

# RECLAMATION

*Managing Water in the West*

Hydraulic Laboratory Technical Memorandum PAP-1080

## Integration of High-Pressure Jets & Automated Trashrack Cleaners for Mussel Removal



U.S. Department of the Interior  
Bureau of Reclamation  
Technical Service Center  
Hydraulic Investigations and Laboratory Services Group  
Denver, Colorado

December 2013

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# Integration of High-Pressure Jets & Automated Trashrack Cleaners for Mussel Removal

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The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

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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.

## **Acknowledgments**

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## CONTENTS

INTRODUCTION .....	3
LITERATURE REVIEW .....	4
FACILITY REVIEWS.....	5
Backhoe Style Rake on Deck Rails .....	5
Cable Style Rake and Gripper Head on Overhead Monorail.....	6
Cable Style Rake on Rails .....	7
Hydraulic Rake (Hand Rake Style) with Support Structure .....	7
CONCEPTUAL DESIGN & SIZING .....	8
CONCLUSIONS.....	11
REFERENCES .....	12

## TABLES

Table 1 - Dimensions for the trash rack cleaners at the Tracy Fish Collection Facility and the Central Arizona Project.....	9
Table 2 - Summary of losses and pump requirement for both the Tracy Fish Collection Facility and the Central Arizona Project. ....	10

## FIGURES

Figure 1 - Average RMS impact pressure results for mussel removal and coating damage (Mortensen, 2013). ....	4
Figure 2 - Backhoe style rake on deck rails at the Roza Dam trashrack .....	5
Figure 3 - Cable Style Rake and Gripper Head on Overhead Monorail on the Central Arizona Project.....	6
Figure 4 - Cable style rake on rails (image courtesy of lakeside-equipment.com).....	7
Figure 5 - Hydraulic rake (hand rake style) with support structure (image courtesy of AtlasPolar.com). ....	8
Figure 6 - Dimensional annotation for the trash rack and trash rake.....	9
Figure 7 - Sundyne HMP pump curves.....	11

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# Introduction

Quagga mussels (*Dreissena rostriformis bugensis*) were first noticed in the Lower Colorado River at Lake Mead on January 6, 2007. Directly following this discovery, the Bureau of Reclamation's Lower Colorado Region began to monitor and gather information on the mussel's spread, survival, and the extent to which it might damage and disrupt water supply and power generation facilities. Even with the extensive knowledge and expertise gained regarding mussel infestation, Reclamation is still challenged with managing the infestation of this species at many of their facilities.

In particular Parker Dam, on the border of California and Arizona, has seen overwhelming populations of Quagga mussels. In early 2008, mussel colonies fouled generator seals and plugged the dam's domestic water line. In addition, large numbers of mussels can be found on gate structures and trashracks. These problems have been compounded by larger than normal aquatic weed loads at the intake to Mark Wilmer Pumping Plant, the intake structure to the Central Arizona Project (CAP). It is suspected that mussel impacts have significantly increased water clarity which has boosted aquatic weed production. Hence, Reclamation is in need of technology that satisfies both aquatic weed and mussel removal requirements.

Currently, many installed gate structures and trashracks covered with mussels and aquatic weeds are cleaned with either mechanical rakes or high-pressure washes. Unfortunately, both of these methods have limited effectiveness when used independently.

When mechanical raking is utilized to remove mussels, only those mussels that come into contact with the rakes are removed. As a result, areas of grates that are un-raked are continuously exposed to mussel settlement and adherence. With trashracks, this includes the sides of vertical or horizontal slats and any tail edges. Mussels that adhere to these surfaces become difficult to remove without disassembling the racks and using some other mechanical method or a high-pressure wash.

When using high-pressure water jets to clean trashracks and gated structures, it is usually necessary for that the structure being cleaned is removed from the water. This includes either draining the supply water to expose fouling or disassembling and removing the structure. Both options cause large operational burdens to Reclamation facilities.

This report investigates the feasibility of combining automatic trashrack cleaners with high-pressure water jets to remove and prevent mussel fouling by considering these questions:

1. Can high-pressure water jets be used to remove mussels from surfaces they have attached to, and if so, what pressure is required to remove them?

2. If removal is possible, how can high-pressure water jets and automatic trashrack cleaners be combined to remove mussel fouling?

This work was divided into several phases. Phase 1 included a literature review. Phase 2 included a comprehensive review of what trashrack cleaners are often utilized at Reclamation facilities and what is currently being done to mitigate mussel fouling. Phase 3 included developmental sizing and design of an integrated high-pressure wash trashrack cleaner and pumping system.

## Literature Review

This work was correlated with S&T Project 1740 which defined operating criteria for mussel removal using high-pressure jetting. Project 1740 determined the limits of using high-pressure jets to remove mussels without damaging underlying material coatings (Mortensen, 2013). Mortensen tested 14 different material coatings and determined that pressures between 16.3 and 18.4 psi would remove mussels without damaging the coatings. Figure 1 provides a chart with all the materials tested and the suggested operational range for mussel removal.

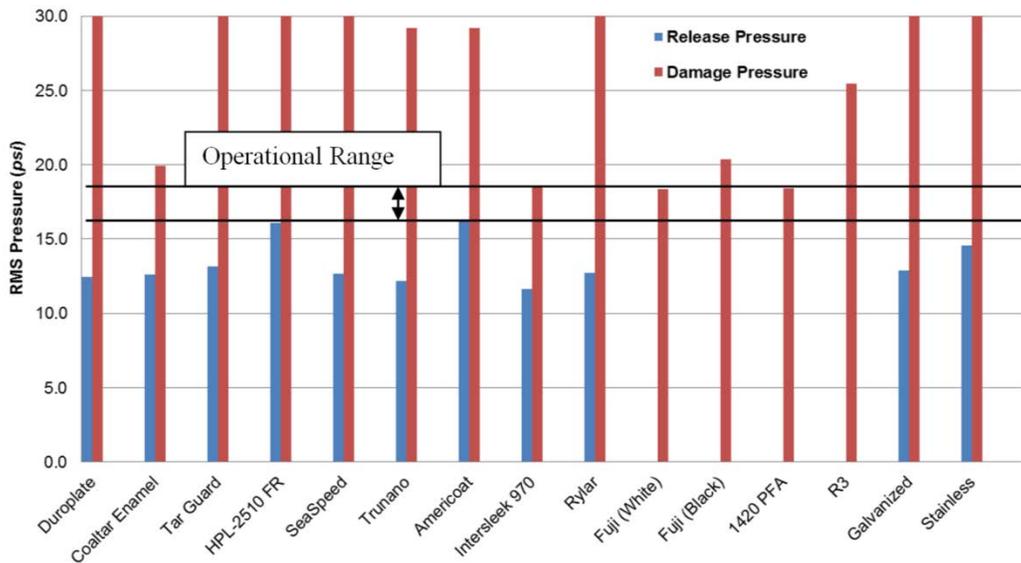


Figure 1 - Average RMS impact pressure results for mussel removal and coating damage (Mortensen, 2013).

Mortensen (2013) also provided two equations for calculating the impact pressure a submerged high-pressure water jet would apply to a surface based on several parameters, including nozzle diameter, distance from nozzle to surface, and the velocity at the nozzle. Equations were presented for both fan and circular (spot) jets. The data developed by Mortensen provided researchers with valuable information needed to design an integrated pressure washing system. Many other papers were reviewed during this project but are not presented as they were

extensively covered in Mortensen's (2013) work and provided little additional benefit to the development of this project.

## Facility Reviews

Researchers scoured documents and visited several Bureau of Reclamation facilities to select a trashrack cleaning system that is both widely used on Reclamation facilities and could possibly be retrofitted to accept high-pressure jets. Several different types of trashrack cleaners were found and an extensive list of pro's and con's for many of them are available in a separate publication (Wahl, Christensen, & Grush, 2008).

### Backhoe Style Rake on Deck Rails

Backhoe style rakes mounted on deck rails (Figure 2) can be operated both manually and automatically. The rake resembles a backhoe body and arm with a claw gripper on the end to allow debris to be scraped from trashrack bars. The backhoe body is mounted on a deck rail system that allows the claw to easily align with the face of the trashrack. Debris is removed by extending the backhoe arm in front of the trashrack and lowering it into the water until the cleaner is against the trashrack. Cleaning is achieved as the backhoe arm is raised while maintaining contact with the trashrack and removing debris. Once debris is removed from the trashrack the backhoe can pivot to dump the debris into a truck or pile adjacent to the trashrack. Some locations where these systems are currently used include the Broadwater Power Station, Tosten Dam in Montana, a fish screen near Palisades, CO, Roza Dam and Smalley trashracks near Yakima, WA, and the Olympus Dam canal intake near Estes Park, CO.



Figure 2 - Backhoe style rake on deck rails at the Roza Dam trashrack

## Cable Style Rake and Gripper Head on Overhead Monorail

Cable style rake and gripper head cleaners (Figure 3) are typically designed to operate automatically by lowering a hydraulically controlled debris gripper suspended from cables down the face of the trashrack. Debris is gripped and removed from the trashrack and transferred back to a designated location. The gripper is mounted on an overhead monorail track. Some locations where these systems are currently used include the Headgate Rock Dam, AZ; Central Arizona Project lift stations; Clifton Court Fish Facility, Byron, CA; Tracy Fish Collection Facility, Byron, CA; and the A-canal, Klamath, OR.



Figure 3 - Cable Style Rake and Gripper Head on Overhead Monorail on the Central Arizona Project.

## Cable Style Rake on Rails

Cable style rakes on rails (Figure 4) can be designed to operate in automatic or manual mode. Trashracks are cleaned one section at a time by lowering a debris gripper, attached to cables, down the face of the trashrack and retrieving debris when it returns to the surface. Debris can be collected by a cart or conveyor that is located near the cleaning mechanism. This style of rake is used at Imperial Dam, AZ.



Figure 4 - Cable style rake on rails (image courtesy of lakeside-equipment.com)

## Hydraulic Rake (Hand Rake Style) with Support Structure

Hydraulic rakes (Figure 5) imitate the action of raking a structure by hand. A large hydraulic arm lowers a rake in front of the trashrack. Debris is collected when the cleaner is positioned against the trashrack (at the bottom) and moved up the face of the trashrack. Debris can be collected on a deck or conveyor above the trashrack. This type of rake is used at New Waddell Pumping Plant, Phoenix, AZ; Grand Valley Irrigation District, Grand Junction, CO; and several screens near Yakima, WA.



Figure 5 - Hydraulic rake (hand rake style) with support structure (image courtesy of AtlasPolar.com).

## Conceptual Design & Sizing

Researchers determined that several of the systems could be retrofitted to accept a pressure washing system. After discussions with other engineers and facility operators, it was determined to focus efforts on integrating high-pressure jets to a cable style rake and gripper head on an overhead monorail. This choice was influenced by the fact that many Bureau facilities are moving towards this method for trashrack debris removal. Two sites that currently use this type of cleaner are the Tracy Fish Collection Facility (TFCF) near Byron, CA and the Central Arizona Project (CAP) pumping stations near Phoenix, AZ. Conceptual designs for both the TFCF and CAP were investigated. Figure 6 depicts a sectional view of a typical cable style rake and gripper head with dimensional annotation. Table 1 provides the dimensional assumptions for each site.

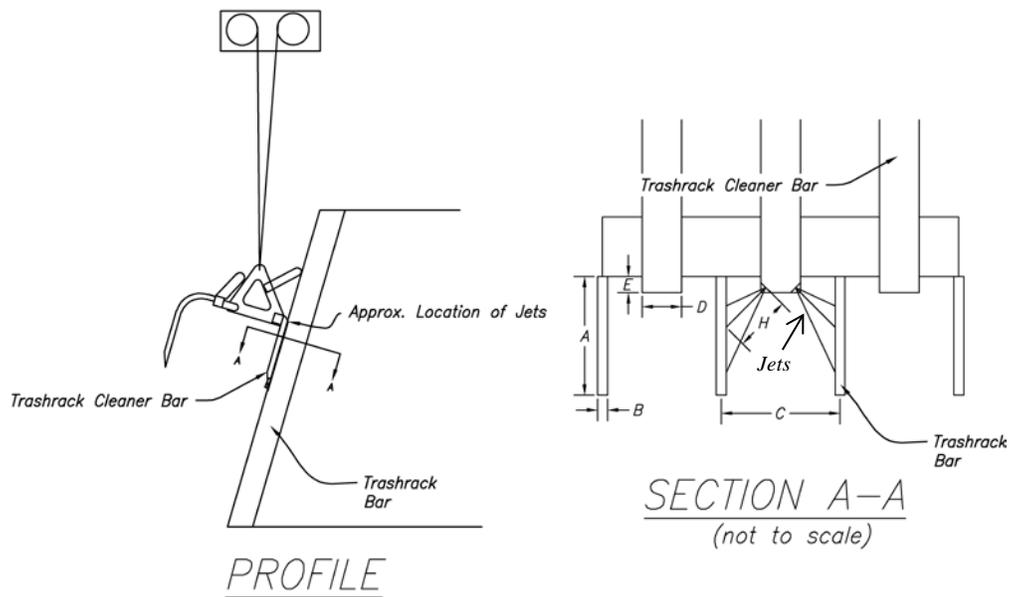


Figure 6 - Dimensional annotation for the trash rack and trash rake.

Table 1 - Dimensions for the trash rack cleaners at the Tracy Fish Collection Facility and the Central Arizona Project.

Trash Rack Bars	TFCF	CAP	Dimension in inches
Length	3.0	4.0	A
Width	0.5	0.625	B
Space between	2.625	6.625	C
<b>Trash Rake Bars</b>			
Quantity	51	20	
Width	0.79	0.75	D
Overlap	0.39	0.75	E
<b>Jet Nozzles</b>			
Quantity	100	38	
Min length to contact	1.20	2.97	$H_{min}$
Centerline length to contact	1.54	3.36	$H_{CL}$
Max length to contact	2.58	4.47	$H_{max}$
Avg. length to contact	1.77	3.60	$H_{avg}$

Other assumptions for both facilities include:

- Required impact pressure: 17.0 psi @  $H_{avg}$
- Jet Nozzle: 0.060 inch diameter 40 degree fan
- Darcy Weisbach equation used for loss calculation
- No static lift
- Swamee-Jain equation used for friction factor

- $P_1=P_2$ ,  $z_1=z_2$ ,  $v_1=v_2$  at surface entrance and exit, Where P=pressure, z=elevation, v=velocity.
- Losses are equal in parallel main and branch hose lines

The layout assumptions for each site are similar. A high-pressure, low-flow pump will be located near the overhead monorail. Water will be pumped through a high-pressure hose to a pressure jet manifold that aligns the high-pressure jets on each cleaner bar as shown in Figure 6. As the cleaner & jet manifold are lowered into the water to clean the trashrack, retractable cables and high-pressure hoses will keep the jets operational. The depth of the trashrack will dictate the length of retractable hosing needed.

For each site, assumptions on the length of high-pressure hose were determined based on site geometry. The TFCF will require about 170 ft of hose and the CAP will require about 410 ft of hose. Several different hose sizes were used to determine pump requirements. The two main sources of head loss for both sites were the high-pressure jets (nozzle) and friction in the high-pressure hoses (hose). Table 2 provides a summary of the hose sizes and the approximate losses in each system for the hose sizes analyzed. Also presented are the required pump pressures, flowrate (or discharge) and horsepower required for the system.

Table 2 - Summary of head loss and pump requirements for both the Tracy Fish Collection Facility and the Central Arizona Project.

	<b>TFCF</b>			<b>CAP</b>		
Main hose ID (IN)	4"	2"	1.25"	4"	2"	1.25"
Nozzle Losses (FT)	1,841	1,841	1,841	7,562	7,562	7,562
Hose Losses (FT)	708	886	2,803	423	685	3,441
Other Losses (FT)	74	122	415	44	69	246
Total Dynamic Head (FT)	2,623	2,849	5,059	8,029	8,316	11,249
Pressure (PSI)	1,137	1,234	2,192	3,479	3,603	4,874
Flowrate (GPM)	235	235	235	181	181	181
Horsepower (HP)	244	265	471	576	596	807

Sundyne HMP pumps were selected as examples of high-pressure, low-flow pumps that meet system requirements. Figure 7 provides a pump curve for the Sundyne HMP pumps. By plotting the flow and total dynamic head required, all configurations for both sites are able to use these pumps. These pumps are large and require significant power to operate, which may make them difficult to use at some sites. In addition, the hose required to withstand up to 5000 psi will be rigid, which may make it difficult to coil and move with the trash rack cleaner.

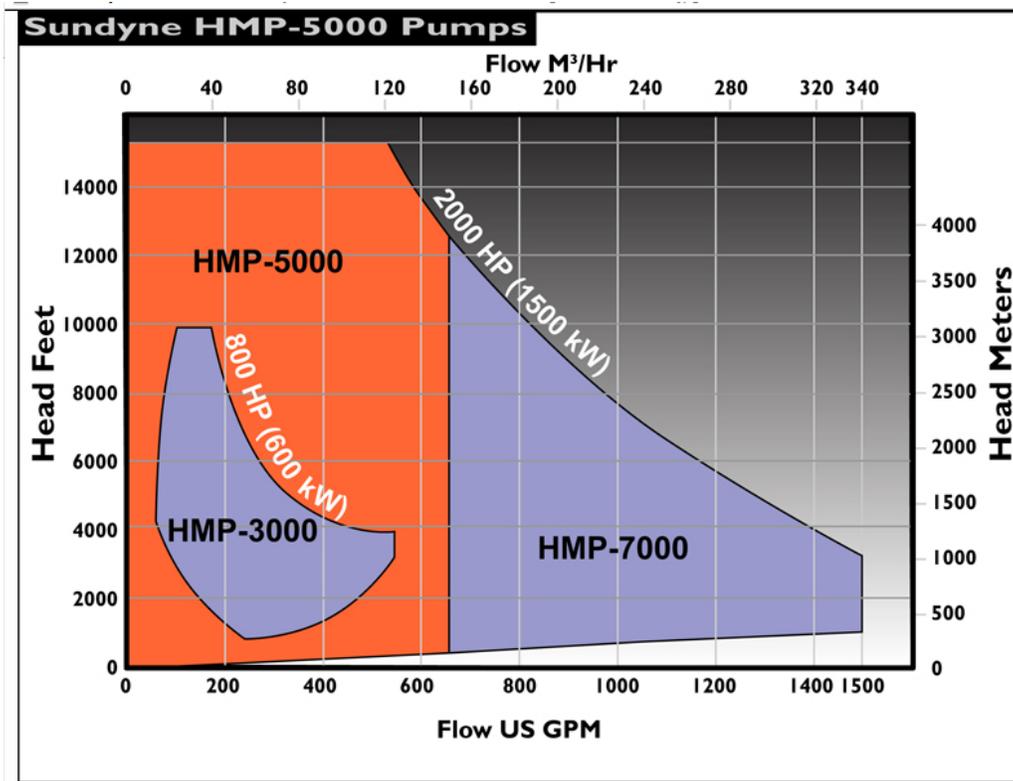


Figure 7 - Sundyne HMP pump curves

## Conclusions

While integration of trashrack cleaners and high-pressure wash systems appears to be possible on paper, several operational and design constraints may prevent a simple integration. Some of the problems realized when developing designs for the two sites include:

- Low-flow, high-head pumps are available but require significant power input and may have a large footprint. No submersible pumps were identified, thus the pumps must sit in a stationary location and not travel with the cleaner.
- High-pressure hoses in large diameters will become rigid which will make them difficult to coil and move with the trashrack.
- If hose diameter is reduced to a manageable size, pressure requirements and pump size increase beyond pump capability.
- The durability of high-pressure hose being lowered into flowing water is a concern.
- The life expectancy of high-pressure nozzles is unknown, but cavitation damage is likely to occur.

## References

- Mortensen, J. D. (2013). *PAP-1074 - Resistance of Protective Coatings to High-pressure Water Jets for Invasive Mussel Removal*. Technical Service Center, Hydraulic Investigations and Laboratory Services Group . Denver: U.S. Bureau of Reclamation - Hydraulics Laboratory.
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