PIGGING RESTORES INTAKE FLOW CAPACITY FROM QUAGGA MUSSEL FOULING IN GREAT LAKES

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QUAGGA MUSSEL INVASION

During the fall of 2018 the City of Toronto initiated a project to clean all three (3) sixty-inch diameter HDPE raw water intakes at the Island Water Treatment Plant, restore intake flow to its original design specification, and reduce plant operating costs. The Island WTP is vital to the City of Toronto and serves as the only source providing year-round deep lake cooling water for Enwave Energy Corporation, a private utility generating electricity. The hydraulic capacity of each deep-water intake as determined by Hazen-Williams "C-Factor" rating was markedly reduced during the 14 years of service since commissioning of these deep-water pipelines.

Figure 1.ROV pictures showing quagga mussel build up prior to pigging

Quagga mussels, an invasive species of mollusk native to the Ukraine, arrived in the ballast water of ships navigating into the Great Lakes. Quaggas adhere to any submerged surface, and then feed off plankton in the water as they grow. This species creates catastrophic environmental impact as it invades new ecosystems, and rapid mussel infestation concurrently affects the maintenance costs for water treatment facilities and power plants by increasing aquatic fouling growth.

Tom Nalepa, emeritus research biologist at the National Oceanic and Atmospheric Administration Great Lakes Environmental Research Laboratory, has stated "*Without question, the quagga mussel represents the greatest threat to the Great Lakes of any invasive species.*"

Quagga mussels propagate at such a massive rate that they alter the natural food chain and displace native species, which dramatically disrupts the ecosystem, and ultimately reduces populations of both game and commercial fish. The quagga mussel may well present a greater immediate danger to lake ecology than the more famous zebra mussel. Neither chlorine nor other chemical procedures have proven effective as a control mechanism.

In 2014 Remotely Operated Vehicle (ROV) inspections of the deep-water intakes extending from Island WTP into Lake Ontario documented quagga mussel infestation. Fouling was heaviest in deep water (250 ffw) at the mouth of the intakes, and the mussels adhering to the interior wall of the HDPE pipe created flow turbulence which diminished the volume of water delivered to the WTP facility, and also increased the pumping cost.

SCOPE OF WORK

Large diameter hydraulic pipeline cleaning is a somewhat unique specialty and particularly so under deep water conditions as encountered off Toronto Island. In summer 2017, Engineers with the City of Toronto Water Division contacted Montauk Services because previously Montauk had successfully pigged Cornell University's 60-inch HDPE deep water Lake Cayuga intake. The Engineers reviewed the criteria, specifications, and budget for hydraulic pigging to restore flow capacity at the Toronto Island WTP in relation to the procedures and results which had been demonstrated at Cornell University.

In June 2018, the City of Toronto finalized project specifications and bid requirements. Montauk teamed with Galcon Marine Ltd., a Toronto-based contractor with marine equipment, local offshore expertise, and previous experience with the City. Galcon provided island transport, support, and overall control for multiple Subcontractor specialists, in addition to undertaking the General Contractor tasks required to handle barge delivery, on-shore piping, hydraulic water supply pumping, ROV services, and the marine operations for pig retrieval.

"Completing the project in the tight timeframe was a challenge due to poor weather conditions," said Ryan Vogt, Senior Project Manager at Galcon. "From a marine standpoint, the prevailing winds during Fall are from a predominantly bad direction making retrieval of the pigs, ROV operations, and drawing water for the operation very difficult." Vogt said the timeframe chosen

PIPELINE RESTORED TO A HYDRAULIC CONDITION BETTER THAN ORIGINALLY INSTALLED. CLEANING FROM THREE PIG RUNS COMPLETELY CLEARED THE QUAGGA MUSSELS AND ANY OTHER BUILD UP

Figure 2.60-inch launcher being moved from one intake to another

Figure 3.60-inch durafoam style pig being placed in launcher

for the project was optimal for the City of Toronto because it was the lowest usage time for its clients.

The specified Scope-of-Work included:

- Design and fabricate a pig launcher and structural supports capable of mating with the Intake Valve Chamber and WTP piping system
- Develop, document, and provide a process, design and procedure for hydraulic pigging of the three WTP intakes consistent with the timing and utilization requirements imposed by the City. The movement of vehicles and personnel along Lakeshore Avenue on Toronto Island was not to be delayed significantly or disrupted.
- Obtain necessary regulatory permits and approvals
- Perform an ROV inspection throughout complete length of each intake before pigging
- Pigging at three deep water intakes, including salvage of used pigs which, in view of environmental considerations, could not be "lost at sea"
- Manual cleaning of the Raw Water Suction Well and the Common Inlet Pipe

Montauk Services handled the overall hydraulic layout, launcher design, and hardware designation as well as pig design, sequence determination, tracking, and recovery procedures. Each pig was tracked leaving the Intake Valve Chamber, entering Lake Ontario, and at the offshore mouth of the intake.

HYDRAULIC PIGGING PROCEDURES

Pigging pipelines is simple in concept, but success usually determined by the experience, planning, and preparation prior to the actual pig runs. In Toronto, cleaning time was very limited because removing even a single intake from service imposed major constraints upon the system, and there were immense operational consequences from any significant disruption such as a "stuck pig".

The proper pig sequence is important because pipe cleaning usually must be completed as quickly as possible, but the procedures must also be conservative enough to avoid any damaging pressure surges in the line or the delays associated with a "stuck pig".

Pigs clean through compression of the foam body as they pass along the pipe propelled forward from hydraulic pressure created by pumps discharging into the line behind the pig. Pigs used for cleaning are often larger in diameter than the ID of the pipe, much like pulling a very large sponge through a pipeline and scrubbing the wall surface as it moves along. The Toronto WTP lines were almost 61 inches ID, however the first pig deployed was a soft foam material and only 58-inch diameter. The intention was to create enough bypass flow to perform initial cleaning, but not have the pig adhere to the wall of the pipe or restrict its movement through the intake.

Figure 4.Each pig is tracked as it leaves the shoreline

Figure 5.60-inch brush pig being readied for tow back to shore

One significant concern when cleaning mussels or removing any similar hard pipeline debris is that a mass of material can accumulate and shoal up ahead of the pig, which may slow down or potentially stop forward pig movement. During the first 58-inch pig shot, submerged video cameras aboard an ROV stationed at the intake mouth monitored in real time the volume of Quagga mussels displaced from the intake ahead of the pig. The amount of discharged material and the documented pressure profile measured by instrumentation behind the pig provided the information needed to determine the specific characteristics of the next pig launched.

Based on experience, the contractor will select and keep available onsite an array of alternative pigs for cleaning, however the actual results of each pig run determines the selection of each subsequent pig from this inventory. Generally, foam density and pig diameter increases after each run with the final pig larger in diameter than the ID of the pipeline. The last pig shot through each of the three Toronto intakes was a full sized pig with embedded plastic bristles to ensure complete cleaning of the pipe wall. The beauty of foam pigs (to a pigging Contractor), is that they can be designed to channel approximately 10% of the propelling water around the pig. This flow thereby displaces the volume of mussels or debris scoured off the pipe wall, suspending it in the flow ahead of the moving pig.

About 5-10 minutes before the pig discharges from the pipe, observations at the intake mouth become exciting, particularly in conditions with very good submerged visibility such as in Toronto. A flow of murky water comes first, followed by a trickle of mussels dropping onto the lakebed from the invert of the intake mouth. The trickle of mussel shell becomes a flow creating a pile on the bottom, followed by a surge of black water, mussels, debris, and finally, the pig. Depending upon the time of day and particulars of the pig run, sometimes creating back lighting above the intake even at depth, the pig itself can be observed by the ROV video. If obscured by a cloud of debris, the pig is tracked and located using sonar. Each pig is fitted with an acoustic transponder, which then is tracked at long distance by a receiver aboard the ROV to allow pig recovery even if it is shifted across the lakebed by bottom currents.

TORONTO INTAKE CLEANING OPERATION

Because contract specifications would not allow any interruption of intake flow before October15, 2018, fieldwork for the project commenced in the Fall. Completion was required by December 14.

For improved cleaning results, the launcher was designed and fabricated to accept oversized pigs at the upstream end. It had a reduced diameter on the downstream end, in order to fit the ID of pipe in the Intake Valve Chamber. Each of the intake lines had an independent connection for the pig launcher so that cooling water supply from two lines was kept in service while the third line was cleaned. The pig was propelled with water pumped from the shore side of Toronto Island passing beneath a temporary bridge installed by Galcon to maintain traffic along Lakeshore Avenue. The pumps were controlled to maintain uniform flow ranging between 18,000 and 20,000 gallons per minute. The three intake pipelines extended from approximately 16,500 LF to 17,300 LF between the Valve Chamber and intake mouth installed at 270 feet of water depth in Lake Ontario. Pig run times for each of the three intakes varied from 75 to 90 minutes. Each of the three intakes, (West, Center and East), were cleaned by three successive pig runs.

With the surface support vessel and ROV stationed at the intake mouth, a pig would be loaded and launched. The pig was tracked as it left the launcher, and again as it crossed the beach into Lake Ontario. If any problem developed during pig transit, gauges and data-loggers would indicate a pressure surge, providing data on the estimated location of the pig. Pigging time was recorded and documented for each run. Just before the pig discharged, a slight change in pressure accompanied the opening of the pipeline.

DEEP WATER & WEATHER CONCERNS

Cleaning at both the West and Center Intakes progressed like clockwork with each pig. All three pigs for both these intakes retrieved without issue. The good luck ran out during the East Intake cleaning when the second pig did not exit the intake mouth. The November weather turned foul with high winds and sea state, which precluded continued offshore operations. The surface support vessel could not safely leave the dock for a week

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to track and retrieve this stranded pig, which was the size of a minivan, lost somewhere in the depths of Lake Ontario.

After a week of delay, the winds and the wave height subsided to the point the surface support vessel could maintain station above the East Intake mouth and deploy the ROV in order to locate the "lost" pig. It was discovered sitting happily in the truncated mouth of the intake structure at the end of the HPDE pipeline. It was a simple procedure for the ROV manipulator to attach a haul line so an auxiliary boat could pull the pig clear of the truncated intake section.

INTAKE CLEANING RESULTS

Other than the predictable weather challenges previously described, the pigging operations progressed flawlessly. Immediately after the first intake cleaning, Montauk Services and Galcon stood by while the City engineers verified the resultant Hazen Williams C-Factor rating achieved for the first intake by the three pig runs. This would also determine if an optional fourth pig run would offer any significant benefit. The City engineers were pleased by the initial (three pigs) results yielding a C-Factor indicating the pipeline was restored to a hydraulic condition better than when it was originally installed. The cleaning from three pig runs completely cleared the quagga mussels and any other build up reducing water flow.

All three intakes were cleaned with It took only three pig runs to clean each intake. C-Factor analyses performed by the City on each intake after cleaning demonstrated better water flow conditions than when the pipelines were new. A perfect C-Factor for this type of pipe is 150+. Built in 2004, the original C-Factors for these pipes were calculated as 137 to 140. Prior to cleaning, quagga mussel buildup had reduced the C-Factor to approximately 110. After the pigging operation, all three intakes at the Island WTP had C-Factors of 149 to 152 as calculated by City engineers.

Figure 6.60-inch brush pig after being towed to shore

This project validated the use of hydraulic pigging for pipeline cleaning and restoration, with results exceeding expectations. Work completed on time and on budget while fulfilling a critical obligation that the Island WTP remain in operation at all times during the work.

This method of pipeline remediation is worthy of consideration for situations on the Great Lakes or in other areas with pipeline flow restricted due to quagga mussels, zebra mussels, or other species of biofouling.

ABOUT THE AUTHOR:

Rex Murphey *has been leading pigging and testing projects across multiple industries since 1986. He is Founder and CEO of Montauk Services, specializing in pipeline pigging services and equipment for pressure pipeline cleaning, focusing on water and wastewater. Rex is relied on among municipalities and utilities for his institutional knowledge and 37 years leading complex projects.*