High Flow Modifications: Rapid Mix

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1 Introduction

For high flow plants, the current AguaClara linear flow orifice meter design is not ideal because it requires a pipe with a diameter of at least 12 inches. These are expensive and difficult to acquire, construct with and maintain. Previous work on high flow plant designs resulted in the design of an LFOM mica sheet, which would have water flow from the entrance tank into a rapid mix channel rather than a PVC pipe. Our task is to continue with the rapid mix channel design to provide rapid mixing of coagulant for high flow plant designs. We need to determine the geometry of the channel that will flow from the entrance tank to the bottom of the flocculator and design for macro- and micro-mixing; thus, we need to understand which constraints are most important. We need to consider where coagulant dosing will occur and include dosing into the design. We need to determine at which point the transition from LFOM pipe to LFOM channel will occur by evaluating hydraulics, construction and cost of materials needed, and include this switch into the design.

2 Design Details

Higher flows will result in larger channel cross-sectional areas, which will result in less lateral coagulant mixing. To adequately mix the coagulant into the larger flow, we need both macro- and micro-mixing to occur before flocculation, so we need to design a macro-mix orifice, a micro-mix sheet, and adequate space between the two.

To find the dimensions of the rapid mix channel we assume that minor losses will be most prevalent and major losses will be negligible. We initially assume a maximum headloss of 5 cm in the rapid mix channel from the entrance into the channel to the exit into the flocculator to minimize energy use while allowing for a decent sized channel (no larger than an entrance tank hopper). We assume the K value for headloss includes the entrance to the channel through the macro-mix orifice, the bend from the vertical section to the horizontal section below the walkway between the entrance tank and flocculator, the micro-mix orifice sheet, and the exit into the flocculator.

To find the dimensions of the macro-mix orifice, we need to determine the governing equations. We assume initially that the macro-mix orifice will be determined by the micro-mix orifice equations used currently, but with a lower maximum energy dissipation rate of 700 mW/kg. Ideally, coagulant dosing will occur at this macro-mix orifice. To find the length of the channel from the macro-mix orifice to the micro-mix sheet, we assume that the $\Delta D/\Delta S = 0.1$ for jet expansion. ΔD is the incremental change in the jet diameter and ΔS is the incremental change in the jet's length. We need to ensure that there will be enough space between the entrance tank and the flocculator, and we need to ensure that the channel will be easily accessible for cleaning and maintenance.

To design for micro-mixing, we designed an orifice sheet similar to the LFOM orifice sheet, but found that the orifices would need to be very large compared to the spacing between orifices. This would not allow for adequate flow expansion and the assumed vena contracta flow may not occur. Therefore, we also designed a micro-mix gate, in which bars of pipe made from steel (rebar) or aluminum would restrict the flow. For the micro-mix gate, we assume a porosity of 0.5 and calculate the spacing required to ensure an energy dissipation rate of 1000 mW/kg. With pipes or rebar, we assume no vena contracta will occur, but with aluminum bars of rectangular geometry we assume that there will be a vena contracta. When there is vena contracta, we use porosity to be equal to the ratio between the flow cross sectional area in (through the bars) to the total area out (the total channel area), which is less than the spacing between bars due to the vena contracta.

For both macro- and micro-mixing, we considered how these sheets or bars would be placed in the channel, what materials would be best, and what would be easiest to construct and most cost effective. Ideally, both of these plates will be removable to allow for maintenance of the rapid mix channel.

3 Documented Progress

We started writing and testing code to draw the orifice sheets for macro- and micro-mixing. Since we will probably need three different orifice sheets (one each for the LFOM, macro- and micro-mixing), we began to write a function that will draw an orifice sheet with a given number, size, and location of orifices (OrificeSheetF).

We calculated the square rapid mix channel cross sectional area and width using the headloss equation with a minor loss coefficient accounting for the flow both into and out of the channel, around a bend, and through the micro-mix orifices. Ultimately we found that the assumed headloss and calculated headloss match up when K through the orifice sheet is around 2, so we assume the total K value for the channel is K.90 (for the bend) + 2 K.RMLfom (entrance and exit) + 2. We calculated the size of the rapid mix orifice using the current equation for D.PipeED. As plant flow rate increases, the diameter of the rapid mix orifice becomes too large to ensure that micro mixing occurs (Fig.1).

Instead, we looked into using a micro-mixing orifice sheet with many smaller

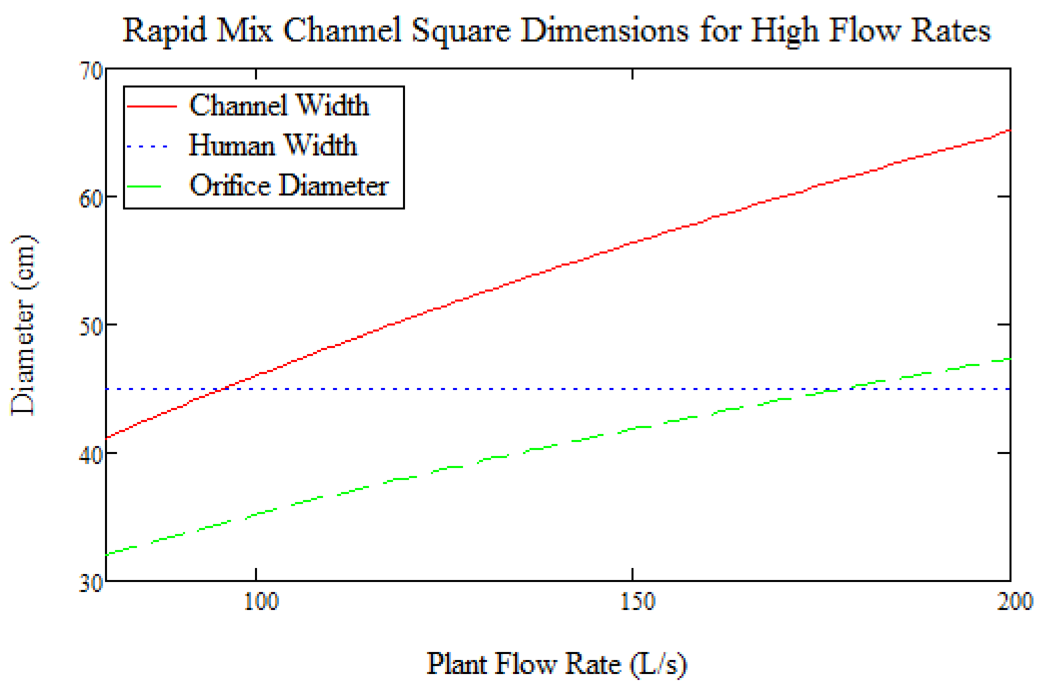

Figure 1: Rapid Mix Channel Dimensions

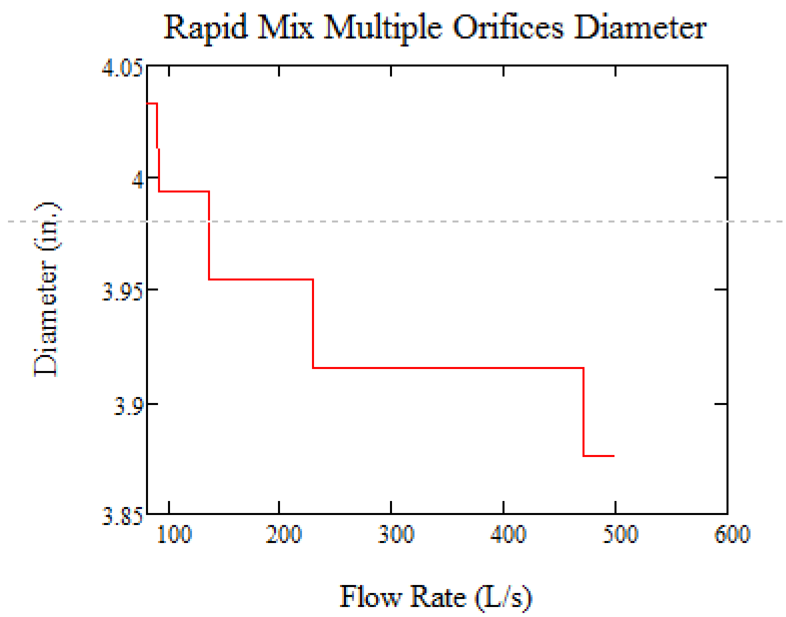

Figure 2: Rapid Mix Orifice Diameters for High Flow Rates

orifices instead of one large orifice. Assuming that the minimum spacing between orifices is the same as that of the LFOM (5 mm), we wrote code to determine the diameter of the orifices needed so that the combined size of all of the jets would not be greater than the size of the channel. Starting with the orifice diameter equal to the LFOM orifice diameter for a given plant flow rate, we created a function that would increase the diameter in 1 mm steps until the area of the orifices would fit in the channel with 5 mm spacing in between orifices. We found that the orifice diameter did not vary greatly with plant flow rate and remains around 4 in (Fig. 2).

Using the diameter of the jets, we determined the number of orifices needed by dividing the plant flow rate by the flow through each jet (Fig. 3).

Then we calculated the headloss through the micro-mixing orifice sheet using the diameter of the jets, the flow through one jet, and a minor loss coefficient for jets of 1. We found that this headloss is similar to the headloss in the rapid mix jets of lower flow plants with one rapid mix orifice (Fig. 4).

Using the orifice sheet headloss and the velocity through the channel (the same velocity used in our total channel headloss calculations) we calculated the minor loss coefficient of the orifice sheet (Fig. 5). The calculated K values are around 2, so our assumption was correct.

We calculated the ratio between A.in and A.out (cross-section areas of the channel in and out, respectively), taking the former to be the area of the jets through all orifices and the latter to be the area of the entire channel (and assum-

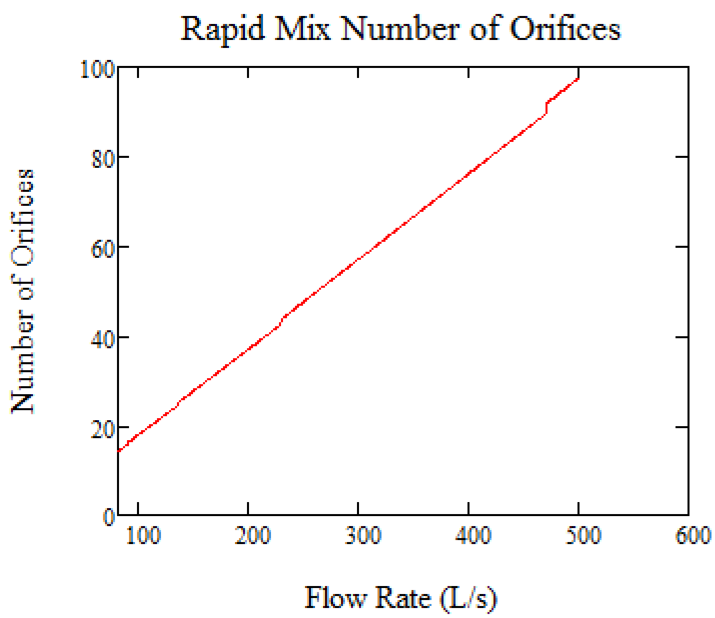

Figure 3: Number of RM Orifices for High Flow Rates

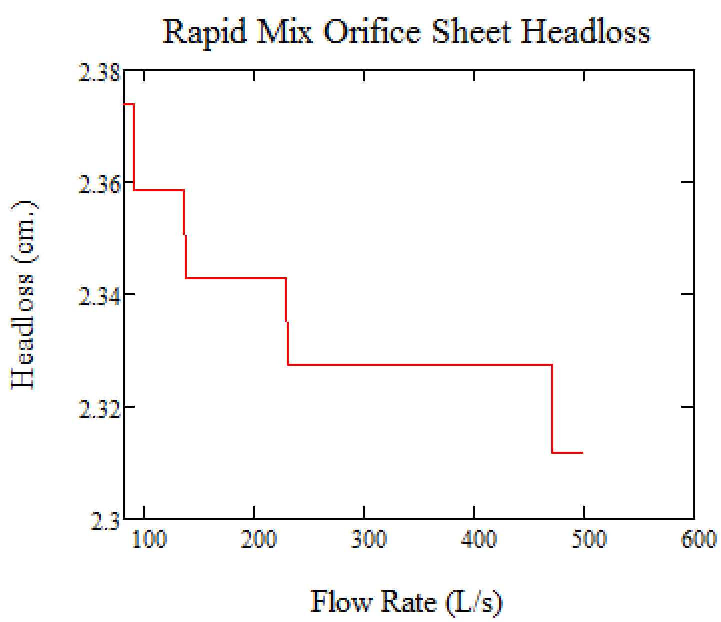

Figure 4: Headloss through RM Orifices for High Flow Rates

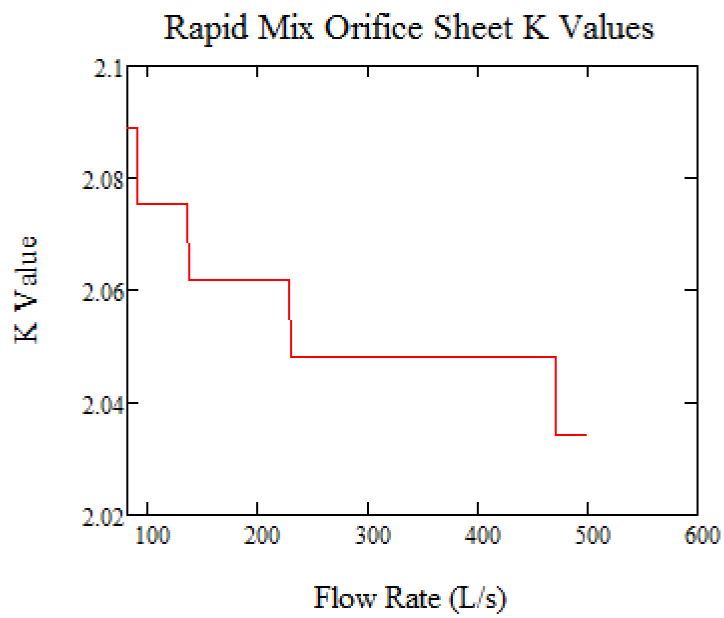

Figure 5: Orifice Sheet Minor Losses

ing full jet expansion and micro-mixing). As A.in/A.out increases, the headloss through the orifices decreases, which is expected. (Fig. 6). The porosity of the orifice sheet is slightly lower than 50%.

We found the spacing between the orifices to be very small. For example, the 80 L/s plant requires orifice diameters of about 4 inches, but the spacing between the orifices would be 0.05 in. We found that to lower the ratio of spacing to orifice diameter, we would need to lower our initial headloss assumption (Fig. 7).

The ratio between spacing and orifice diameter seems to be reasonable (at least 0.1) only when headloss is very small (Fig. 7). A smaller assumed headloss creates a larger channel cross-sectional area, which allows for lower velocities and more space between orifices. If we lower headloss to only 2 cm through the rapid mix channel, the channel size grows about 25%, which is not optimal.

Because of the spacing issue, we analyzed a different option: creating a "micro-mix gate" with either PVC pipes or rebar to create slots through which micro-mixing would be achieved (Figs. 8, 9). Assuming a porosity of 0.5, Ain:Aout is 0.5 and Vin:Vout is 2, so the minor loss coefficient through the gate is effectively 1 and the headloss through the gate is about half the headloss through the orifice sheet. The lower minor losses through the plant would lower the size of the channel, assuming the same 5 cm headloss. We calculate the space between the bars assuming the velocity through the spaces is double the velocity through the channel and an energy dissipation rate of 1000 mW/kg. We

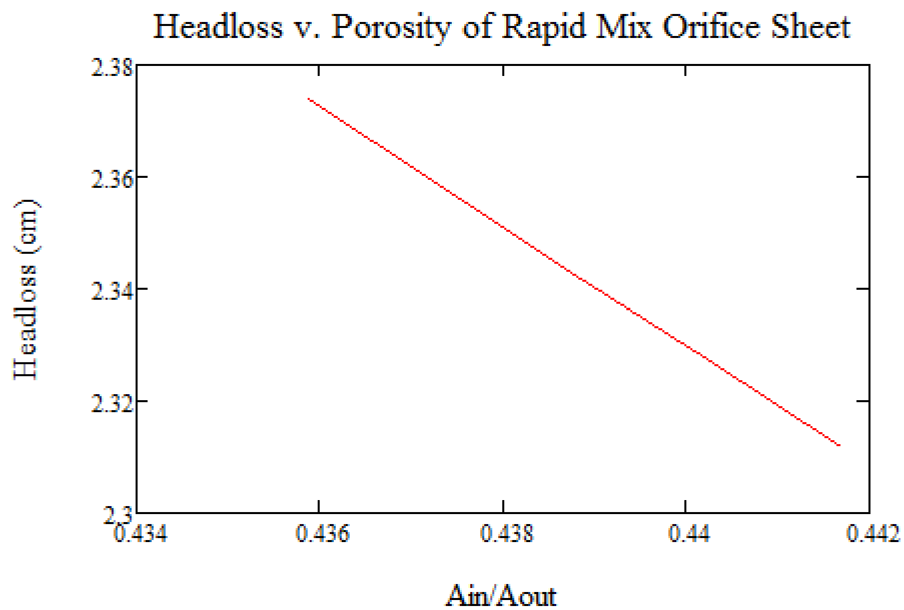

Figure 6: Headloss vs. A.in/A.out

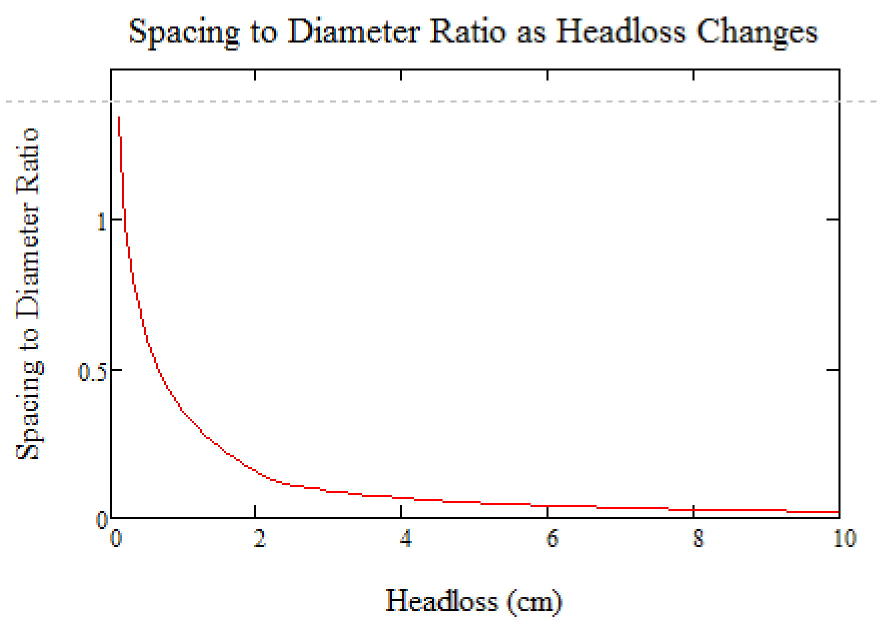

Figure 7: Spacing:Diameter v. HL

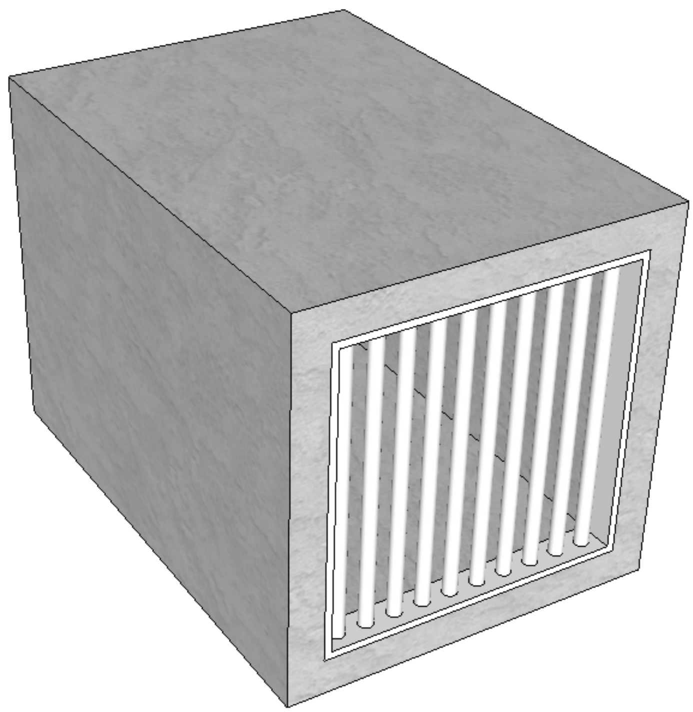

Figure 8: Rapid Mix Channel and Micro-mix Gate

then determine the number of spaces in the channel and, assuming there is one less pipe than there is spaces, we calculate the pipe diameter needed. Using the PVC pipes, we assumed there was no vena contracta effect. The bar diameter fluctuates around 1 cm (Fig. 10). The graph of the bar diameter oscillates because we want a whole number of bars; therefore, the diameter of the bar increases as flow rate increases until another bar is added, at which point the diameter decreases until another bar is added and so on.

When we considered the case for the non-corrosive aluminum, we took the vena contracta effect into account when determining the number of bars and spacing between the bars. The bar diameter decreased slightly to about 0.45 cm, so less material is needed (Fig. 11), but aluminum would be more expensive. This micro-mix gate would be placed at the end of the rapid mix channel, right at the entrance into the flocculator.

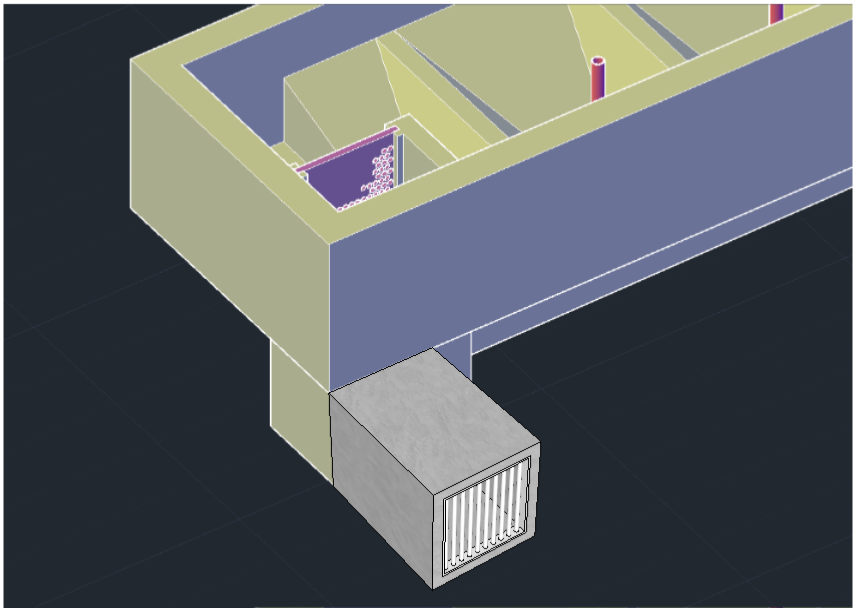

Figure 9: High Flow Rapid Mix Channel

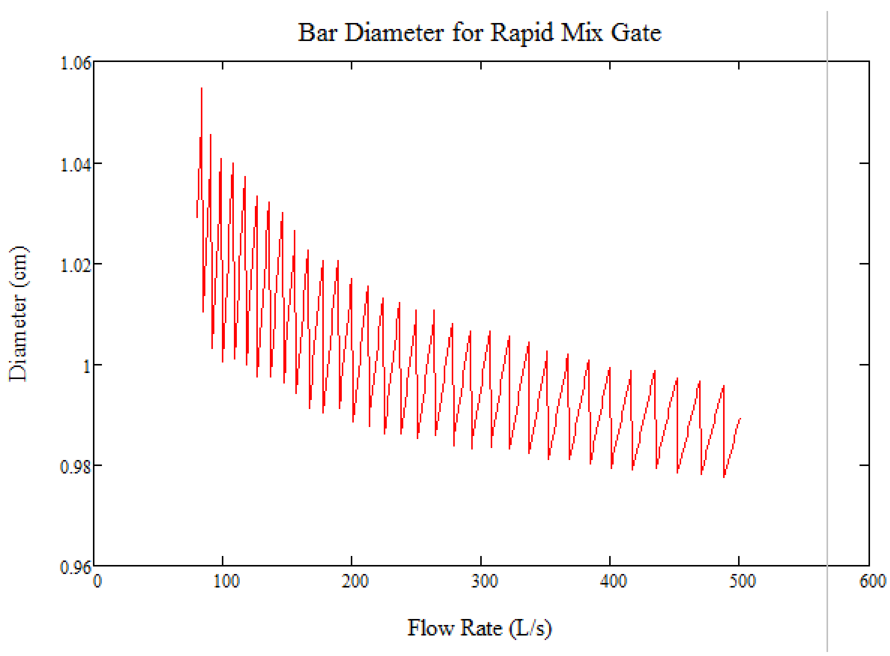

Figure 10: Bar Diameter v. Q

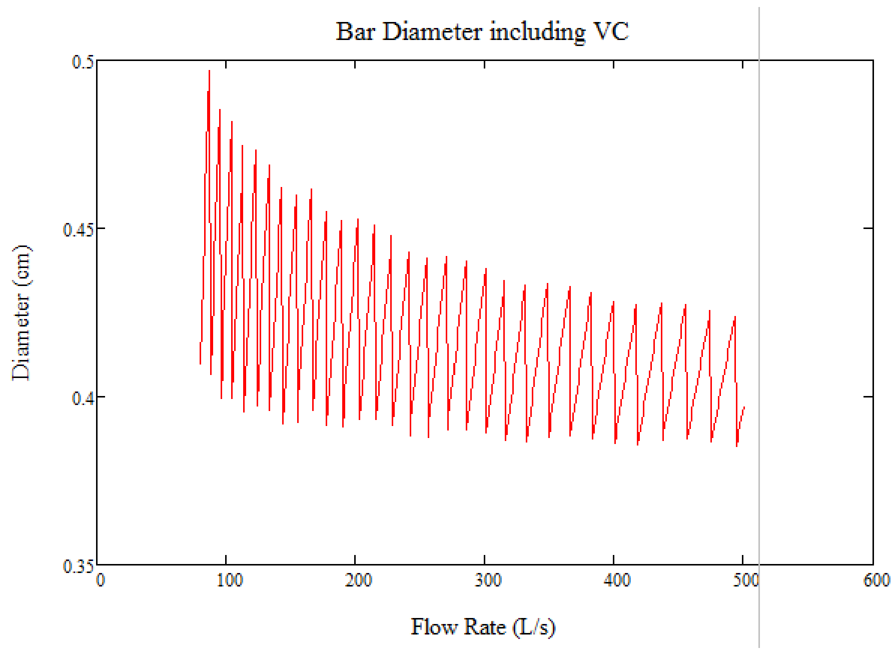

Figure 11: Rectangular Bar Diameter

4 Future Work

Continuing rapid mix high flow modifications, the three options (orifice sheet, PVC pipe gate or rebar gate) will be compared to determine the how to best achieve micro-mixing. The orifice sheet has higher headloss and smaller spacing while the rapid mix gate might be more expensive and difficult to implement. We can consult with our Agua Para El Pueblo contacts to see which option would be most feasibly constructed and implemented in the plants.

We may need to revisit and reconsider some of the assumptions that were made about the entrance tank design. For high flow plants above 200 L/s, the hoppers become very long while remaining relatively shallow. We might consider two rows of hoppers, or re-evaluating the height constraint on the entrance tank, keeping in mind their effects on the plan view area of the plant.

Finally, modifications to rest of the plant (starting with the flocculator) need further work and evaluation to update AguaClara technologies so that they are applicable to plants with high flow rates.