RECLAMATION

Managing Water in the West

Investigation of Fish Screen Cleaning by Air Burst and Water Jet Systems

Research and Development Office
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Final Report ST-2017-1710-01
Hydraulic Laboratory Report HL-2017-05

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Mission Statements

Protecting America's Great Outdoors and Powering Our Future

The Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

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14. ABSTRACT Information from a literature review on different cleaning methods for fish screen facilities is presented and covers passive (no cleaning), air burst, water jet and automated brush cleaning systems. In addition, background information is presented on screen materials and types of fish screen designs. The automated brush cleaner method is the least complex to design, the best cleaning efficiency, and was determined to be the best method for most applications. Air burst and water jet can be effective but have limited application as a primary cleaning method. Fish impacts of each of the cleaning methods were estimated, and would be an interesting topic for future research.

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Executive Summary

This scoping-level research project focused on a comparison of air burst and water jet cleaning systems for fish screening facilities and how they perform compared to an automated brush cleaner system. A literature review was conducted to find design guidance on the type of cleaning system that is most appropriate for certain types of facilities... Other than rules of thumb, no such guidelines exist.

Background information is presented on the three common fish screen materials (woven wire, perforated plate and wedge wire) as well as their relative rates of clogging. Four main types of fish screens (flat plate, traveling screen, drum, and cylindrical) are described and limited details of their suitability with respect to cleaning systems are also presented.

The comparison of cleaning methods evaluated passive (no cleaning), air burst, water jet and automated brush cleaning methods against four metrics: mechanical complexity, hydraulic impacts, cleaning performance and fish impacts. Information discovered in the literature review and personal communication with designers, facility operators and biologists is covered for each category and cleaning method.

Below is the best rated fish screen cleaning method for each of the four metrics:

- Mechanical complexity was lowest with the automated brush system because it had the least complex design with fewer components and no plumbing required.
- Hydraulic impacts were lowest with the water jet system that creates a limited zone of turbulence, and no impacts to the diverted water.
- Cleaning performance was highest with the automated brush system as it was the only in-water method that could remove biofouling as well as debris.
- Fish impacts were estimated to be comparable between the automated brush system and a continuous water jet since both create a smaller zone of turbulence and the constant nature allows fish to avoid the turbulence.

Fish screening facilities require low approach velocities to prevent injury to fish due to the potential for impingement on the screen face and are therefore subject to sediment deposition as the flow velocity is reduced. Many projects utilize either an air burst (most common) or a water jet system to reduce sediment deposition at the base of the fish screen or downstream of the fish screen within the intake chamber with high success rates. These systems have been used to prevent damage to automated brush cleaner systems by mobilizing sediment that could deposit along the path of the brush arm, as well as to ensure the screen area remains clear of sediment. In some locations, an air burst system has been used to alter the location where sediment deposits to make annual cleaning and dredging easier to perform.

While there was enough information discovered to make a clear recommendation that the automated brush cleaner system is the most cost effective and efficient method for cleaning fish screens, there were a few knowledge gaps that could be improved with future research. Primarily, there was no direct research found that studied fish behavior for any of the presented cleaning methods. Sudden turbulence and acoustics caused by an air burst may cause stress or

damage to fish in the area, but more information is needed to make this determination. Since air burst systems are common due to a less mechanically complex design and proven cleaning performance, it would be beneficial to further study the fish impact from the air burst system.

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Background

Fish screening facilities protect fish by preventing entrainment of fish into canals, pump intakes, or other facilities. While behavioral methods have also been used, positive barrier screens are a structural control that places a porous screen between the water course and the diversion and are the most widely used and accepted by fishery resource agencies. Since most rivers also contain debris carried by the flow, the screens must also include some method of cleaning to prevent excessive head loss across the screen (difference in water surface elevation between upstream and downstream) and to maintain uniform flow velocity through the screen. The two velocity components for flows along a screen face are perpendicular to the screen (approach velocity) for flow that enters the screen and parallel to the screen (sweeping velocity) for flows that sweep fish and debris past the screen and is illustrated below in Figure 1. Types of debris may include plants, leaves, branches, logs, and trash.

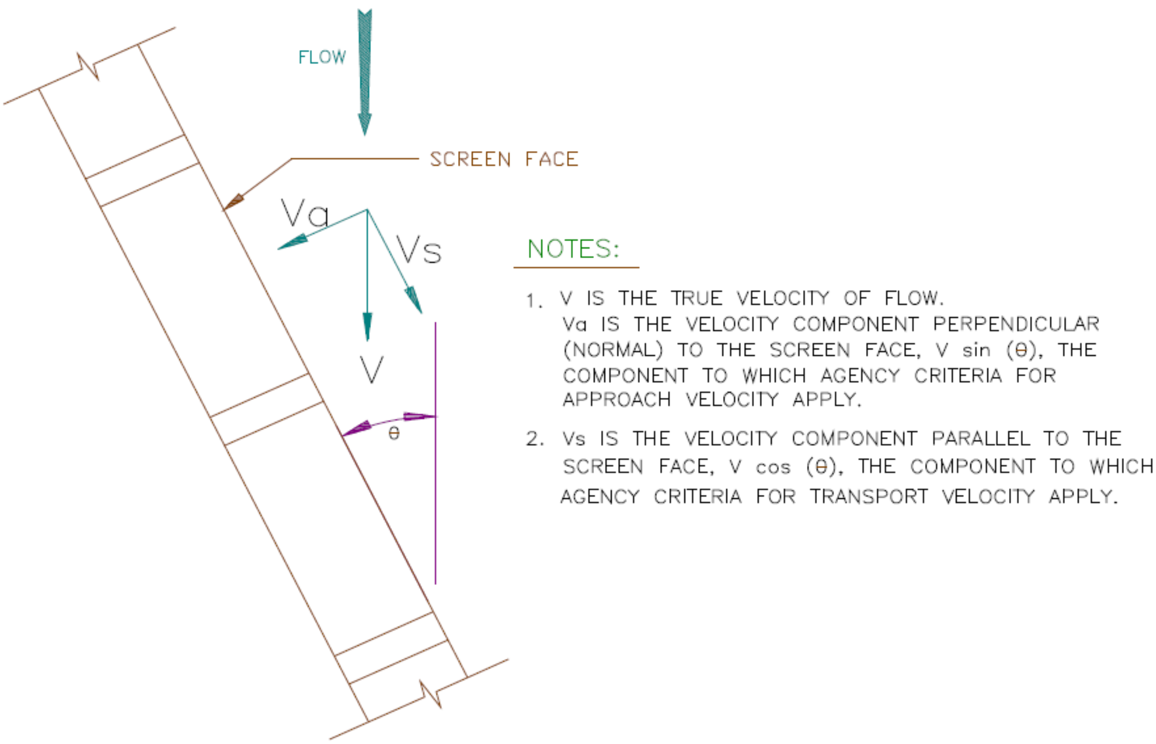

Figure 1. Incoming flow velocity and its components (Nordlund, 2008).

For this scoping level project funded by Bureau of Reclamation’s (Reclamation) Science & Technology Program, a brief summary of typical screen materials and screen types is presented and information on applicability of cleaning with an air burst or water jet system is discussed. In addition, a list of Reclamation fish screen projects where the Technical Service Center (TSC) has been involved with design or modifications is included.

Screen Fabrics

The physical screen that separates the fish and debris from the water diversion is typically constructed from stainless steel or aluminum (although coated steel, copper and synthetic materials may also be used) in one of the three following patterns: woven wire, perforated plate and wedge-wire (also called profile bar). Federal regulatory criteria state that the openings in the screen shall not exceed 3/32 inch (2.38 mm) for woven wire and perforated plate and 1.75 mm (0.0689 inch) for wedge-wire unless fry sized salmonids are not present at the site (NMFS 1997). Figure 1 shows images of each of the common patterns of screen material. A study performed on the Sacramento River to compare the different screen fabrics to relative rates of clogging showed that it took perforated plate 1.5 times longer to clog and wedge wire 3 times longer to clog than woven wire (Smith, 1982).

Selection of the screen fabric is a consideration of cost, durability, structural design and ease of cleaning for the facility being designed. A discussion of the advantages and disadvantages of screen fabrics can be found in *Fish Protection at Water Diversions* (Reclamation 2006). Woven wire while relatively inexpensive is the least common due to the texture created by the weave and square openings with sharp corners that can catch debris. Perforated plate is widely used and has the benefit of being cost effective as well as a flat surface with round holes that are less likely to catch debris. Wedge-wire is ideal for fish screens since it has a smooth upstream face formed from triangular shaped bars that allows the effective slot size to enlarge once the flow enters the screen as shown below in Figure 2. The main disadvantage of wedge-wire is cost.


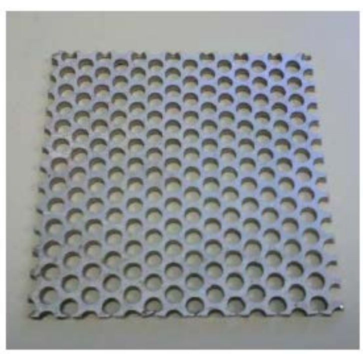


Figure 2. Screen material types. Woven wire (left), perforated plate (center), profile bar (right) (Reclamation, 2006).

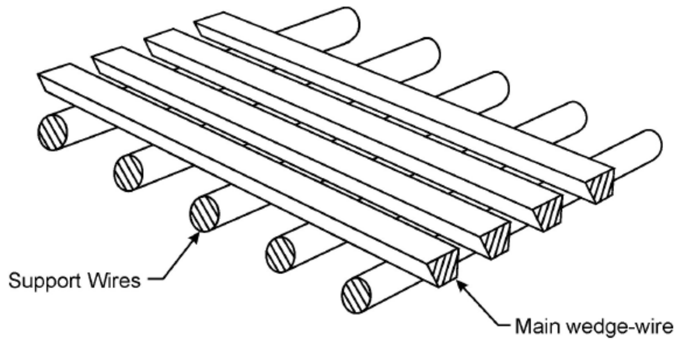

Figure 3. Detail view of wedge-wire screen (Reclamation 2006).

Screen Types

The selection of the structure type to be constructed occurs simultaneously with the screen material and pattern. Considerations to the design of the facility include location, constructability, access to utilities, diversion flow rate, species and life stage to be excluded, and operational criteria amongst others. Common types of fish screens include flat plate screens (vertical, inclined and horizontal), drum screens, traveling screens, and cylindrical screens. There are many other screen types (e.g., Coanda screens, cone screens, closed conduit screens) that are not covered by this scoping level research report, and additional information on these screens as well as more detail on the presented designs can be found in *Fish Protection at Water Diversions* (Reclamation, 2006)

Flat Plate Screens

Flat plate screens consist of a series of flat screen panels mounted to a structural frame. The screen configuration is often angled into the approach flow to allow the diverted flow to pass through the screen while the sweeping velocity carries fish and debris to the bypass (if included in the design). This screen type is adaptable, and can be installed in canals, rivers, and pools and in many positions (vertical, inclined and horizontal) with a range of water levels. The flat screen panels simplify the design for mounting cleaning systems, and is very common. Figure 3 and Figure 4 illustrate two types of flat plate screens.

Figure 4. Horizontal flat plate screen diversion (East Fork Ditch Company, ID).

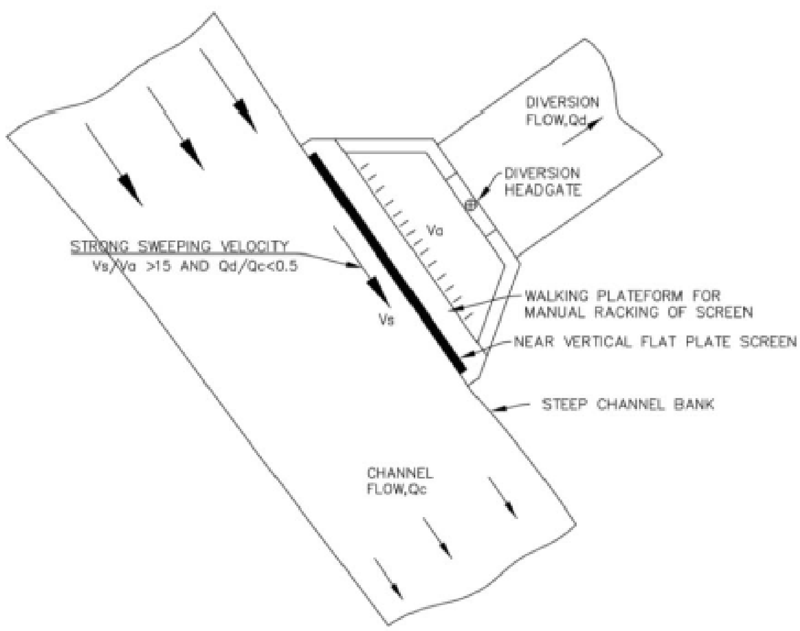

Figure 5. Schematic of a vertical flat plate screen diversion on a river bank (Mefford, 2013).

Drum Screens

Drum screens consist of a cylindrical frame covered in a screen material and rotate slowly on the horizontal axis. Water levels must be maintained such that the drum screen is 65% to 85% submerged, which allows debris to exit the water on the upstream face and be washed off on the backside from flow passing through the screen. Due to this requirement, drum screens are only suitable for locations where the water level is relatively stable which excludes in-stream locations. Similar to a flat plate screen, the axis of the drum is oriented at an angle to the flow to provide adequate sweeping velocity. Figure 5 shows how debris clearing works with a drum screen.

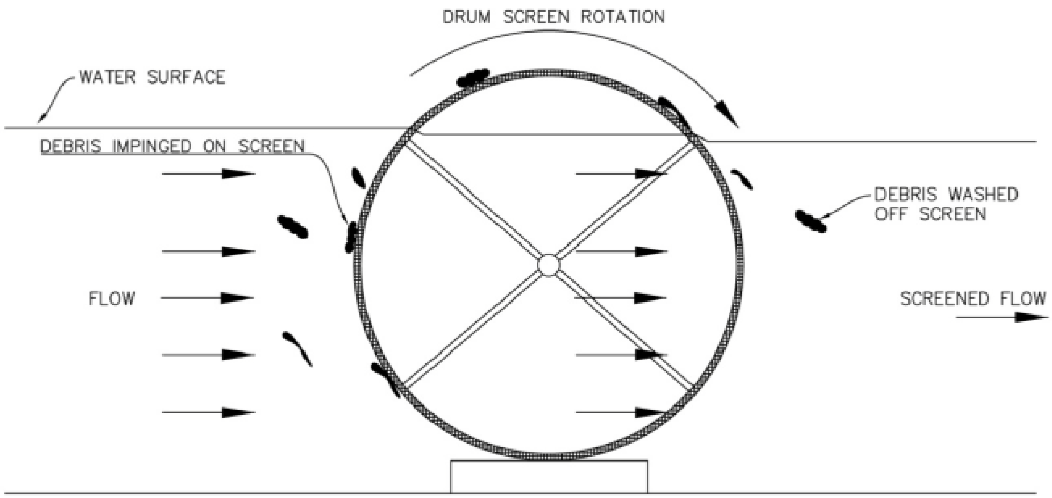

Figure 6. Drum screen profile view (Mefford, 2013).

Traveling Screens

Traveling screens are a continuous belt of screen material that is mechanically rotated to keep the screen clean. For durability, a majority of the mechanical drive system is installed above the water (everything except the lower bearing). Design of traveling screens can either be vertical or inclined, however flatter slopes are more likely to carry fish over the screen. Similar to flat plate and drum screens, traveling screens are installed to ensure that the sweeping velocity is high enough to minimize the amount of debris that collects on the screen. Sizing of a traveling screen is similar to a flat plate, and both are suitable for a range of water levels. Since the screen material moves in this design, a fixed brush can be used to provide cleaning. Figure 6 shows a traveling screen installation with a fixed brush from the Tracy Fish Collection Facility.

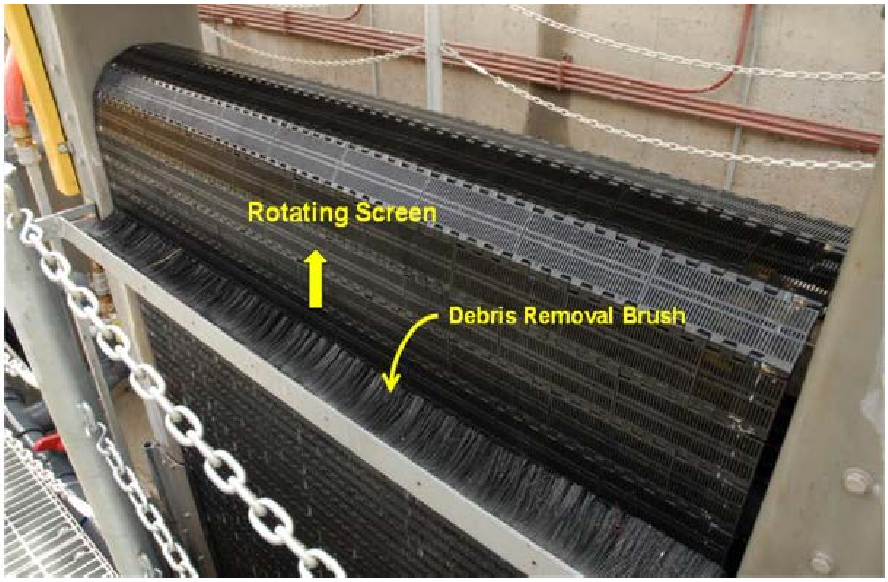

Figure 7. Traveling screen (Hydrolox Screens, Elmwood, LA).

Cylindrical Screens

Cylindrical screens are submerged screens that are typically installed on pump intakes in either lakes or rivers. They are commercially available which reduces cost and leads to these being the most commonly used screen type (Reclamation, 2006). Installation occurs with the screen length oriented parallel to the flow to ensure sweeping velocity is adequate, however too high of velocities can affect approach velocity uniformity. Since these have to be fully submerged to maintain adequate screen area, cylindrical screens need to be located a certain distance above the stream bed (to prevent entrainment of sediment), as well as below the water surface. Some designs incorporate internal or external brushes, air or water systems and can be incorporated with mechanical connection to rotate the screen.

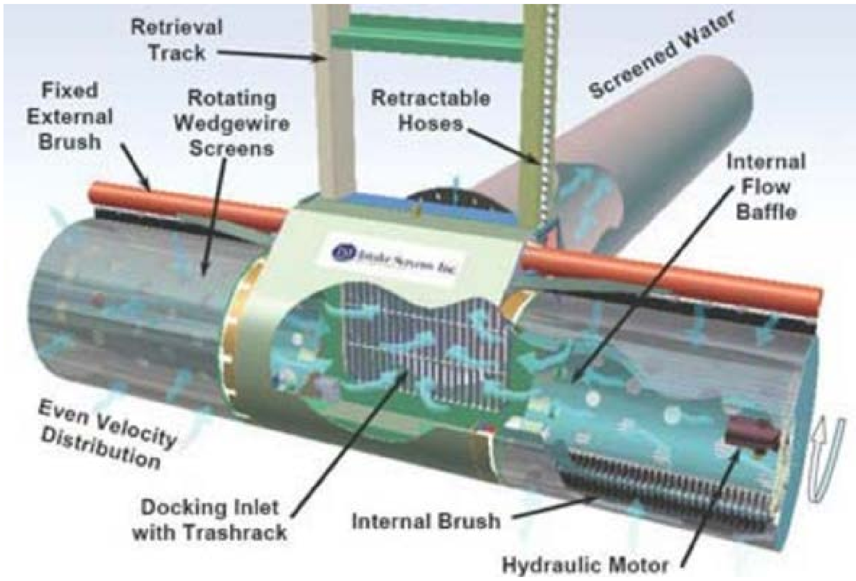

Figure 8. Cylindrical screen conceptual drawing (Intake Screens, Inc., Sacramento, CA).

Importance of Screen Cleaning

Since fish screens extract water from the water course, there is always the need to clean off any accumulated debris that is captured by the screen void space. As debris accumulates, head loss through the screen increases and can lead to velocities in other locations of the screen that exceed federal fish screening criteria (NMFS 1997). The process of debris accumulation on a screen surface is regulated, e.g. if leaf litter blocks a portion of the screen, this increases the velocity throughout the remaining open area of the screen and creates a greater likelihood of attracting more debris to the open area. The most effective cleaning for any fish screen is from the upstream to the downstream to allow the sweeping velocity to carry detached particles away from the recently cleaned screen panels.

In addition to debris that accumulates on the screen, biofouling may also occur when aquatic organisms (both plants (e.g. algae and sponges) and animals (e.g. mussels)) attach and grow on the screen material. While debris will only accumulate on the outside face of the screen, biofouling can block any location of the screen structure (e.g. external face, screen openings, and internal face). In locations where biofouling is present, an aggressive cleaning system that can clean both internal and external faces is recommended.

Most screens are designed to operate with a relatively narrow range of head loss through the screen before a cleaning cycle occurs, which is a function of the design and can range from a few inches to a few feet. If cleaning is delayed by either the timing of cleaning cycles or damage to the cleaning system, the hydrostatic force from this water surface differential can exceed the design strength of the screen or structural members and lead to damage of the facility. At the Soda Springs Dam fish screen, a minor flood event (1/50 Annual Chance Exceedance) brought enough debris into the diversion to overwhelm the system within 5 minutes by a head differential across the screen increase from 1 foot to over 11 feet when structural failure occurred. To prevent any future structural damage, Soda Springs has installed shear pins designed to fail and pivot two of the 22 screen panels once the head differential exceeds 2.5 feet. Figure 9 shows the screen forebay with the structural damage. Figure 9 shows a damaged cylindrical screen for a backwater section of the Sacramento River where suction load failed the screen (Hayes, 2000).

Regardless of the cleaning system utilized, the design must incorporate a route for the cleared debris to pass downstream once it is removed from the screen face. This can be as simple as cleaning panels from the upstream to the downstream direction to ensure the sweeping velocity carries removed particles away, to a complex conveyer belt and hopper system. Failure to account for debris escape will allow the debris to reattach to the screen panels and eventually overwhelm the system.

Figure 9. Screen damage on a flat plate screen from excess head pressure (Soda Springs Dam fish screen, Umpqua, OR).

Figure 10. Cylindrical screen damage
(Sacramento River, CA, Hayes, 2000).

Cleaning Methods for Fish Screens

Passive (no cleaning), air burst, water jet, and automated brush cleaning methods are assessed in this report. To evaluate these cleaning methods, the following four metrics were used.

- Mechanical complexity. Includes the effort of the design, installation and operation of a cleaning system's essential components
- Hydraulic impacts. Includes discussion of impacts to the flow and potential for creating turbulence either during operation or between cycles.
- Cleaning performance. Includes discussion on the ability of each method to effectively clean the screen. Much of this information is taken from selected dive reports from NMFS screen inspections.
- Fish impacts. Includes discussion on the biological impacts either during a cleaning cycle or between cycles.
- Operational impacts. Includes discussion on the cost, effort, maintenance, inspection and repairs necessary for the facility to operate effectively. Since costs are dependent on many factors, only generalizations are discussed, and is based on the additional cost for the cleaning system.

Passive Cleaning

Passive screens do not have a cleaning system, and should only be used for small diversion flows with low expected debris loads. While a majority of passively cleaned intake screens are for pumps, drum screens may also be passively cleaned due to their ability to pass debris downstream. Additional screen types that do not commonly have cleaning mechanism are

Coanda screens and horizontal flat plate screens. For fishery agencies to accept a passive screen pump intake design, the following must be verified (NMFS, 1997):

- Oversize the screen to minimize the chance of debris impingement, and
- Installed in a location with high sweeping velocity to reduce debris buildup, and
- Where the maximum diversion is 0.01% of the total minimum streamflow, or
- The intake is deep in a reservoir away from the shoreline

Mechanical complexity - No additional design required, or need for electrical & mechanical systems.

Hydraulic impacts **–** No additional impacts from the baseline design of the fish screen.

Cleaning performance **–** Poor. Screens must be removed or cleaned in situ manually by operators.

Fish impacts **–** No additional impacts from the baseline design of the fish screen.

Operational impacts- No additional costs for the design of the cleaning system. However, since there is no cleaning system, a passively cleaned screen will likely require more frequent inspections of the facility to ensure the screen is not fouled and manual cleaning may be required. Depending on access to the screen, divers may be required to enable cleaning.

Air Burst System

Air burst cleaning of a screen consists of timed release of pressurized air. The force and velocity of the expanding air lifts trapped particles from the screen as it ascends. Typically, air burst systems are used on cylindrical screens with either fixed or rotating installations. While these systems are not usually effective in cleaning fixed vertical or angled screens, systems have been successfully installed to prevent sediment from accumulating at the base of the screen which can reduce maintenance and repairs to an automated brush assembly. Typically, velocities through fish screening facilities are low to minimize the potential for fish injury. However, these lower velocities allow sediment to settle out of the flow and deposit in front of and within the fish exclusion facility.

The critical components of this type of system are the air compressor and receiver (storage) tank. Automated solenoid valves control timing and duration of discharges for airburst systems and are typically cycled to clean a section of between 1 to 3 screen panels on each air charge. Power demands are typically lower than a similarly sized water jet system. Large receiver tanks can be used to offset power requirements by being paired with a smaller compressor whilst still providing adequate supply for the fish screen cleaning.

Mechanical complexity **–** The design needs to incorporate an on-site structure to house the compressor and receiver tank. Airline plumbing to the screen is typically by hard pipes, but can be with flexible lines if the air nozzle is not stationary. Systems must also have electrical supply for the compressor and solenoids. Baffle configuration may need to be altered to account for plumbing associated with air burst systems, and to ensure the air patterns are optimized on the screens. For any rotating screen installations, the piping must be fed through the axis of the drum and routed to the edge of the screens, in addition to dealing with the constant rotation of the screen.

***Hydraulic impacts* –** During cleaning cycles which typically last less than 1 minute, the approach and sweeping velocities at the screen face are significantly altered. The expanding air will rapidly rise to the top of the water column creating a large amount of turbulence and will bring anything in its path with it as shown below in Figure 10. Depending on the relative proportion of screen panels being cleaned, the diverted flow rate may decrease during the cleaning cycle as the expanding air locally reduces the screen approach velocity. It is uncertain if the approach velocity at other screen panels would be increased while an adjacent panel is being cleaned.

***Cleaning performance* –** Air burst plumbing is typically contained within or behind screen assemblies and does not create any additional instream turbulence when a cleaning cycle is not being performed. For stream entrained debris, air burst systems generally work well for areas that the expanding air passes. While these are mostly installed on cylindrical screens, the systems do not provide effective cleaning on parts of the screen below the air nozzles. Air burst cleaning does not always clear all debris leading to preferential air passing through already open areas of the screen. The air burst system is ineffective at removing biofouling from screen panels, and leads to the prevalence of different species of aquatic growth (NMFS dive reports). Air burst systems are able to prevent sediment from accumulating in certain areas and can be used to direct where sediment will settle. Wilkins Slough Pumping Plant uses an air burst system to reduce sedimentation at the screen, and allows it to deposit in an area upstream of the pumping plant which is easier to access and dredge at the end of the pumping season (Vermeyen 1996). In addition to air bursts to clean screens, bubble curtains which use a lower volume and pressure of air have been used successfully around cylindrical screens to prevent debris from attaching to the screen (personal communication Rick Christensen). Air nozzles are normally located at the bottom of the screen to allow cleaning as the air travels upwards. With a short cycle time, debris that is lifted may not fully clear the downstream extent of the screen depending on the sweeping velocity. Laboratory tests on an air burst cleaned cylindrical screen found that two air cycles with a short gap in between were effective at cleaning the screen (Mefford, 1997).

***Fish impacts* –** Air bursts create turbulent flow conditions without warning which may be stressful or damaging to fish in proximity to the screen.. No studies directly related to the impacts of air burst screen cleaning systems on fish were found during the literature review; however, studies have been accomplished on the effects of seismic water cannons and air guns used as fish deterrents. Pulsed pressure waves from underwater air guns can emit acoustics that are damaging or lethal to fish, particularly fish with swim bladders (USACE 2013). In addition, fish migrating along the screen face may be delayed in finding the bypass channel and exit the screened area during air burst cleaning cycles. There is also potential that the sudden influx of expanding high pressure air could alter the oxygen saturation levels in the affected area (personal communication with Jason Wagner).

Operational impacts- Fish screens cleaned by an air burst system will add some additional maintenance. The air plumbing, nozzles and solenoids will require inspection and potentially cleaning when the facility is dewatered, as well as observations during operation to ensure no deficiencies are found. Costs associated with an air burst system include the compressor and receiver tank, and are not expected to be as high as a water jet system.

Figure 11. Air burst cleaning at Reclamation's Princeton Pumping Plant (Princeton, CA).

Water Jet System

Water jet cleaning systems use pressurized water to create high velocity spray that clears debris from the screen face. For this system to be effective for primary cleaning, the spray pattern must cover the entire surface of the screen and is typically used on rotating screen assemblies above water. Systems installed below the water line were investigated, but performed poorly (Smith, 1982). While more complicated, nozzles can be installed on a rotating frame or a movable arm to clean a fixed screen panel. Water jet systems are also used to prevent sediment from depositing in certain locations of a screening structure.

The critical components of this type of system are the water pump and power necessary to drive the water pump. A sump may be necessary depending on the installation and facility layout. The spray nozzle is held close to the screen, typically only a few inches away from the screen, and is operated at a pressure of between 30-100 pounds per square inch. This allows the water discharge from the nozzles to reach the screen before the energy is dissipated. Power requirements for the water jet systems tend to be higher than comparable air burst systems due to the density of water, flow rate requirements, and the inability to utilize compressed storage.

***Mechanical complexity* –**Plumbing requirements for water jet systems are similar to air burst systems, with the exception that the nozzles are likely to be positioned closer to the internal screen face. Power requirements and costs are higher due to the pump system.

***Hydraulic impacts* –** Water jet plumbing is typically contained within or behind screen assemblies and does not create any additional instream turbulence when a cleaning cycle is not being performed. The high velocity jets of the spray nozzles will create a localized zone of disturbance that will be much smaller than the turbulence created by an air burst. Since the impact zone of the water jet is likely small compared to the area of the screen, it would be unlikely that the diverted flow rate would change during water jet cleaning cycles.

***Cleaning performance* –** During the cleaning cycle, which can either be continuous or cyclical, debris removed from the screen may reattach further downstream. Water jet designs can be arranged vertically to clean from upstream to downstream, but are often installed horizontally as the screen travels vertically. This can allow the removed debris to reattach in previously spray cleaned areas further downstream. For installations either above or below the water, a strong sweeping velocity is needed to prevent cleared debris from reattaching to the screen. Water jet systems installed above water to clean a traveling screen have been very successful at removing debris as well as some biofouling. Cooperative research performed by Reclamation and United States Forest Service with California Department of Fish and Game and California Department of Water Resources studied different pressures and distances of the nozzles from the screen and concluded that screens are most effectively cleaned when the water jet is above the water surface (Smith 1982). Screen cleaning by water jet is not common in Reclamation and is only used as a primary cleaning system for two traveling screen facilities. Designers in the Mechanical Equipment group at Reclamation have been warned that it is difficult to make water jet cleaning systems work well, and very high flow rates to the nozzles are required for a successful installation. Water jet systems that are used to prevent sediment from accumulating either in front of the screen or behind the screen have also been effective at maintaining a clear path near the nozzle.

***Fish impacts* –** While the impact zone for the water jet will be smaller than that of the air burst, the potential damage to any fish present in the zone upon onset may be higher due to the greater density of water if the system is operated cyclically. If the system is continuously operated, fish would likely avoid the zone of turbulence created by the water jet. Acoustic impacts may also be detrimental to fish during operation of the water jet either continuously or cyclically (USACE, 2013). For any water jet system installed above the water level, no impacts to fish would be expected.

***Operational impacts*-** Water jet cleaning systems require a high volume / high pressure which will likely require additional inspection and maintenance than a comparably sized air compressor. Depending on the size of the nozzles, an additional screen or filter may be required to prevent plugging of the nozzles from the supply water. This system will also require inspection during dewatering. Costs are expected to be slightly higher for the pump as compared to an air compressor, and electricity costs may also be higher depending on if the system is operated continuously.

Automated Brush Cleaning System

Cleaning fish screens with an automated brush is the standard method that is utilized at a majority of sites with debris concerns. Information is presented here to compare brush cleaning with air burst and water jet systems. Brushes can be designed to clean either the external or internal screen faces and are the best method for removing biofouling on screen faces.

Mechanical complexity **–** Brushes are normally attached to a rail and pulley system at the top of the screen and utilize a lever arm that uses the weight of the arm to apply brush pressure onto the screen face. This is a relatively simple design that keeps most of the mechanical connections above the water. On-site electrical power is required for the motor operator of the brush system.

Hydraulic impacts **–** Brush systems protrude from the screen face and create a zone of turbulence both upstream and downstream of the brush cleaner location. The extent of the zone depends on the size and shape of the brush and mast arm that holds the brush as well as the sweeping velocity along the screen face. Ramps which move the brush head away from the screen face to prevent the brush bristles from becoming flattened during non-cleaning cycles can also alter hydraulic conditions. Ideally, the brush ramps for storage would be located on the downstream end of the screen, some distance from the last screen panel to prevent hydraulic impacts. Reclamation's hydraulic laboratory has studied impacts from the brush cleaning assembly at Red Bluff Pumping Plant with both numerical models (Figure 11) and in-situ validation. These tests resulted in altered hydraulic conditions 4 feet upstream of the brush arm, and over 6 feet downstream for a sweeping velocity of approximately 2.5 feet per second during field testing (Vermeyen, 2013).

Cleaning performance **–** Brush cleaning is the best method for cleaning screens. If the brush is operating correctly, both debris and biofouling can be cleared from the screen face. Brush maintenance and replacement is required for the systems to operate correctly as the bristles become worn or damaged. In addition, the brush alignment is critical in the ability to clear the screen. Figure 12 shows a brush misalignment, and the resultant screen section that is not being cleaned properly.

Fish impacts **–** The brush arm creates an area of turbulence that extends both upstream and downstream of the arm. While the numerical model in Figure 12 shows the turbulence zone, the brush arm is either stationary while stored, or moves slowly during its cleaning cycle and fish can likely sense the flow disturbance and avoid it if possible. Smaller fish that cannot avoid the turbulence may become disoriented.

Operational impacts- An automated brush will likely require a greater amount of maintenance and inspection than either the air burst or water jet system due to the moving arm and brushes of the cleaning assembly. The motor and drive mechanism will also require inspection and adjustment, but since this is out of the water, access to it does not require dewatering. To ensure optimal operation, the cleanliness of the screen needs to be inspected which may be visualized from above the water surface, but it will likely need a dive inspection as well. Power requirements for the brush arm motor are likely comparable to the water jet system, but may be high for large brush assemblies depending on any potential gear reduction. Costs for this system are likely higher than the water jet or the air burst due to fabrication of the brush arm and pulley system.

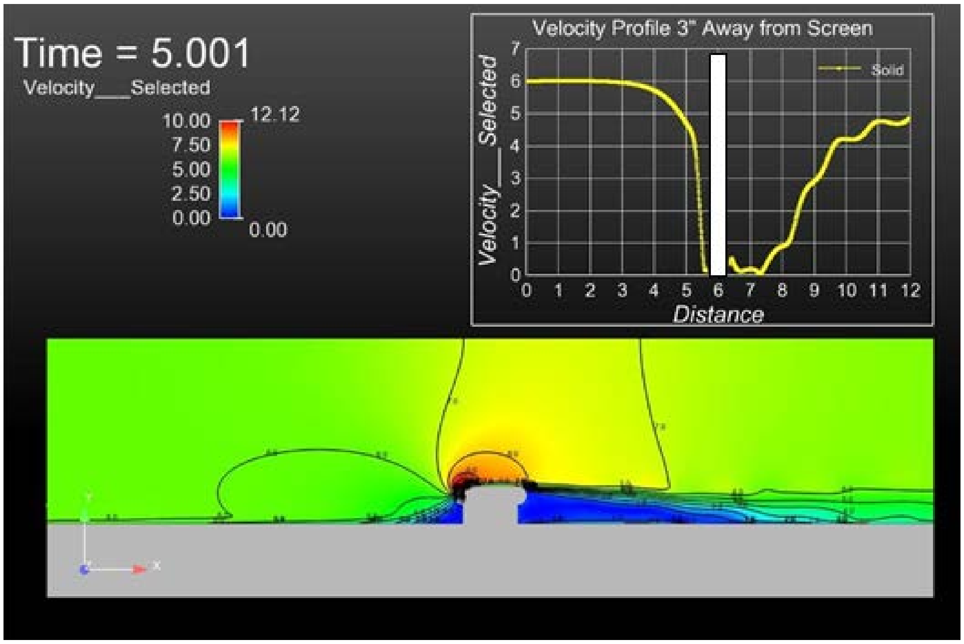

Figure 12. Results of 2-D computational fluid dynamics (CFD) model for a brush cleaner mast assuming a solid fish screen panel. The bottom graph shows expected velocities near the brush cleaner arm (upstream is to the left). The white rectangle in the upper graph shows the location of the brush cleaner. Flow disturbance can be seen approximately 3 ft. upstream (left) and for over 6 ft. downstream (right) of the brush arm.

Figure 13. Brush misalignment from a NMFS dive inspection showing a section of fish screen that is not being cleaned properly (Natomas Mutual Water Company, Sankey water intake and fish screen, Natomas, CA).

Fish Screen Inventory

The following list is a partial inventory of Reclamation fish screen facilities that have either an air burst or water jet as a primary cleaning system (provided by Mechanical Equipment group (8410) at Reclamation’s TSC). Note that every system that uses a water jet is a traveling screen and the jets are used to clean the screen above the water surface.

Table 1. Partial inventory of Reclamation facilities designed by the TSC with either air burst or water jet cleaning systems.

Project	**Screen Type**	**Air Burst Cleaning System**	**Water Jet Cleaning System**
San Justo Dam, Hollister Conduit Outlet Works	Profile wire screen, half a cylinder shaped screen	X	
Chandler Canal Fish Facilities, Secondary Pumpback Structure	Traveling water screens modified to be traveling fish screens		X
Roza Diversion Dam Fish Facilities, Secondary Pumpback Structure	Traveling water screens modified to be traveling fish screens		X
Three Mile Falls Diversion Dam Left Bank Fish Facilities, Secondary Pumpback Structure	Traveling fish screen		X
Oroville-Tonasket Pumping Plants: Bonaparte, Ellisford, East Tonasket, Cordell, and Crater Lakes	Profile wire, cylindrical tee screens	X	
Osoyoos Pumping Plant	Profile wire, cylindrical tee screens	X	
Diamond Creek Dike Pumping Plant	Profile wire, cylindrical tee screens	X	
Evansville Water Plant Modification	Profile wire, cylindrical tee screens	X	
Columbia River Pumping Plant	Profile wire, cylindrical tee screens	X	
Nimbus Fish Hatchery Water Supply Intake	Traveling water screen		X
Clear Lake Dam Modifications	Profile wire fish screens – flat panels installed in vertical guides		Manually remove screen panels and clean using pressure wash
Lilley Pumping Plant	Traveling fish screens		X
Savage Rapids Pumping Plant	Profile wire fish screens – flat panels inclined at 26.6 degrees from horizontal	X	
Chiloquin Dam Fish Screen Structure	Profile wire fish screens – flat panels inclined at 25 degrees from horizontal	X	
Coleman Fish Hatchery – Intake 3	Traveling fish screens		X
Tracy Secondary Louver Replacement	Traveling fish screens		X

Note: “Profile wire may be wedge wire, vee wire or profile wire depending on the screen company that received the contract.

Note: All water jet cleaning (except as noted for Clear Lake) is accomplished above the water surface by rotating the screening fabric past an internal spray bar cleaning system that sprays and deposits debris into a downstream conveyor system or sprays the debris back upstream to be carried away by the sweeping velocity.

Knowledge Gaps

Research performed for this investigation of screen cleaning methods resulted in a few notable knowledge gaps that could be researched to improve the state-of-the-practice. Currently, there is no published research that studies the behavior of fish during any cleaning cycle (e.g., air burst, water jet or automated brush). There is, however, literature related to how fish respond to acoustics and rapid changes in turbulence that may be able to be applied. Estimates of fish behavior for this report were based on personal communication with Jason Wager, hydraulic turbulence and the rapid onset of the cleaning cycle and will likely be supported by future research.

In addition, air burst and water jet systems are designed on rules of thumb and what has worked at other facilities. Air burst systems are designed from a mechanical aspect where the pressure of the initial charge of air is a function of the storage volume of air required for the duration of the cleaning, and the pressure ratings of the receiver tank. No studies have been performed to determine what air pressure results in optimal cleaning and how this changes when the depth of the system (resisting head pressure) is varied. Additionally, while it is understood that water jet nozzles need to be located in close proximity to the screen face, no research was discovered to determine the optimum spacing of air burst nozzles from the screen face.

Conclusions

While there are some data gaps on the optimization of designs for both air burst and water jet cleaning systems as well as biological studies performed to document fish behavior with the two systems, the research performed for this scoping level project indicates that the use of an automated brush cleaner system is preferred over a water jet or an air burst system on a flat plate screen.. While a brush cleaner will benefit a cylindrical screen, this is the one application that can typically be effectively cleaned with the air burst system alone. Similarly, traveling screens that exit the water can be effectively cleaned with a water jet system. In terms of each of the 4 metrics evaluated, the automated brush system contained the least complex mechanical design and performed the best in cleaning screens. The brush arm does protrude into the channel and create turbulence, but the turbulence is a function of the brush arm shape and does not create sudden changes in turbulence since it remains in the water. In addition, the steady state of turbulence is likely much less of an impact to fish than the rapid air or water pressure delivered to start a cleaning cycle by the air burst or water jet cleaning systems.

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