. Low calcium levels (assumed < 8 mg/L) combined with persistently low temperatures (< 45°F) at depth would limit or preclude mussel establishment. Nevertheless, the facilities were assessed for potential impacts should an invasive mussel infestation occur.

Response Planning

It is recommended that this report be used in conjunction with the Columbia River Basin Response Plan to develop site-specific actions for the possibility of a future mussel infestation at Dworshak. One specific response action worth considering would be the inclusion of mussel impacts and associated requirements into SOPs and O&M schedules where possible. Appendix B provides some management options for response planning, including links to various response planning guidelines and online examples.

Facility Protection Options

While a variety of solutions may exist (or new technologies may become available), not all solutions are applicable to all situations or all facility components. Some options may be as straightforward as routine cleaning while submerged or inaccessible structures and systems may require unique measures, including redesign or retrofit, to deal effectively with invasive mussels. The options provided below are suggestions on where to begin should a future infestation occur, but they do not substitute for thorough planning and engineering.

Dam & Spillway

Mussel fouling on submerged surfaces of the dam would not be expected to require corrective actions. However, long term settlement would become a source of mussel shell debris which could be drawn into downstream systems depending on location. If an invasive mussel infestation occurs at Dworshak, more frequent monitoring and inspection of structural drainage systems would be warranted. If mussel fouling or changes in drainage system flows are observed, more frequent inspections and cleanout of accessible portions of the systems may be required.

Few options are available to proactively protect the spillway gates, but the operating conditions (high and dry for the majority of the year) will considerably reduce mussel mitigation requirements. Provisions for cleaning bulkhead seats prior to installation may be required to achieve adequate seating and seal performance.

The outlet works would be more challenging, but the low temperatures will likely limit mussel related impacts and associated maintenance requirements considerably.

Powerplant

Trashracks

One option for trashracks throughout the facilities includes removal and replacement with backup sets followed by manual cleaning where possible. However, depending on the level of infestation, frequent cleaning could become expensive. Foul-release coatings could also be considered as a proactive strategy to reduce the maintenance frequency and facilitate cleaning. Various coatings for metallic structures have been tested at Reclamation’s Parker Dam which is heavily infested with quagga mussels. Results to date are promising, but limitations in durability have been identified. Nevertheless, suitably durable coatings systems may become available in the near future which could provide solutions for reducing fouling in many cases.

Other options could involve high pressure water jetting. In such cases, a mussel free water supply would be needed to eliminate impacts to water delivery piping and nozzles for the water jetting system.

Intake Gates & Bulkheads

Available options for proactively protecting the intake gates are generally limited to removal and manual cleaning at regular intervals. Storage of gates and bulkheads above the water surface (where possible) can also significantly limit impacts by eliminating long-term fouling. Regularly exercising the gates can reduce mussel attachment along the guides and seals, but doing so can also increase wear on seal elements and mechanical components. A means for cleaning bulkhead slots and seats prior to installation may be required for adequate sealing. Consideration could also be given to alternative materials of construction for guides and sealing surfaces to prevent or reduce mussel fouling where possible.

Cooling Water Systems

The units cooling water systems appear somewhat protected by utilizing tailwater as the source. The supply strainers would benefit from reduction in strainer media to 1/8-in should an infestation occur. Installation of high capacity filtration on cooling water lines would also be an option to exclude veligers and reduce settlement in downstream piping. In addition to filtration, ultraviolet (UV) light treatment systems have been demonstrated effective in reducing mussel settlement in cooling water systems. It may be possible to install UV equipment with sufficient dose just downstream of the existing strainer. It should be noted that portions of the cooling water supply piping and equipment upstream of the strainers would remain susceptible to mussel fouling which may require more frequent manual servicing, depending on levels of infestation.

Conversion of HVAC systems to closed loop is another proactive option to reduce or eliminate mussel-related impacts. Although makeup water would be periodically needed, there are substantially more treatment options available for closed loop cooling systems as compared to single-pass or once-through systems.

Waterways & Draft Tubes

As with other bulkheads, options for the draft tube bulkheads are limited to manual cleaning of guides and seats prior to installation of the bulkheads in order to prevent seal damage and ensure adequate seating. Storage of bulkheads in the dry is recommended when and where possible. Alternative materials may also be considered for the guides to reduce mussel fouling and facilitate cleaning. Access hatch try taps should also be rodded to ensure draft tubes are fully drained before opening hatches.

Drainage & Unwatering

The drainage and unwatering sump systems will likely require regular manual cleanout when possible to manage mussel fouling on continuously submerged surfaces and remove accumulated mussel shell debris. Increased inspection and maintenance frequencies for float switch arrangements and pump intake screens (where so equipped) will also likely be required to ensure reliable operation of the system. Consideration could also be given to replacing float switch arrangements with a noncontact level sensor/switching arrangements (e.g., downlooking acoustic water level sensor) to improve pumps and sump system reliability.

Air Vents

Inspection and cleaning of all air vents would likely be required at more frequent intervals and should be a high priority if an infestation occurs. While there are few options available for ensuring that air vents operate reliably for the intended purpose, more frequent inspections will provide information on the extent of the problem. If significant blockage is observed, retrofit of the vent systems, perhaps using copper-based materials to reduce mussel fouling, could be considered.

Service & Domestic Water Systems

For domestic water systems, options for proactively protecting supply and distribution piping beyond the use of strainers, filtration, and UV would include moving treatment processes as far upstream as possible. If the domestic intake is separate from other raw water systems, provision may still be required to protect the intake(s) from clogging which would likely involve manual cleaning. Station service water lines, equipment, and taps utilizing raw water will likely require frequent disassembly and cleaning to maintain operability.

Fire Protection Systems

The best available proactive strategy for maintaining reliable operation of water-based fire protection systems is conversion to a treated or mussel-free water supply (i.e., well water) where possible, or use of alternative suppression technology that does not rely on raw water. Any fire system solution utilizing infested water should be considered susceptible to acute impacts from heavy mussel shell debris loads which can, even for dry deluge systems, overwhelm strainers upon activation.

Fish Hatcheries Water Supply

Like other intakes, the trashracks or grating on the hatcheries water supply intakes would likely require some means of cleaning at regular intervals. Periodic pigging of the pipelines may also be an option to remove mussels. In any case, provisions for handling shell debris at downstream facilities (hatcheries and private power plant) would likely be required at the very least.

Instrumentation

The forebay and tailrace level monitoring systems would likely require frequent inspection and cleaning to maintain operability. Consideration for replacing existing level sensors with non-contact (e.g., downlooking acoustic level sensors) would be worthwhile if an infestation occurs. Other instrumentation including pressure taps, gages, temperature sensors, pressure and temperature switches, and flow measurement devices would likely also require frequent inspection and disassembly for cleaning to maintain accurate and reliable operation. In the event of an infestation, all instrumentation critical for safe systems operation should be inventoried and priority schedules should be developed for inspection and testing to ensure reliable operation.

Appendix A

Facility Assessment Checklist

Project Name: **Dworshak Dam, USACE**

Prepared by: Kubitschek & Willett **Date of Preparation:** 8/26/2015

2. Preparation (Step 1)

Item No.	*Item*	Status [1]	Comments / Plan to Resolve
1	**Planning**		
1.1	Has the project scope – including definition and objectives – been prepared?	Y	
1.2	Has the *Project Scope Statement* been approved?	Y	
1.3	Is there a *Project Plan* against which to measure progress?	Y	Project Management Plan (PMP)
1.4	Does the *Project Plan* address the following areas:		
1.4.1	• Project Scope and Deliverables	Y	
1.4.2	• Project Schedule	Y	
1.4.3	• Project Budget	Y	
1.4.4	• Project Organization and Resources	Y	
1.5	Were key project stakeholders brought into the *Project Plan*?	Y	
1.6	Were potential customers involved early in the planning process?	N/A	
1.7	If there are vendors, have they signed off on the *Project Plan*?	N/A	
1.8	If there is an independent oversight contractor, have they signed off on the *Project Plan*?	N/A	
1.9	Is the Project Sponsor function identified and defined?	Y	
1.10	Are there alternate persons if key members of the project are not available or become reassigned?	Y	
1.11	Other organization items (*please list*):	N/A	
2	**Tracking & Monitoring**		
2.1	Are the various types of reports, their contents, frequency, and audience defined and communicated to the Project Team?	Y	
2.2	Are the input requirements from Project Team members clearly documented and communicated?	Y	
3	**Meetings and Input Data**		
3.1	Have the various meetings, purpose, context, frequency, and participants been defined and communicated?	Y	
3.2	Have the drawings and documents from the facility sites been requested?	Y	

[1] *Enter one of the following:* **C** (Complete), **P** (Partially Complete), **Y** (Yes), **N** (No); **NA** (Not Applicable)

2. Preparation (Step 1)

Item No.	*Item*	Status [1]	Comments / Plan to Resolve
4	**Project Assumptions and Constraints**		
4.1	Are there any key assumptions upon which the assessment is based and have these assumptions been documented?	Y	
4.2	Does the Project have any Constraints such as:		
4.2.1	• Facility shutdown schedules?	Y	Facilities operating at time of site visit
4.2.2	• Facility access limitations and ventilation requirements?	Y	Access limited to structures, systems, and equipment accessible without requiring shutdown
4.2.3	• Monitoring issues such as availability of reports from sampling plates set out in previous seasons?	N	No WQ data provided
4.2.4	• Any training needed for key project staff?	N	
4.2.5	• Any pre-project procurement needed for portable field equipment?	N	

3. In-house Review and Preparation for Field Visits (Step 2)

Item No.	*Item*	Status [2]	Comments / Plan to Resolve
1	**Reviewing**		
1.1	Have drawings and documents from the facility site been reviewed?	N	Dwgs not provided or not avail
1.2	Have questions arising from the document review been communicated to and discussed with the site experts?	Y	Generally during site visit
1.3	Did the document review identify any pre-site-visit activities that should be done such as video inspections requiring divers or shutdown of equipment that needs to be scheduled?	N	
1.4	Are all pre-site-visit tasks needed to be done at site completed?	Y	
1.5	Has the deliverables list been updated based on the information from the site documents?	Y	
1.6	Have all system checklist sheets been prepared?	Y	

[2] *Enter one of the following:* **C** (Complete), **P** (Partially Complete), **Y** (Yes), **N** (No); **NA** (Not Applicable)

4. Site Visits, Follow-up and Reporting (Step 3)

The general approach should be to follow the path of the water through the site facility. The water path will become more complicated each time the water branches into a specific system. Follow each system in turn and you will have covered the complete flow of water through the facility.

Item No.	*Item*	Status	*Comments / Plan to Resolve*
1	**Field Walkthroughs**		
1.1	Has the pre-meeting at site been completed?	Y	Presentation on mussels given to project staff including brief discussions with project personnel on purpose/intent of the assessment
1.2	Were all necessary site staff available?	Y	
1.3	Have follow-up discussions with staff not available during the site visit been scheduled and completed?	N/A	
1.4	Have all the system walkthrough checklists been completed?	Y	
1.5	Have all actions arising from the site meeting and system walkthroughs been documented and communicated to the person responsible for the action?	Y	
1.6	Has the draft project report been reviewed by all contributors?	N/A	Will be completed following site visit
1.7	Has the final report been approved for issue?	N/A	Will be completed following site visit
1.10	Has the final report been distributed?	N/A	Will be completed following site visit

5. Mussel Vulnerability Evaluation - Project Team Contact List

Project Name: Dworshak Dam, USACE

Project Lead: Kubitschek & Willett

Some suggestions for the roles of the various team members and the skills or knowledge that would be helpful for each team member are contained in Appendix A.

Name	***Title***	***Location***	***Office Phone & E-mail***
Joe Kubitschek	Hydraulic Engineer	Reclamation, TSC – Hydraulic Investigations and Laboratory Services, Denver, CO	(303) 445-2148 jkubitschek@usbr.gov
Leonard Willett	LC Region Mussel Task Force Coordinator	Reclamation, LC Region, LC Dams Office, Boulder City, NV	(702) 494-2216 lwillett@usbr.gov
Greg Moody	Fisheries Biologist	USACE – Walla Walla District	(509) 527-7124 gregory.p.moody@usace.army.mil
Jess Godfrey	Mechanical Engineer	USACE – Dworshak Dam	(208) 476-1207 Jess.L.Godfrey@usace.army.mil

6. Mussel Vulnerability Evaluation – Sample Facility Deliverables List

Facility Name: Dworshak Dam, USACE

The deliverables are internal document packages prepared for each system or major structure. Once all deliverables are completed, they are then used to prepare the overall assessment report which would be the only external deliverable. It will be helpful when preparing this list to refer to Appendix D for additional detail about typical systems and components at risk that should be considered.

Major Structure or System	***Reference drawings Used***	***Deliverables***
Dam & Appurtenances	No dwgs provided	
eg2: pump station unit cooling water system	N/A – No pumping plant	
eg3: powerplant & fire water system	No dwgs provided	
Continue with systems or structures until all areas in contact with raw water are covered.		

System Walkthrough Checklist

System or Structure Name: **Dworshak Dam, USACE**

Prepared by: Kubitschek & Willett **Date of Preparation:** 8/26/2015

1. Instructions for Using this Document

- Prepare one of these sheets for each system or major structure identified in the Deliverables list.
- For each *Item No.* below, complete all blank fields (see footnotes for *Status* and *At Risk of Mussels* columns).
- For some of the components such as valves and strainers there may be several in one system. If more than one component needs to be considered add an extra sheet for that particular component group.
- Refer to Appendix C for additional information and suggestions about various systems and components.
- Add additional rows as required where you identify items that need to be considered and are not covered elsewhere in the list.

2. Walkthrough Checklist

Item No.	*Item*	*Status* [3]	*At Risk (yes/no)*	*Comments*
1	**General for Dams, Reservoirs, Aqueducts**			
1.1	Are there any membranes, control joints, permeable construction media, drains, etc. that will let raw water pass?	Y	Y	No specific structural drainage systems were identified/pointed out during the walk thru. Spillway under drain system and formed drains for the concrete section. No observed clam shells in drainage galleries. Potential for mussel related impacts to drainage systems currently unknown.
1.2	Are there any air vents?	Y	Y	Various throughout the facility.
1.3	Check if the spillway and appurtenances are always wet or dry and record duration of dry period.			Spillway operates seasonally and tainter gates typically dry.
1.4	How much does the water level (i.e. reservoir water surface elevation) fluctuate?			Varies significantly, typically about 100 ft annually. Normal operating range can be between El. 1445 – 1600 ft
1.5	Are all potential water seepage paths inspected on a regular basis?	Y		
2	**Water Intake Structures**			
2.1	Types of intake structures present (more than one may be present):			
2.1.1	• Open Canal Direct into Facility (concrete)	N		
2.1.2	• Open Canal Direct into Facility (other material-specify)	N		
2.1.3	• Forebay (specify lining material)	N		
2.1.4	• Tower (specify construction material)	N		
2.1.5	• Submerged Tunnel or pipe intake (specify construction material)	N		
2.1.6	• Penstock intakes (specify construction material)	Y	Y	Separate power plant and outlet works intakes.
2.1.7	• Fish Barriers	N		
2.2	Is the floor of any intake structures likely to be covered with silt or sediment?	N		

[3] *Enter one of the following:* **C** (Complete), **P** (Partially Complete), **A** (Absent); **Y** (Yes), **N** (No); **NA** (Not Applicable)

2. Walkthrough Checklist

Item No.	Item	Status [3]	At Risk (yes/no)	Comments
2.3	Are any structures duplicated to provide a backup?	N		
2.4	What is the flow velocity range in the structure?			Velocities will likely range from 0-5 ft/s at the intakes and exceed 20 ft/s depending on operating conditions.
2.5	Is the structure accessible for inspection?	N		Intakes submerged and operating at time of site visit.
2.6	Are there any shutdowns to provide easy access and what is their frequency?	Y		For regularly scheduled inspection and maintenance cycles.
2.7	Are there scheduled maintenance cycles and what are their frequencies?	Y		Varies depending on the system/equip, but typically annual.
3	**Trash Racks, Grates, Screens**			
3.1	Record spacing, size and material of trash rack bars.		Y	Unavailable at time of site visit but intake trashracks bar spacing likely between 6-8 in.
3.2	Are trash racks fixed or easily removable for maintenance?		Y	Powerplant intake trashracks not removable.
3.3	Is there a planned maintenance frequency for the trash racks? If so what is interval?	N	Y	
3.4	Is there a trash rake or other style of cleaning system?	N	Y	
3.5	Are the rake fingers sufficiently large to remove mussels from sides of trash rack bars?	N/A		
3.6	Record location, material, size and grid spacing of any small intake grates.		Y	Hatcheries supply intake, unknown whether trashrack or grating.
3.7	Are grates fixed or removable for easy maintenance?		Y	
3.8	Check if grates at bottom of pipes or channels get covered with silt or sediment.	N/A		
3.9	Record location, material, size and grid spacing of any screens.	N/A		
3.10	Are screens fixed or removable for easy maintenance?	N/A		
4	**Wells and Sumps**			
4.1	Location and material of constructions of wells.	N/A		
4.2	Identify level fluctuations in pump wells.	N/A		
4.3	Distance of pump suction from bottom of wells. Will pump ingest shells that are transported along the floor into the well?	N/A		
4.4	Location and material of constructions of sumps.		Y	Powerplant drainage and unwatering sump systems - concrete
4.5	Is there a float or other instrumentation in sump that could become covered with mussels?	Y	Y	Float in drainage sump, ultrasonic in unwatering sump
4.6	Frequency of sump inspection by plant staff.		Y	Monthly (assumed)
5	**Pumps and Turbines**			
5.1	Is pump motor or turbine generator water or air cooled? Water cooled motors are at risk.		Y	Generator air coolers and bearing oil coolers utilize raw water
5.2	Can mussel shells get into wear ring gaps?	Y	Y	Assumed possible
5.3	Does pump have a mechanical seal?	N/A		
5.4	How is the seal flushed during start-up?	N/A		
5.5	How is the seal flushed during normal running?	N/A		
5.6	Does the turbine have a stuffing box?	Y	Y	

2. Walkthrough Checklist

Item No.	Item	Status [3]	At Risk (yes/no)	Comments
5.7	Is there a stuffing box lantern ring or other cavity for cooling and flushing water?	Y	Y	
5.8	How is the ring flushed during start-up?		Y	Flushed prior to startup
5.9	How is the ring flushed during normal running?		Y	Continuous
5.10	Check if the turbine bearings have water cooled lubrication?	Y	Y	Bearing oil coolers for all units use raw water
5.11	Check if the pump has water cooled bearings?	N/A		
5.12	Can mussel shells get into the water lubricated bearing passages?	N/A		
5.13	Do seal or stuffing box cavities have a means of monitoring or inspection?	N/A		
5.14	Can seals or stuffing box be cleaned without removing generator?	N/A		
6	**Piping**			
6.1	Identify materials of construction for piping.		Y	Steel, copper
6.2	What is flow velocity range in piping?		Y	Varies depending on system & operating conditions
6.3	How much time is velocity above 6 ft/sec?		Y	Varies depending on system
6.4	How much time is velocity below 6 ft/sec?		Y	Varies depending on system
6.5	Are there any offsets or changes in pipe diameter?	Y	Y	Offsets, bends, fittings, etc... throughout the facility
7	**Instrument Tubing and Instruments**			
7.1	Identify any small diameter lines (2” diameter or less) including material of construction such as:		Y	Service water taps, bearing oil coolers distribution piping, turbine packing supply line, turbine pit drains, etc…
7.1.1	• Flow measurement taps	N		
7.1.2	• Piezometer taps	N		
7.1.3	• Pressure taps	Y	Y	Pressure taps/gages/switches throughout the facility
7.1.4	• Sample lines	N		
7.1.5	• Pressure balance lines	N		
7.1.6	• Other – Outlet works flowmeter	N		
	• Other – Reservoir El. gauge	Y	Y	Reservoir and tailrace level sensors (bubbler)
8	**Heat Exchangers**			
8.1	Identify material of construction of plenum.		Y	Generator air cooler tubes and bearing oil coolers heat exchangers
8.2	Identify material of construction of tubing.		Y	Assumed copper
8.3	What is diameter of tubing?		Y	Smallest diameters ~¾-in tubing
8.4	What is flow velocity range in tubing?		Y	Depends on operating conditions, but likely less than 6 ft/s
9	**Valves**			
9.1	Identify all normally open (NO) valves.		Y	Cooling water systems and various throughout the facility
9.2	Can NO valves fail to seal properly if valve seat or valve face becomes mussel coated?	Y	Y	Possible, particularly for butterfly valves
9.3	Identify all normally closed (NC) valves		Y	Various throughout the facility

2. Walkthrough Checklist

Item No.	Item	Status [3]	At Risk (yes/no)	Comments
9.4	Can NC valves fail to open if valve face becomes coated with mussels?	Y	Y	May be possible depending on size, operational frequency, and levels of infestation
9.5	What is throat diameter of valve? Is it small enough to become plugged by mussel shells?		Y	Various valves through facility
10	**Strainers and Filters**			
10.1	Identify the style of strainer, material of construction of strainer body and basket as well as the size of the basket pores. Typical styles are:			Various strainers on cooling water supply lines
10.1.1	• Fixed In-line strainer	N		
10.1.2	• Duplex strainer	Y	Y	Cooling water supply lines
10.1.3	• Self-cleaning strainer	Y	Y	Fire system supply line
10.1.4	• Wye (Y) strainer	Y	Y	Cooling water supply lines
10.1.5	• Other type - specify			
10.2	Identify the style of filter, material of construction of body and filter element, as well as the size of the filter pores. Typical styles are:	N/A		
10.2.1	• Self-cleaning filter	N/A		
10.2.2	• Replaceable cartridge filter	N/A		
10.2.3	• Other type - specify	N/A		

Appendix B

Management Options for Quagga & Zebra Mussel Infestations

Concurrent with Prevention & Public Outreach/Education Activities

Most water bodies in the western United States are at risk of infestation by invasive quagga and zebra mussels. While actions taken to prevent or respond to infestation must be tailored to each specific location, the following activities represent options for consideration as part of any readiness planning as well as options for dealing with mussels following detection. Information on preventing the spread of invasive mussels can be found at the 100th Meridian Initiative website http://100thmeridian.org/ and http://protectyourwaters.net.

Guidance has also been developed by Reclamation and is documented in Technical Memorandum No. 86-68220-07-05 *Inspection and Cleaning Manual for Equipment and Vehicles to Prevent the Spread of Invasive Species* which provides information for inspecting and cleaning vehicles and equipment to help prevent the spread of invasive species. The manual can be found at http://www.usbr.gov/mussels/prevention/docs/EquipmentInspectionandCleaningManual2012.pdf

Actions to consider prior to detection of mussels:

1. **Develop Coordinated Response Plan(s) -** This plan would detail policies, command and authority structure, strategies, communications, roles and responsibilities, and response actions to be implemented – Involves multiple federal, state, and local agencies and stakeholders. An example Response Plan for the Columbia River Basin may be found at the 100th Meridian website http://www.100thmeridian.org/Columbia_RBT.asp. The National Parks Service also has information and guidelines for prevention and response planning that can be found at http://www.nature.nps.gov/biology/Quagga/index.cfm.

2. **Perform Infestation Risk Assessment(s) –** This activity may be completed as standalone or as part of the Coordinated Response Plan. The purpose is to identify which water bodies are most at-risk of infestation within the geographic region of interest or management jurisdiction. The likelihood of infestation is typically based upon recreational usage, the nearest known infestation, and the extent to which environmental conditions (including calcium, pH, dissolved oxygen, temperature, etc…) are likely to support mussel establishment. This information can be used to prioritize facility vulnerability assessments (below). A variety of examples for risk assessments are available on the web. Information specific to environmental suitability based risk assessments is available at the U.S. Army Corps of Engineers Zebra Mussel Information System (ZMIS) website http://el.erdc.usace.army.mil/zebra/zmis/zmishelp.htm.

3. **Perform Facility Vulnerability Assessment(s) –** This activity may be completed as standalone or following the infestation risk assessment(s) and consists of a detailed inventory of critical water related infrastructure and how each component is likely to be affected by mussels should infestation occur. The results can be used to prioritize facility protection needs and actions. A facility vulnerability assessment template can be found at www.usbr.gov/mussels/.

4. **Implement Monitoring Program(s) –** Monitoring programs should be considered for high priority water bodies where infestation is either likely or would cause significant impacts to water systems or other key resources. Monitoring programs, designed to provide early detection of mussel larvae (through water sampling and lab analysis), potentially provide 2-3 years of lead time for planning and implementing protective actions before the infestation impairs operations via adult settlement on hydraulic structures or within critical systems. Additional information on monitoring can be found at the U.S. Army Corps of Engineers Zebra Mussel Information System (ZMIS) website http://el.erdc.usace.army.mil/zebra/zmis/zmishelp.htm.

Actions to consider following detection of mussels:

1. **Execute Coordinated Response Plan –** Involves notification, information exchange, and implementation of containment and control actions (i.e., components of the response plan).

2. **Increase Monitoring –** Transition from monitoring for detection to monitoring with increased frequency to confirm detection, identify or locate the presence of adults, and track infestation levels. This activity may also include regular facilities inspections to determine when facilities are being impacted by adult colonization. The information obtained can guide facilities protection actions and assists in anticipating ecological impacts for future mitigation planning and budgeting.

3. **Identify and Implement Appropriate Facilities Protection Measures –** Identify which actions or technologies are best suited for maintaining operations and reducing O&M costs or other expenses. Various conventional technologies have been used with reasonable success. The table below provides some conventional as well as experimental options, each of which has advantages and disadvantages. It should be noted that there are a number of commercial treatment products that have not been listed, but may be applicable in various situations.

Table 1 – Control and facilities protection options for various applications

Technology	Potential Applications
Filtration to prevent mussel entry to piped systems – Self-cleaning 40-80 micron filters may be more than adequate depending on exclusion requirements. Exclusion avoids the need for treating infested systems.	Low volume systems - Facilities service water, unit or transformer cooling water, HVAC, pumped systems, and piping
Ultraviolet (UV) Treatment of water in piped systems – In-line UV systems are being evaluated to prevent mussel settlement. UV has additional water treatment benefits and is not expected to require discharge permitting [†]	Low volume systems - Facilities service water, unit or transformer cooling water, HVAC, pumped systems, and piping
Chemical Treatment – Injection or delivery of chemicals (oxidizing and nonoxidizing) to kill mussels or impair ability to attach to surfaces • Bromine • Chlorine • Chlorine dioxide	Low and medium volume systems - Facilities service water, unit or transformer cooling water, HVAC, pumped systems, and delivery pipelines. Permitting required for chemical treatment methods

• Hydrogen peroxide • Ozone • Potassium salts • Potassium permanganate • Sodium Hypochlorite	
Alternative Treatments – Alternatives to kill mussels or impair ability to attach • Thermal • Biological • Desiccation	Low and medium volume systems – Facilities service water, unit or transformer cooling water, HVAC, pumped systems and delivery pipelines. Desiccation requires capability to dewater system for extended durations
Coatings to protect exposed surfaces – Prevents mussel attachment or facilitates cleaning (anti-fouling & foul-release) †	Hydraulic Structures & Equipment - Gates, valves, penstocks, intake structures, trashracks, fish screens
Alternative Materials – To prevent mussel attachment or facilitate cleaning • Copper • Galvanizing (requires high zinc content)	Intake grating, piping/tubing, heat exchangers, HVAC systems
Mechanical Removal – Routine maintenance • Mechanical raking/scraping • Hydrojetting • Pipeline pigging • Traveling intake screens (self-cleaning)	Structures, systems, equipment, and instrumentation where access is possible – Diversion structures, pipelines, trashracks, intakes, fish screens. For instrumentation, noncontact methods should be considered where possible
Redundant Systems – Multiple intakes or duplicate systems for switching during treatment or cleaning to provide uninterrupted service	Systems for which retrofit is possible/practical

† - Under development or being field tested.

Technologies selection for each application depends on a number of considerations including periodic or continuous mussel exclusion requirements, operations and maintenance requirements, permitting requirements, environmental impacts, and cost; to name a few. If conventional technologies are not applicable then alternatives should be developed and demonstrated as early as possible to meet unique facilities requirements. Operational strategies may also be available to reduce or eliminate mussel impacts. However, such strategies are often limited depending on the type of system and available flexibility. Additional information on control strategies and facilities protection methods may be found in Mackie & Claudi, Monitoring and Control of Macrofouling Mollusks in Fresh Water Systems, 2010 and at the U.S. Army Corps of Engineers Zebra Mussel Information System (ZMIS) website http://el.erdc.usace.army.mil/zebra/zmis/zmishelp.htm

Identify Ecological Impacts – Involves developing and initiating actions to track ecological changes, develop mitigation plans, and implement long-term mitigation actions (considers endangered species, food webs, aquatic weeds, water quality, etc…)