Low Flow Stacked Rapid Sand Filter Summer 2012 Final Report

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Literature Review

To begin research on building a stacked rapid sand filter for a low flow plant, several design plans from the CEE 4540 capstone design class were consulted, as well as previous AguaClara publications.

- **Fabricating Stacked Rapid Sand Filters for Low Flow Rates** - this is a power point presentation from the capstone design class by Alberto Ferrero Diez, David Gonzalez, Miree Eun Li, Hui Goh. This design used four layers of sand, and could potentially be built in a garbage can.
- **SRSF for a Low Flow AguaClara Plant** - this is a power point presentation from the capstone design class by Bradshaw Irish, Siwei Oon, Weiling Xu, Ruonan Zhang. It looked at a potential design similar to the one aforementioned, with a square filter and four layers of sand.
- **Stacked Filters: a Novel Approach to Rapid Sand Filtration** Michael J. Adelman; Monroe L. Weber-Shirk; Anderson N. Cordero; Sara L. Coffey; William J. Maher; Dylan Guelig; Jeffrey C. Will; Sarah C. Stodter; Matthew W. Hurst and Leonard W. Lion - This paper explained in detail the ideas behind AguaClara's current stacked rapid sand filter, and evinced the benefits of using a six layer sand filter.
- **A Novel Fluidics Control System for AguaClara Stacked Rapid Sand Filters** Michael J. Adelman, Monroe L. Weber-Shirk, Jeffrey C. Will, Anderson N. Cordero, William J. Maher, and Leonard W. Lion - This publication highlighted the virtues of the stacked rapid sand filter and also explained the current siphon system which is used during the backwash cycle to remove the particles that were trapped in the sand during filtration.

About the Stacked Rapid Sand Filter

The stacked rapid sand filter operates by passing water through layers of sand, which removes particles from the water by trapping them in the sand. There comes a point in the filtration process in which the sand has trapped all of the particles that it can, and the water exiting the filter is no longer at its ideal standard. In order to remove the particles from the sand, the filter enters a backwash mode: the valve at the top of the siphon in manually opened, and due to the negative pressure in the siphon the water in the filter is removed via the siphon instead of the outlet box; Additionally, the water level in the inlet pipes has gone below the riser pipes, and as result, water is only going through the lowest manifold in the filter, with the same flow as during filtration. This fluidizes the sand bed completely so that the particles trapped during backwash are released and able to exit with the water via the siphon.

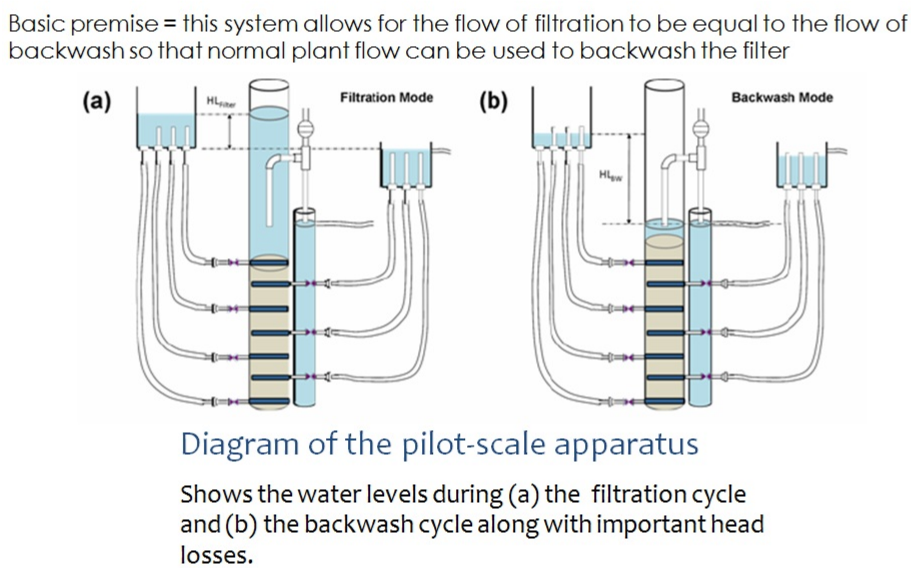

Figure 1: A diagram indicating the SRSF filter in its two modes of operation

Methods

The primary objective for this summer was to construct a low flow stacked rapid sand filter, for water treatment plants with flows between 0.3 and 3.0 L/s. Using the information obtained from the aforementioned sources, several designs were considered. Some features of the higher flow stacked rapid sand filter were kept and not modified in our potential designs; Specifically, the use of slotted pipes, and the idea that the filter would operate in two distinct modes, filtration and backwash, were pillars in the design process.

The geometry of the filter varied with each design. The large stacked rapid sand filter in Tamara is a square filter. One advantage is that it was easy to build a manifold system which evenly distributed water throughout the filter. The pilot scale filter that was used for testing in the lab was made from translucent four inch PVC pipe, and worked for an ultra low flow filter. One advantage with this design was that the pipe was relatively easy to obtain, whereas square tanks were far more expensive, and were not available in sizes ideal for the needs of this project. One disadvantage to the circular design was that a new manifold system would need to be developed for a circular filter. In the end, it was more economical to purchase a 12 inch PVC pipe and develop a new water manifold system than to custom order a rectangular tank and use the current manifold system.

Analysis

Manifold System

The pilot scale model has a geometry similar to that of our design. Since the pilot scale is so small, using one slotted pipe works well for water distribution, but using this method in a 12 inch pipe filter is an inefficient use of space and would generate ineffective flow distribution. The manifold system that we will be using consists of a 1 inch trunk line which distributes water to six slotted pipes which are capped on the ends. Since there is no brace connecting the end of the slotted pipes to the wall, the slotted pipes will be free at one end and therefore not as stable. To fix this, the strong axis of the slotted pipes will be oriented vertically in the filter so that they are rigid in the vertical direction.

Figure 2: The square filter and manifold system in the Tamara Plant

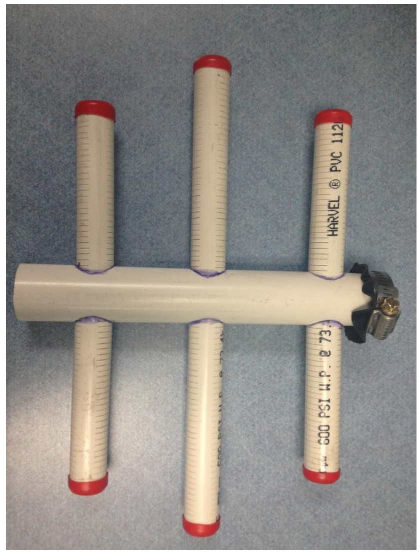

Figure 3: The manifold system that will be used in the low flow SRSF

Pilot Scale Experiment

The pilot scale was modified to see if the design of a pressure filter was feasible. There were some initial problems with the first few trials, and these failure modes were documented below. In order to make the previous pilot scale filter into a pressure filter, the top segments of the filter were removed, along with the siphon piece, and an airtight cap and a backwash pipe with a valve were added. Below is a picture of the stacked rapid sand filter before it was modified and after.

Figure 4: Photos of the pilot scale model before and after being modified as a pressure filter

Failure Modes

- When the inlet box is too low, there is not enough water velocity to completely fluidize the sand bed during the backwash cycle. Also, if it is too low, the riser pipes for the top three inlet manifolds take in water during the backwash cycle, when water should only be going through the lowest manifold. See Fig. 1).
- If the inlet box is too high, the water level plummets so quickly during the backwash cycle that the filter takes in air through the inlet box resulting in bubbles in the sand bed. This causes the sand to be released via the backwash outlet. Over time, this will cause the top layers of the sand bed to deplete. This is due to a large amount of negative pressure, and was solved by implementing plumbing traps where the water goes from the inlet pipes to the filter.
- One problem that arose during the testing of the pilot scale model was that there was supercritical flow, a flow which contains both significant amounts of water and air, through the backwash outlet. This issue was resolved by placing the end of the back wash outlet in a pitcher which when filled with water prevented the water from free falling in the backwash pipe.

Figure 5: The end of the pilot scale backwash outlet resting in a pitcher of water

- Using a pressure filter requires that it be perfectly sealed. One problem that arose was that the seal in the pilot scale model was not as tight as it needed to be, and as result, it released water during filtration and took in air during backwash. Therefore it is crucial to avoid this mechanical failure which leads to supercritical flow.

Conclusion

The final design for the low flow stacked rapid sand filter will comprise of large buckets for inlet and outlet boxes, which are connected to the filter by 2 inch PVC pipelines to each manifold, four connecting to the inlet box, three connecting the the outlet box. The inlet PVC pipes will have the plumbing traps before entering the filter. In the final prototype, the backwash outlet will come out of the top of the filter as opposed to the pilot scale model, in which it came out of the side. The manifold system will consist of a 1 inch PVC trunk line, with six total 1/2 inch PVC slotted pipes, three on each side, oriented with the strong axis parallel to the long axis of the filter, and capped on each end. The end of the backwash outlet will need to rest in a container of water to prevent the free fall of water in the backwash outlet and therefore supercritical flow. Below is a photo of the partially finished design.

Figure 6: The partially finished filter prototype

Future Work

The next step in the process of creating the stacked rapid sand filter will involve constructing the full size model. The fabrication team has recently drilled the holes in the 12 inch PVC pipe for the inlet and outlet pipes, and has also created a prototype of the manifold system. The exact geometry of the inlet pipes with the plumbing traps needs to be finished on the AutoCAD drawing. Once completed, the filter and its inlet and outlet boxes will be joined with the hydraulic testing facility, which is capable of generating the flow needed to test this filter. Depending on the actual flow produced by the hydraulic testing pumps, devices like values, flow gauges, and orifice plates may be necessary to regulate the flow to 0.8 L/s, the flow rate for which the 12 inch filter was designed.