Small Scale Carp Exclusion Pilot Plant

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Problem and Objective

Gull Lake in central Alberta was challenged by falling water levels from the 1920s to the 1970s. In 1976, Alberta Environment (AEP) implemented a stabilization system to pump water into the lake from the Blindman River via a pump house, 30-inch pipeline and canal. The pump house has three 480 volt pumps with a combined output of 53m^3/minute (14,000usgpm) at pressures of up to 70 psi to overcome the dynamic and hydraulic head in the pipeline. Since the stabilization system was built, the lake has gone through various ups and downs in water level, but with the system, these variances have been held to a relatively narrow band.

Prussian carp (*Carassius gibelio)*, a non native species and prolific invader of freshwater ecosystems, was first detected in south-central Alberta in 2000 and has expanded geographically at an exponential rate (Docherty 2016). Prussian carp have been documented in the Red Deer watershed (Docherty 2016, Ruppert et al. 2017), including the Blindman River (Jason Cooper pers. comm. November 20, 2017). There is considerable concern regarding the potential introduction of Prussian Carp to Gull Lake due to their ability to outcompete native species and associated impacts to fish, benthic species and their habitat (Elgin et al. 2014; Ruppert et al. 2017).

AEP retained ISL Engineering and Land Services Ltd. (ISL) of Red Deer to study possible ways to continue pumping without risking the introduction of carp into the Lake. ISL's brief "desktop" study concluded there was no reliable way to do so. It looked at a number of esoteric deterrent methods but did not consider filtration. On October 31st, 2018, the AEP set a 5 year suspension of pumping for lake stabilization[1] just as the lake reached the trigger level where pumping would have resumed.

AEP forwarded the ISL report to the GLWS. Our review indicated that filtration was not evaluated, although it appeared to be a potentially reliable and economical approach that we felt should be considered. The GLWS decided to evaluate filtration and came up with two potentially viable methods to manage the substantial sediments present in the Blindman River and reliably remove carp fry/eggs from Blindman water before transfer. The methods were the Geotube and the Forsta backwash filter.

Executive Summary and Recommendations

1. Both filters tested reliably removed carp eggs from the river water.
2. The Forsta filter was better able to handle the sediment load of the river water due to the higher operating pressure and backwash capability.

[1] Letter dated October 31, 2018 to Lacombe County Entitled Lake Stabilization License Suspensions - Prussian Carp. https://www.lacombecounty.com/councilpackage/2018Nov08Council/10.3.pdf

3. There was a concern that the Geotube filter may not withstand an overpressure condition if it plugs off and would have to be carefully monitored. We believe a catastrophic failure could be possible.
4. The Forsta filter could be installed downstream of the current stabilization pumps and those pumps have sufficient pressure and flow capability to properly operate the backwash at the normal pipeline backpressure. The filters are rated for 150 psig so there is no risk of catastrophic failure.
5. The Forsta eliminates the need for a preliminary pumping step so would not significantly increase the electric power requirements of the stabilization system.
6. Forsta supplied a quote for three filters with a combined capacity of 13,500 usgpm for a cost of $95,000USD including the automatic controls. Using a typical three-times factor of major equipment cost to total installed cost, we estimate a conceptual project cost of $315,000CAD. More work would be required to reach a higher quality estimate but this provides an indicative project cost for feasibility purposes.
7. For the full scale system a piping system is recommended that would allow initial diversion of filtered water back to the inlet channel for testing of filter efficiency before transmission through the 30 inch pipeline. That would allow verification of each full scale filter before normal operation.

A. Geotube Filter Test

1. Introduction

The first segment of this report covers the Geotube filter. This filtration technology was originally developed to dewater sewage sludge but has been used for many other purposes including levee construction, dredge spoil disposal etc. It is characterized by very large bag filters that the water/sediment mixture is pumped into, water flows out through the pores while sediment and other solids are retained. A Geotube filter 200 feet long by 45 feet in circumference was proposed to handle the full flow of the stabilization pumps. The Geotube pore size is 0.4mm and Prussian carp eggs are typically in the range of 1mm in diameter (Tarkan et al. 2007; Şaşı 2008), so on inspection it appeared the filter would contain them.

A bench scale Geotube test first conducted in the Lambourne Environmental lab. The bench test indicated that the Geotube retained poly spheres over 0.5 m in diameter. The bench test was followed by a small scale pilot test of the Geotube filter. The purpose of the small scale pilot plant test was to:

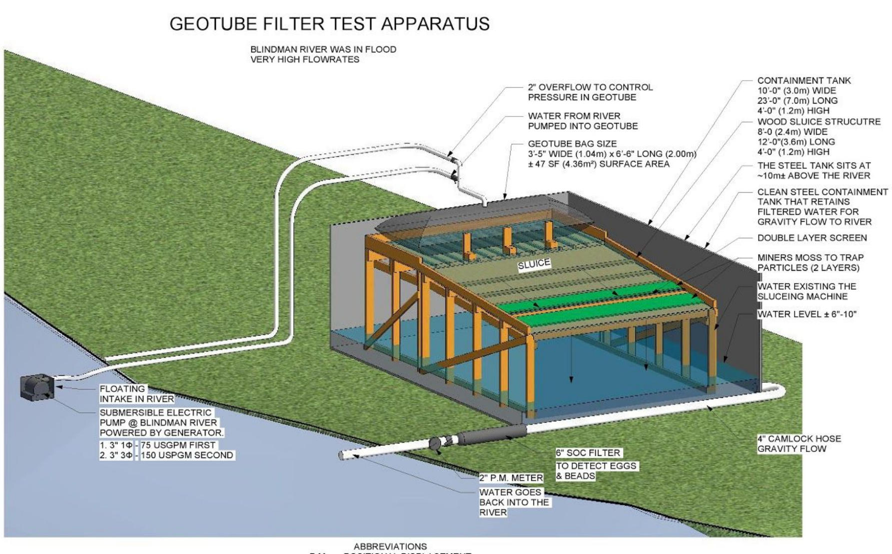
a. scale up the lab bench scale test and pump actual river water through the filter;
b. evaluate the performance of a Geotube at removing carp eggs.
c. test the ability and longevity of the Geotube when filtering river water.
d. evaluate the difference in water quality by the removal of sediment from river water.

2. Description of Apparatus

The apparatus used is shown in Figures 1 through 5 of Appendix 1. The Geotube was mounted on a platform in a watertight tank with filtered water flowing down a sloped sluice equipped with a screen and miners moss that would allow observers to visually see if any of the dyed carp eggs passed through the Geotube. The drain from the tank was connected to a fine SOC filter element which was also examined to see if any eggs passed through the Geotube pores. River water was pumped by centrifugal pumps located in a floating intake strainer supplied by Northside Construction who also supplied the onsite generators to run the pumps. A 2-inch PD water meter was used to determine the rate and total volume of water pumped through the filter.

The test filter was a two sided bag 6’ 10” long X 3’ 5” wide for a total area of 47 sf. The potential full scale filter would be 9000sf and capable of handling a flow of 14,000 usgpm for a flow per unit area of 1.55 usgpm per sf. To make the scale comparable, we needed a flow of ≈72 usgpm in the small scale pilot test.

Figure 1: Geotube Filter Pilot Project Set-up



The Geotube test apparatus with the sluice set up

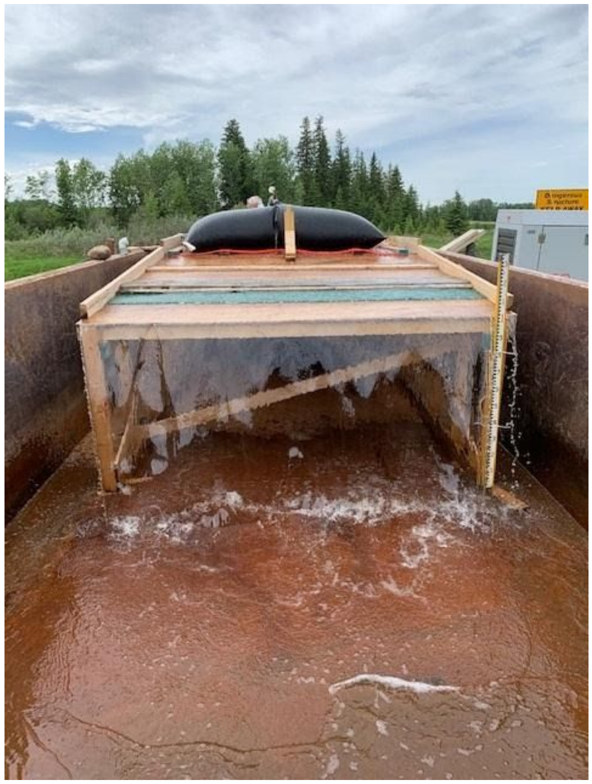
A test size Geotube filter before starting the test note the flanged inlet on top

3. Summary of Geotube Trial Runs

The Geotube pilot plant was built and started up in May with GLWS volunteers. We decided it needed to be attended while operating. GLWS Volunteer coordinator was Keith Nesbitt who was also present for much of the pilot's running time. The pilot operated only during daytime hours.

Date(s)	Comments
May 28	Startup and volunteer orientation was held, initial meter reading was 6,634,685usg. Initial flow with two 2" pumps was less than expected at 47 usgpm.
June 2	A larger 3- inch pump was installed which brought our flow rates up to 60 usgpm.
June 4	Official pilot startup. A with a new SOC filter installed downstream, 1000 egg batch introduced via inlet hose and in 8 hours pumped 11,000 gallons of river water pumped through the filter during 8 hours of pumping, No eggs observed on sluice or in SOC filter.
June 5 to 8	Introduced 2000 Carp eggs each day and pumped a total of 34,000 usg through the Geotube in 32 hours of operation over the 4 days. Sluice and SOC filter was inspected each day with no eggs observed. Concerned that flow rate through the apparatus was falling off sharply and did not know why.
June 9	Stringy grassy material was building up on the floating intake screen and was cleared but still had much lower flows than desired. However, even with a flow of only 25 usgpm, the Geotube became more inflated at 10.5 inches high. With agitation, expanded Geotube would reduce in size, but would increase in size fairly rapidly again. The pressure gauge on top of the bag inlet read zero so it was removed and only a small amount of water flowed out indicating no pressure head on the Geotube. By 11 am the flow was only 22 usgpm and the bag was showing pinhole openings with tiny jets of water emerging, indicating internal pressure had affected the porosity of the Geotube filter.
June 10 to 11	Pumped 19,000 usg in 18 hours
June 12	Replumbed a larger 3-phase pump to improve flow and removed the water meter on the inlet. Determined internal screen was clogged with grassy debris, causing the flow restriction. The flowmeter screen was cleaned and then installed downstream of the SOC filter where it would not plug. Introduced 5000 carp eggs. The flow rate was now well over 100 usgpm and the Geotube appeared compromised, some pinhole streams appeared to be almost 2 mm in diameter and there were significant seepage at the seams but no carp eggs were seen in the sluice or in SOC filter.
June 13	Replumbed to provide a 1 inch inlet bypass to reduce the flow, but based on the rate of the tank filling, the Geotube was operating at nearly 150 usgpm or double the scale rate wanted. The weight of the 4" inlet hose on the Geotube inlet fitting caused it to pull away from the fabric slightly. A partially closed valve was added upstream of the Geotube to restrict flow

	and the inlet to the Geotube was supported to take the strain. It was run for 45 minutes in this fashion and the bag inflated to 20 inches high and was clearly quite strained by internal pressure and greater water volume through pinhole streams were observed. Volume run was 3600 usg for a rate of ≈ 80 usgpm which was just over the scale rate. However, it was clear that this first bag was partly plugged/ compromised so it was decided to install a fresh bag. The new Geotube did not inflate like the old one. It ran for an hour at 83 usgpm and no sign that any eggs made it through on the sluice or in SOC Filter..
June 14	Introduced 5000 eggs to new Geotube and ran for 4.2 hours and put through 17,430 gal for an average rate of 69 usgpm or just over the scale rate desired. During the 4 hours the Geotube expanded noticeably as it went from 8.5 to 14 inches in height.
June 15	Installed a new SOC in the downstream filter. No eggs were observed in the SOC filter. Introduced 5000 eggs and ran for 68 minutes with the Geotube quite extended and needing to agitate the Geotube to keep the filter bag from over expanding. Volume run was 3534 usg. Rate had dropped to 52 usgpm which indicated the Geotube pores were starting to restrict the flow. No eggs observed on sluice or in SOC filter
June 17	Demonstration run with AEP personnel Angela Fulton and Carlin Soehn in attendance. Introduced 5000 eggs, ran for 1.5 hours and put through 8000 usg for a rate of 88 usgpm. However the Geotube needed agitation to keep the inflation level reasonable and it was clear that the pores were plugging up. After 1.5 hours the Geotube was inflated to over 16 inches high. The first Geotube was cut open and there was a thin coating of brown mud covering the pores and yet not very much sediment actually in the bag. The SOC filter was removed and opened and there was a layer of brown soil material in it, a much thicker layer than in the Geotube but no eggs visible.



The inflated geotube being run at full flow rate of about 80 usgpm early in the test

Adding 5000 dyed Carp eggs to the inlet hose to the Geotube

Final test configuration with a fully inflated geotube showing signs of pressure stress

Inspection of the first Geotube and the downstream SOC filter after test run

4. Observations and Conclusions on the Geotube Filter Test

a. After the run on June 17th the second Geotube and the final SOC filter were opened and examined by Paul Anderson using a hand lens. During the examination of the Geotube it was noted that there was a very thin layer of fine claylike material clogging the pores, particularly on the bottom of the bag. No eggs were visible in either the Geotube or the SOC filter. It was surprising that none were visible in the Geotube as over 15,000 brightly dyed eggs had been introduced and none had been observed flowing out of the Geotube down the sluice. The eggs are difficult to see and may be ruptured while pumping them into the bag or dessicate very rapidly if the bag is allowed to dry out before being examined (it had been at least 24 hours between the last test and examination of the bag contents). It was noted that unlike the Geotube, the SOC filter had a buildup of clay-like material, enough that you could scrape out spoonfuls.

b. The test of the first Geotube was marred by the water flow meter location between the pump and the bag as the meter's internal screen plugged and reduced the flow below that planned for a scaled experiment. This was corrected on June 12 for the last part of the first Geotube test and then for all testing of Geotube #2 .

c. The first run was also marred by the change to a high pumping rate with the 3 phase 3-inch pump with over 150 usgpm or over 3 usgpm per sf. which is twice the scale flow planned. This flow rate appeared to risk bursting the bag and many pinhole streams were exiting at high velocities from the seams and corners and shooting out up to 2 feet. That was corrected by adding the inlet bypass that allowed the flow through the bag to be brought down to 80 usgpm and pressure on the top of the bag to be controlled to ≈ 3 feet of head. Even with the reduced flow, the bag inflated to over 20 inches high in the 36 minute final run and small streams were visible at the seams and around the inlet.

d. A total of 85,000 USG were pumped through the first bag and by the end of the run it was clear that it had reduced flow capacity due to pore plugging. The test bag of 47 sf had an area 0.5% of the proposed full scale bag. It had been speculated that a bag would take several years to fill and require renewal. If the full size bag were to be restricted after a similar volume per unit area as in this test it would only be able to filter 17 million usg, or 64,000m3. That suggests it could be restricted after only 1 day of full stabilization pumping.

e. Fresh Geotubes were capable of receiving high flow rates. The manufacturer indicated possible rates of 20 usgpm per square foot although we were proposing only 1.5 usgpm per sf. However their capacity fell off much quicker than expected as pores clogged.

f. They appeared sensitive to the pores plugging with fine clay-like material. It had been assumed the bag would fill with sediment from bottom to top and that it would have capacity to hold a large amount of sediment before it would have to be replaced - but that was not the case in our small scale pilot project.

g. Much greater flow capacity may be reached with heavier or coarser sediment that would settle better or create a porous filter cake instead of plugging off the pores between the fibers. The flow capacity of the bag could be restored by agitation during operation which likely opened up the pores and encouraged sediment to settle better.

However in our case with this fine sediment and need for large volumes it was concluded that the Geotubes may need changing too frequently to be practical.

h. We noted that the test Geotubes appeared sensitive to pressure as they became partially plugged and in a full scale scenario pressure would have to be controlled or structural integrity could be compromised. This is not a serious concern in the traditional use of the Geotubes but is a concern where it is essential that no eggs get through. It would be essential to ensure that the Geotube is not overpressured as it is clogged with silt.

Our conclusion was that the Geotube was successful at retaining all the carp eggs, but that it was not able to handle the fine sediment present in the river and that there was some risk to its integrity once it became plugged and the pressure increased. Based on this conclusion we decided to test the second filter that had been recommended by one of our members

B. The Forsta Filter Pilot Test

1. Introduction

The Forsta filter was recommended by Dan Coulter of Northside Construction partnership. It is a backwash type filter developed in California to remove sediment from large volumes of irrigation water intended for drip irrigation. This filter was quite different in concept. It was designed to run at fairly high pressures with relatively small filter elements that would be automatically backwashed with filtered water when a designated pressure drop was reached over the filter element.

Research indicated the pump required at least 40 psig to properly backwash and it was determined that the existing stabilization pumps normally operated at least that pressure to overcome the gravity head and friction loss of the 30-inch pipeline that delivered stabilization waters to the canal that feeds the lake.

That indicated that the filters could be installed downstream of the existing stabilization pumps and we would not need to pump the water twice, which had been a cost concern with the Geotube filter. Forsta also provided a preliminary quote for three filters to handle the full 53 m^3/minute flow at $95,000USD total. During our research, we determined that other companies, notably Alfa Laval, also offer backwash filters with somewhat different but probably acceptable backwash systems.

It was decided that the Forsta filter should be tested as part of our small scale pilot test. Fortunately Forsta had developed a demonstration size filter kit that included a filter with 0.4 sf filter element and a backwash controller and control valve, all scaled down to a size that could handle up to 100 usgpm. The filter element was 2% of the area of a full size unit with an 18 sf filter cartridge designed to handle 5000 usgpm. Three filters of this size would be required to handle the full lake stabilization flow rate of 53 m^3/min (14,000 usgpm) The key to making this filter work is that the fairly high operating pressure is required for the backwash.

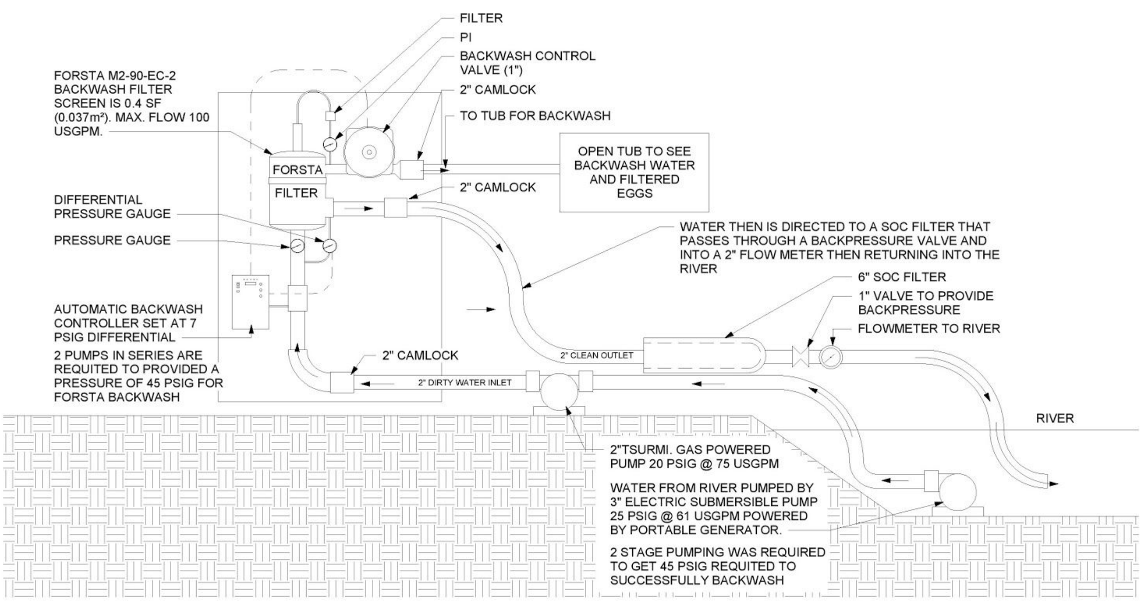
2. The Apparatus for the Forsta Filter Test

The Forsta test kit was purchased and a design developed for a pilot configuration which is shown in Figure 2 below. It was decided to use two pumps operating in series to achieve the required pressure of at least 45 psig at scale flow rates of 50 to 60 usgpm. Both a 400 micron and 100 micron filter cartridges were received with the test kit with the 400 micron being installed in the filter vessel.

The kit was received in early July and assembled according to their detailed instructions. This took some time as the connections had to be adapted for Camlock hose fittings for the inlet and outlet water and wiring was needed to connect the control module to the automatic backwash valve. The components were mounted on a sheet of plywood and the pipes/ connections supported with wooden members. The Forsta filter includes a rotating internal cleaning system designed to ensure an efficient backwash. It also includes a differential pressure gauge that indicates the differential pressure "∆P" between the filter inlet and outlet. It was factory set to backwash at a differential of 7 psi. A picture of the assembled test kit and an individual filter cartridge is attached.

Figure 2

FORSTA TEST FILTER APPARATUS



The assembled Forsta filter test system connected to the camlock hoses

3. Summary of the test runs of the Forsta filter

Date(s)	Comments
July 10	The first trial run of the apparatus with the 400-micron filter was carried out on July 10th. The river was in a dramatic flood condition due to heavy rains and visibility in the water was less than 2- inches. The backpressure valve at the outlet of the SOC filter was pinched back until we had a pressure of 38 psig at the filter which gave the desired flow rate of 55 usgpm. The filter ∆P increased very slowly but did not reach the 7 psi required to trigger an automatic backwash, so we initiated a manual backwash after 20 minutes of running time. Very dirty backwash water. We then reduced the backpressure to maximize flowrate but pressures gradually increased and after an hour we had to shut down as the downstream SOC filter was plugged with brown sediment. The SOC filter was removed and the first automatic backwash occurred after another 15 minutes but the ∆P did not fall significantly indicating that the backwash was not efficient. The filter tried to backwash soon after again but the pressure during backwash fell much below 20 psi and again a high ∆P indicated an ineffective backwash. We shut down and called Forsta who advised us that we needed reserve pressure and pumping capacity during the backwash cycle to ensure that the internals rotated adequately to thoroughly clean the screen. We found a pressure of at least 45 psig was needed at the filter inlet to get the backwash piston to move properly and do an effective backwash and get the ∆P back down to < 2psi. The meter registered 4555 usg over 3.5 hours of running off and on.
July 27	The next run was July 27th when 12,600 usg was put through the filter at flow rates of 55 to 60 usgpm. The river stage was much lower and cleaner looking with visibility in the water of 8-inches. After a run of 1.2 hours, the differential pressure gauge still read below 2psi. 5000 fish eggs were introduced and then a manual backwash was carried out at an inlet pressure of 50 psi. Numerous eggs and egg sacs appeared in the tub collecting the backwash water. A new SOC filter was inserted and flow was restarted still with low ∆P across the Forsta. Another 5000 eggs were inserted, the pressure raised by pinching back the outlet valve and another manual backwash was conducted. Again the backwash appeared to include substantially all the eggs and membranes. Altogether the running time was over 4 hours. The run appeared to be successful but when the SOC filter was examined with a hand glass a few very small eggs were discovered.
July 27	The detection of the eggs was concerning and several theories were developed as to how they could have gotten through the 400 mm filter: ● By this time our eggs were more than a month old and we had been warned that they lose their structural integrity over time. It may be the 40 psig inlet pressures caused the 1mm eggs to deform enough to pass through the 400 micron mesh (0.4mm openings). ● The weld seam on the filter cartridge had a small concavity that may have allowed some flow to bypass the filter where the O- rings sealed against it. ● The size of the eggs that passed through were extremely small. These eggs were likely not mature and were much smaller than the 1.04 to 1.94 mm diameter size of ripened Prussian carp eggs quoted in the scientific literature (Tarken et al 2007).

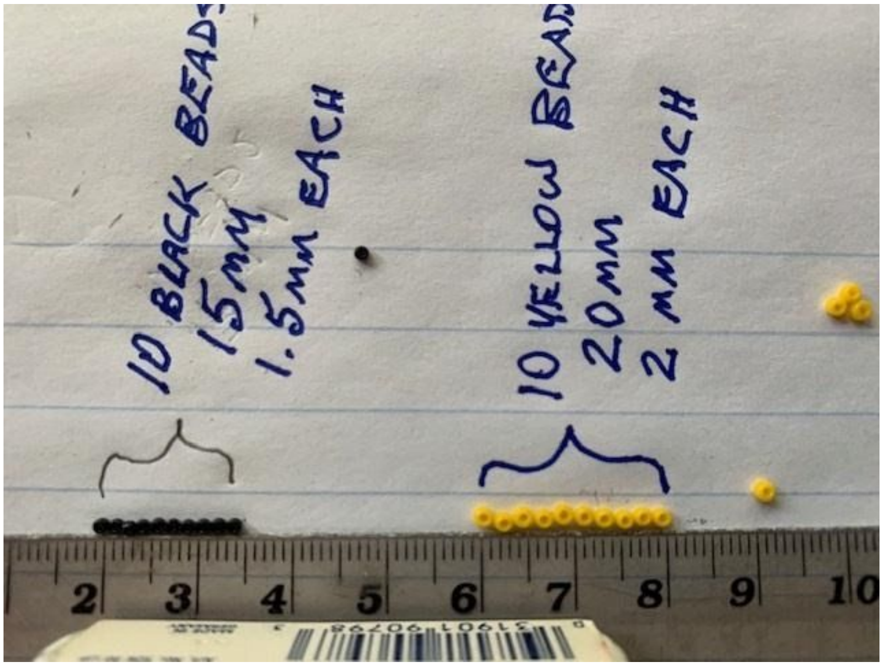
July 28	The filter was disassembled and the sealing system checked and looked secure. It was decided to run with a new filter cartridge of 100 microns to avoid any potential “squeezing through” of eggs. The new filter weld seam was lightly filed to ensure good sealing with the o-rings and the filter reassembled. It was then run for 1.5 hours with Carlin Soehn and Angela Fulton and Sean of AEP witnessing all aspects. Two sizes of beads were introduced into the river water pumped through the filter {black beads of ≈ 1.5 mm diameter (very similar to the Carp eggs) and highly visible 2mm yellow beads see photo}. A manual backwash was initiated and it appeared all the beads were collected in the backwash tub. 5000 aged Carp eggs were introduced and we were just preparing to do a backwash when the generator driving the pump in the river failed. Shutdown was required. We opened the Forsta filter and the Carp eggs appeared to all be trapped on the inlet side of the filter. The SOC filter was pulled and examined with the hand lens and no eggs or beads were observed. The 100-micron filter appeared to have succeeded but further testing was required.
July 29	The final run was conducted on July 29th with a new generator and the 100-micron filter installed. River flow was down further and visibility in the water was >8 inches. Over 4000 usg was pumped in 2 hours. Two injections of counted black and yellow beads were done and 1 injection of 5000 aged Carp eggs. Two manual backwashes were carried out as the filter never approached the 7 psi differential where an automatic backwash would have occurred. This time the number of beads injected were counted and on both trials 100% of the 1.5 mm black beads were recovered from the backwash. In the second backwash with both beads and fish eggs we only recovered 14 out of 20 yellow beads injected. It appeared the backwash may not have been fully effective as we found 5 yellow beads on the inlet side of the disassembled filter. We surmise the last bead was caught up in the backwash hose as it did not appear in the SOC filter. The SOC filter was carefully examined after shutdown and no beads or fish eggs were observed in it. It was observed that with the pressure available the filter could handle quite a bit of flow without plugging or backwashing. The performance of such a small cartridge was quite surprisingly good.

Forsta filter and backwash controller, the lower hose is the inlet, the middle one is the outlet and the differential pressure gauge is between them. The top (red) hose with the control valve goes to the backwash tub. The grey box is the automatic backwash controller.

The disassembled filter showing the Forsta Filter cartridge beside the case with the backwash mechanism to the left

New SOC filter

Carp eggs inside filter cartridge



Test beads injected with the feed water into the Forsta filter

100 small black beads - 100% recovered from the backwash - success

4. Observations and Conclusions on the Forsta Filter

1. We were surprised at how long the tiny filter could run at 50 to 60 usgpm on dirty river water without reaching the 7 psi of differential pressure where it would perform an automatic backwash. It is surmised that the 40 psi operating pressure forced the water through the filter cake on the inside of the filter. This was in sharp contrast to the Geotube which was running at less than 2 psi.
2. Nearly all backwashes were manually started using the backwash controller except when the unit was run at low pressures that did not result in an effective backwash.
3. It was noted that a considerable reserve of flow and pressure were required when it came time to backwash the filter. The Forsta design needs reserve pumping or backpressure capability to maintain the filter inlet pressure and drive the rotating cleaning mechanism. The pilot pumping setup did not have an adequate reserve and we had to simulate it by pinching back the outlet valve in order to backwash at over 45 psi. During the backwash the pressure at the inlet to the filter fell below 30 psi but that seemed adequate to operate the backwash mechanism rotation. In the case of the full scale stabilization pumps with the hydraulic back pressure head imposed by the pipeline can more than meet this requirement.
4. It appeared that some aged eggs may have been squeezed through the 400 micron filter. It is important that the filter cartridge be completely sealed with the o rings.
5. The black and yellow beads were very visible in both the backwash and inside the filter and would be useful for testing a full scale filter as well as the actual Carp eggs.
6. The Forsta filter would go downstream of the existing stabilization pumps so would eliminate the dual pumping that would have been necessary with a full scale Geotube installation.

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