Preface to Report:

This project is in progress as of December 2014. The funds from X6002 were transferred into an Advanced Funding Agreement A276F. Mechanical and Electrical Engineering staff conducted a site visit in September 2014 and have produced a Report of Findings. The project will continue through an appraisal design of fire systems renovations.

The report below is from a site visit by Water Treatment and Mechanical Engineering personnel.

Report of Zebra and Quagga Mussel Infestations on Fire Protection Systems at Reclamation Hydroelectric Facilities

Problem Statement:

Infestations of invasive species such as zebra and quagga mussels have increased across the western US and have begun to impact routine operation of Reclamation facilities. One potential impact is to water-based fire suppression systems. Mussels have the potential to foul suppression systems to the extent that they may not function as designed. This document will spell out the specific impacts and possible solutions for water based fire suppression systems.

Introduction:

Non-native mussels were first observed in the Lower Colorado River in 2007. They have greatly multiplied since then and have become problematic at the three major hydroelectric dams – Hoover, Davis and Parker. Mussels have adapted to the Southwest readily and affect LC Region facilities using raw water.

Reclamation facilities make use of the large reservoirs impounded by dams for a water source. The raw water is used for hydropower to drive turbines, in heat exchangers to cool bearing oil and HVAC air, service water and fire protection. Mussel infestation has reduced flow in some of these systems. The reduced flow has economic and safety consequences. An example of a safety consequence would be plugging of the fire protection piping such that when water flow is needed to suppress a fire, it may not be available. An example of an economic consequence is the reduced head available for power generation due to the fouling of penstocks.

Upon site visits to Hoover and Parker Dams and interviews with Reclamation personnel, it became clear that one of the most critical issues remaining unsolved, related to mussel infestation, is the large amount of debris left behind after mussel dieoffs in and near the hydraulic equipment. The shell debris deposited in the hydraulic equipment can build up until when there is a large sudden increase in demand, such as when fire suppression water is needed, there is a corresponding sudden large increase in velocity of the water which can scour the debris and entrain it into rapid water flows. Fire suppression systems using raw, untreated water are currently not designed to function with large amounts of debris.

Original / Existing Design

Fire suppression systems protect transformer decks and lube oil storage rooms of hydroelectric facilities with deluge-type systems. Other areas are typically protected with fusible link sprinkler heads. While National Fire Protection Association (NFPA) 851 codes are recommended, not mandatory, some of the potential consequences of having an inoperable fire suppression system are mentioned below:

- Transformer fluid can burn for up to 24 hours if it is not suppressed (ENR, 2011). The burning fluid can spread fire to adjacent areas of the deck and spread toxic fumes into the air.
- Typical concrete mixes can lose up to 65% of their strength when exposed to the high temperatures of a transformer oil fire (ENR, 2011). This would require extensive demolition and reconstruction of walls and decks exposed to the high temperatures.
- If fire spreads, more transformers could be compromised, potentially resulting in spilling transformer oil into rivers.

Since the Bureau of Reclamation follows NFPA 851 and it is known that there are infestation issues at Reclamation facilities, then this research effort will assume there is a problem requiring a solution.

Problem Analysis

The invasive zebra and quagga mussels are not native to the United States. They are presenting a significant problem to the fire protection systems at Reclamation facilities.

Zebra and Quagga mussels belong to the Dreissenidae family of bivalve mollusks. Their life cycle begins as a fertilized egg that upon further development becomes planktonic in size and floats in the water column. The next stage is the veliger stage where it develops a velum that allows it to move through the water column. The veliger stage can be from 40 to 200 microns in size. The veliger stage is the most mobile and due to its small size it is the most intrusive. The next life stage is when the juvenile mussels develop a thicker shell and attach to a surface, at which point they rely upon filtering the water column for their food, which consists mostly of plankton.

Once settled, adult mussels grow up to 2 cm in length. They filter such huge amounts of water that a turbid reservoir can be made completely clear of suspended solids.

Several routes of fouling are possible from mussel infestation. Veligers can swim to or be drawn into hydraulic intakes and equipment. In the early stages, due to their small size and lack of a hard shell, they are not likely to be in sufficient numbers to foul equipment. However, they can settle and attach under favorable conditions. Once they settle they impact the flow path, increasing the surface roughness of the pipe, resulting in higher energy loss. In extreme cases of fouling from settlement, adult mussels can grow several organisms deep from the original surface, drastically reducing the area of flow in a conduit.

Mussels can settle if the water velocity is less than six feet per second. They have attached to nearly every kind of solid surface tested or exposed. The only materials that have been resistant to settlement are copper and synthetic materials impregnated with molluscicides.

Once mussels have attached to a solid surface, others mussels settle and grow on top of previously attached mussels. They can grow to layers up to six inches deep. When the adults at the bottom of the layer can either no longer access food in the flow stream or reach old age, they die and detach, taking the others on top of them with them, which results in debris being deposited downstream. The debris can accumulate in large channels such as penstocks (when flow is lower than 6 fps) and build up several feet deep, until a large flow disturbance flushes the debris downstream. As the debris is carried downstream into smaller pipes, obstruction occurs and flow is reduced or completely blocked. This situation with mussel debris is a serious issue faced by some Reclamation facilities.

Current Status

NFPA 25 identifies the inspection, testing and maintenance of water-based fire suppression systems. If the testing protocols are performed and the system passes, then it is considered ready for service. It is not known whether the fire suppression systems at Reclamation facilities are being maintained and tested as required by NFPA 25. Facility surveys have been ongoing by Reclamation staff, but a comprehensive summary has not been published. In order to define the extent of the problem, it is recommended that every facility with a fire suppression using raw water and with potential mussel infestation perform a survey and testing per NFPA 25. The surveys and testing would provide clarity as to which facilities are currently inoperable, which are compliant and functioning as designed and which may be vulnerable to fouling in the future.

The possible solutions and options below are presented in case some facilities find their systems inoperable or vulnerable to future fouling issues.

Possible Solutions

The possible solutions to mussel fouling of fire protection systems can be grouped into two categories; restoring original functionality as designed, or providing alternate fire suppression.

At most Reclamation facilities the original design involves an intake of raw water from the reservoir or tailbay, a fire pump and delivery system. Where mussels are present, there is little prospect of using the original equipment as designed without modifications to the inlet and treatment. The current systems could experience plugging from settlement in currently wet intake equipment. Water flow in piping may also sweep large amounts of debris into the system if untreated. Original functionality can be preserved through either preventing the entrance of debris into the intake or handling and removing debris before flow is decreased or equipment fouled. This following examines options for restoring original functionality:

- Alternate Water Sources. One way to eliminate the need for mussel treatment is to use a source other than the reservoir. Alternate sources include groundwater from a new well or treated water from a current municipal or other public supply. The alternate source must be capable of meeting the demand required for fire suppression by either direct delivery from the well or from a water tank used for fire protection.

A new well would provide a water source guaranteed to be free of invasive mussels. The well could be paired with a water tank to provide a more fail-safe supply, but it is not necessary if the well provides adequate and dependable required fire flows year round. The reliance on a well without storage would require a hydrogeological investigation to assure required flow rates would be met. In addition to finding sufficient groundwater, there would be issues regarding water rights and/or permits.

An onsite water tank filled from a well can provide added reliability for a fire system. The well could have a lower flow capacity, although NFPA requires that the supply to the tank must be sized to refill the water tank in 8 hours.

Another alternate source which may be feasible for some facilities is a nearby municipal supply. Some communities may have unused capacity or distribution system infrastructure no longer in service. Other communities may not have existing capacity, but may welcome the expansion if it was accompanied by funding for overall improvements to provide the needed capacity.

- Screened Intermittent Supply. One possible solution is to use the original intake as designed, but have as much of the system as possible a dry pipe system. The supply would be screened when flow occurred. However, NPFA requires fire pumps to be flooded and fire suppression water must be delivered to the hazard in a maximum time of 45 seconds (assuming Extra Hazard - Group 1 Occupancy). Therefore, only a small amount of piping could be dry. Since the water in the intake piping, pump, and piping up to and including the dry type valves would contain water with mussels, this solution would not be practical at most power plants.

  The cooling water and fire suppression water supplied from the reservoir or tailbay is typically strained between 1/32-inch to 1/8-inch. NFPA requires UL listed strainers to be used for straining fire water. These UL listed strainers would need to be capable of handling a sudden increase in the amount of debris entrained into the flow stream. While the strainers are designed to handle some level of debris, they may be overwhelmed by a large amount of mussels or algae when fire flow is required. An option may be to install a cyclone separator to handle large amounts of debris or algae, if allowed by NFPA.

  The cyclone separator should be tested with systems that are likely to have debris, or be tested in a laboratory setting with debris similar to natural shell debris or algae. If it is proven to be effective at removing large amounts of debris and algae, it may be a cost-effective solution to fire protection, allowing facilities to maintain most of the original system function. Preliminary preparation has been made for setting up testing equipment at Parker Dam if this option is pursued. It is believed that Parker Dam may have enough debris present that it would be a robust testing environment for a cyclone separator.

- Store Treated Water from the Reservoir. Another possible solution is to store treated fire suppression water which was taken from the reservoir. The water could be withdrawn from the reservoir using the existing equipment at a slow enough flowrate to not impact other uses such as cooling. The fire suppression water would be treated down to 80 microns which would filter any adult mussels or even large veligers. The stored water could contain live mussels smaller than 80 microns, but as the water is stored, the mussels would not thrive because they would exhaust whatever resources were available. Settlement would be short-lived and debris would not form as growth would not occur. Physical or chemical treatment (chlorine) would accelerate the process of killing the mussels as well as protect the water from becoming objectionable for fire suppression.

- Alternate, Normally Dry Intake. An option that was considered would be to use a new intake that would be normally dry and dropped into the river during a fire. The benefit would be that if the equipment was only submerged in water when fire suppression water was needed, it would remain free of mussel debris and juveniles that would be entrained into the flow would never have the chance to settle and grow. Since NFPA requires the fire pump bowl to be flooded, it does not appear that this option meets NFPA.

	Advantages	Disadvantages
Alternate Source (groundwater)	No treatment equipment required. No concern for future infestation.	Possibly no water available. Well can be costly.
Alternate Source (Municipal)	No treatment equipment required. No concern for future infestation. Certainty of supply.	Possible long transmission line. Possible costs with rights acquisition.
Cyclone Separator	May handle extreme loads of debris.	Unproven. Requires testing. Requires new equipment and space.
Stored Supply	No debris issues. No concern for source	Large expensive tank. Large space necessary for tank.

	infestation level.	

Suggested Roadmap for Next Steps

The next step in determining the best course of action is to get planning level costs for various options and investigate any regulatory issues associated with these options. The needs of each option are as follows:

Alternate Sources

Items needing investigation:

- Cost of new well with and without storage
- Cost of storage equipment
- Cost of site acquisition for storage
- Cost of municipal tie-in
- Availability of groundwater / rights

Cyclone Separator

- Cost of intake modification
- Cost of separator
- Cost of reconfiguration of piping
- Equipment footprint

Stored Supply

- Cost and amount of storage
- Cost of Piping / pumping from source to storage to fire system