Floc Hopper Probe Team, Spring 2015

Steve Love & Garret Jancich

May 13, 2015

Abstract

The Fabrication Team's purpose is to address current issues or areas of improvement in AguaClara plants. This semester, the team's tasks included designing and fabricating a probe for monitoring sludge accumulation in the floc hopper. The floc hopper probe team created an operational tool for peering into the floc hopper in order to know when to drain it. The team also began work for developing the research capabilities of the probe. This would be achieved by taking image data via borescope snake camera and translating it into meaningful turbidity/DOM readings.

Table of Contents

Introduction

The floc hopper probe is used for measuring the depth of flocs in the floc hopper - a chamber extending off the sedimentation tank and separated by a weir. The upflow velocity pushes the flocculated particles into a floc blanket, which will pass over the weir at a rate dependent on the influent turbidity. As soon as the particles pass the weir, the upward flow ceases and they drop into the hopper. Unfortunately, the hopper itself isn't accessible aside from a 2" hole through the settled water channel. The purpose of the device is to allow operators to peer through the settled water channel and below into the floc hopper to determine how full it is and when it should be drained. The probe should be very simple to construct and operate, using low-cost and easily obtainable materials. Considering the small, circular pipes that open to the hopper, the probe should be thin and extendable for ease of use.

It is also useful to take images of the activity in the hopper. A borescope camera will be fed down through the probe to take such images. To further advance the research component of the probe, these images could be analyzed to produce turbidity readings over time and in varying tank conditions.

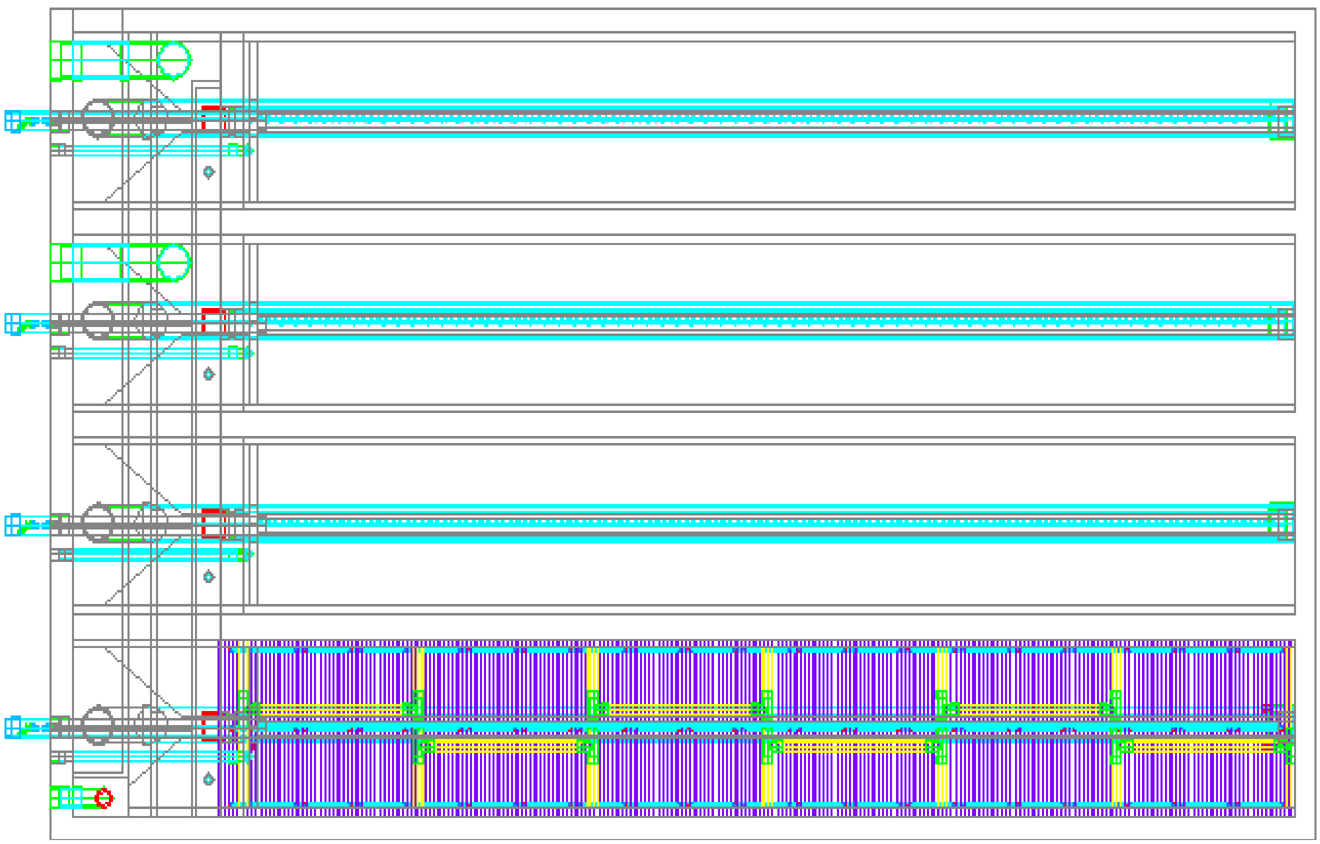
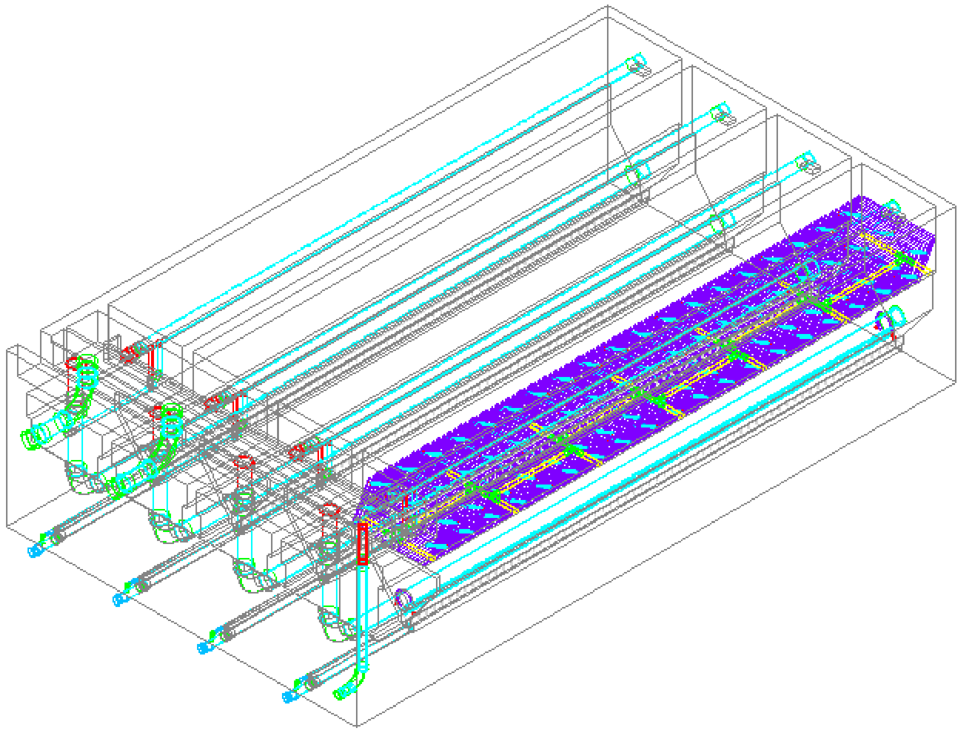
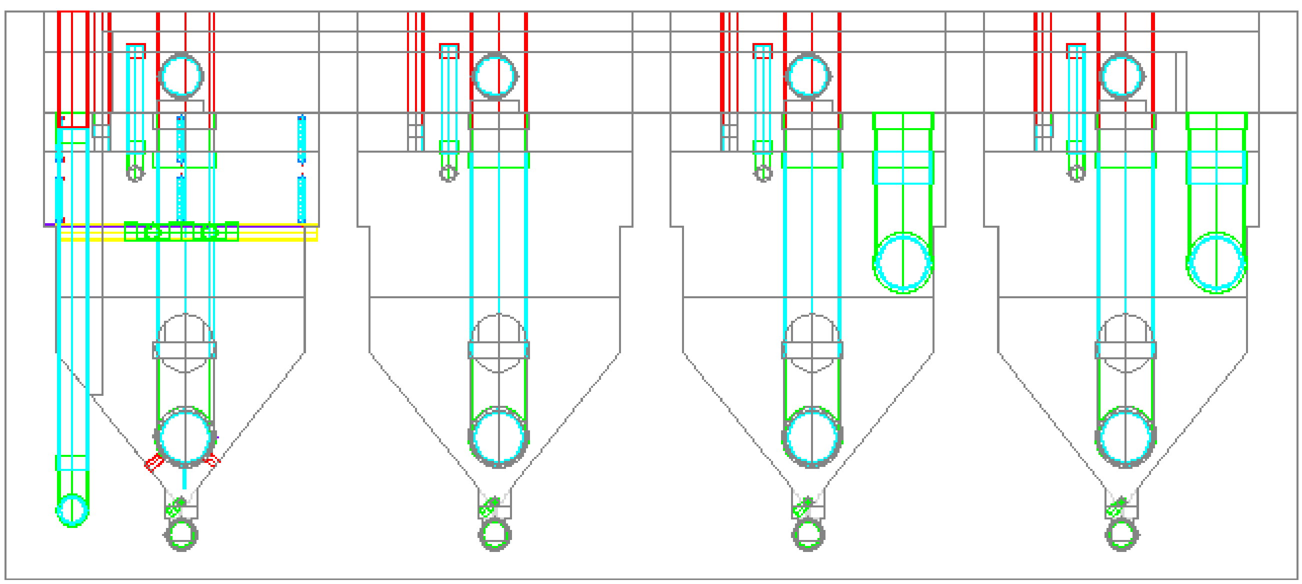


Figure 1: Schematic of sedimentation tanks in an AguaClara plant - aerial view.





(*Sed Tank angles*)

Figures 2 and 3: Schematics of sedimentation tanks in an AguaClara plant - full view and side view, respectively. Image 3 gives a good visualization of the cross-section that the probe will be going down into.

Literature Review

The floc hopper probe's most prominent challenge is limited access to the hopper itself. According to the Floc Probe Final Report from Spring 2014, a team analyzed the feasibility of sensors to determine turbidity. Their conclusion was that light is the best possible option. A device they created, the "sludge judge" was fabricated from a long pvc pipe and a transparent lens held on by an epoxy. The team ran into issues with the length of the pipe - it should be 6 feet to reach the bottom of the hopper, but that is not a compact and easily transportable size. Therefore, the new probe is made of two separate pipes (about 3.5 feet in length) that can easily be joined by a threaded union piece. The spring 2014 team also had issues with the epoxy smearing and clouding the lens. This challenge will need to be addressed when deciding on lens materials and implementation strategies.

From the same report, it is clear that testing will be an issue. In Spring 2014, they were unable to simulate the change in floc density and had too little information about the current conditions in the Honduras plants. We will either have to gain access to this information and these testing capabilities or create a more universally useful and resilient model that can be trusted and tested here.

According to another report from Fall 2012, Smartphone Turbidimeter, the idea of tethering a smartphone to a handheld turbidity meter was presented. This requires an energy source and understanding of technology to operate, which will increase price and requirements for operation. However, this idea can be useful in a new design application by instead using a low cost borescope camera to take image data through the probe looking into the hopper. This could easily connect to a PC or mobile device and be usable by those without much tech savviness. With further research, these images could ideally be manipulated to output turbidity readings.

Methods

The floc hopper probe design for the operational tool has been subjected to several phases of redesign, but fabrication of most of the physical probe itself is complete. Placement of the light source is the biggest remaining physical challenge, which will be discussed in detail later in this report. For insights and data in this semester's work, the current team has referenced previous AguaClara reports - mainly the Spring 2014 Floc Hopper Probe report.

Sketches of our initial design ideas and material choices are seen on the following page.

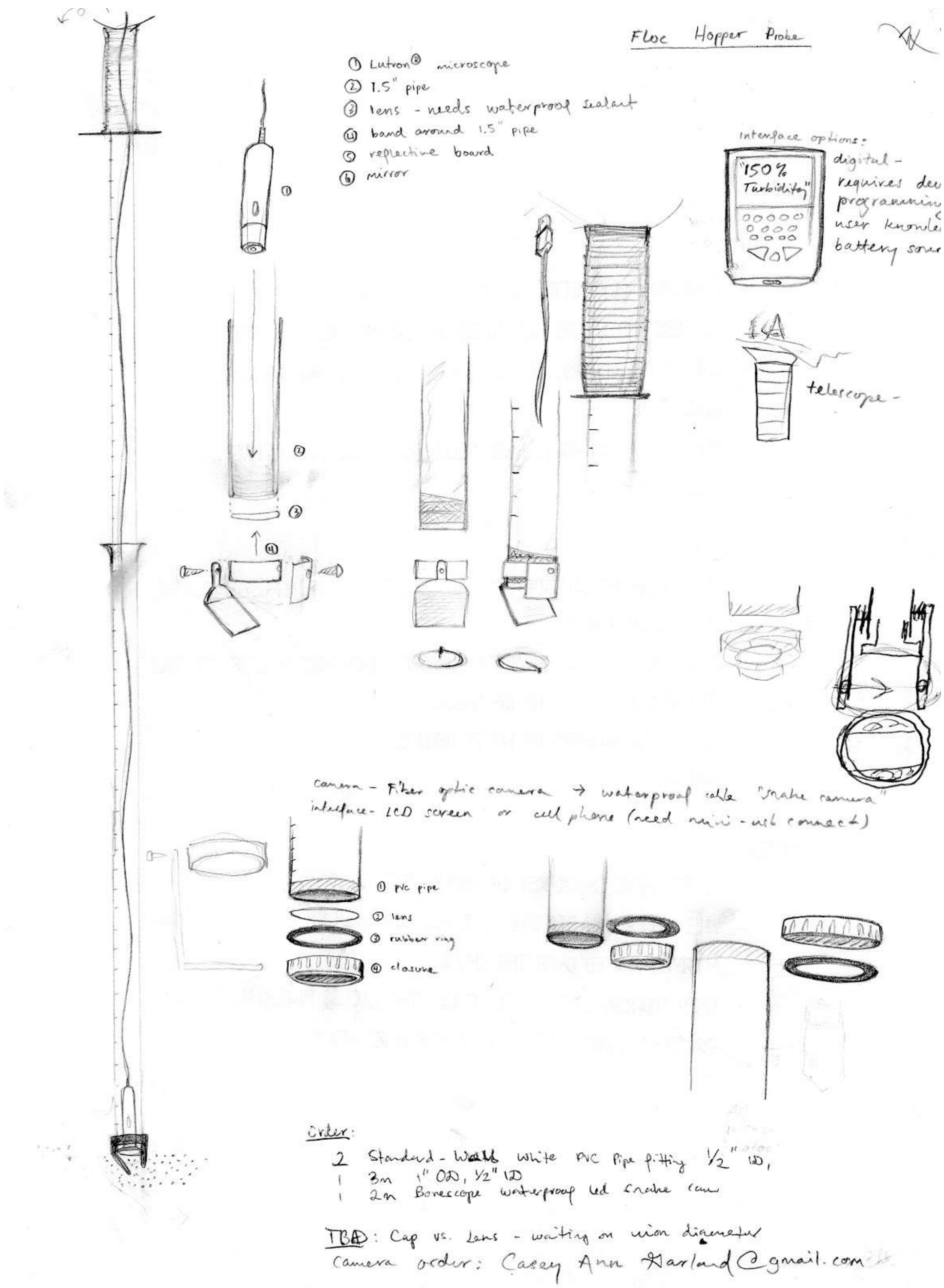


Figure 4: Sketches of possible probe designs. The leftmost sketch shows a generalized drawing of the whole probe, with the borescope camera inside. The other sketches show initial designs of the reflective piece and glass lens. However, more robust and simplistic design options were chosen for both of these components. Our next iteration of designs are shown in the sketches on the following page.

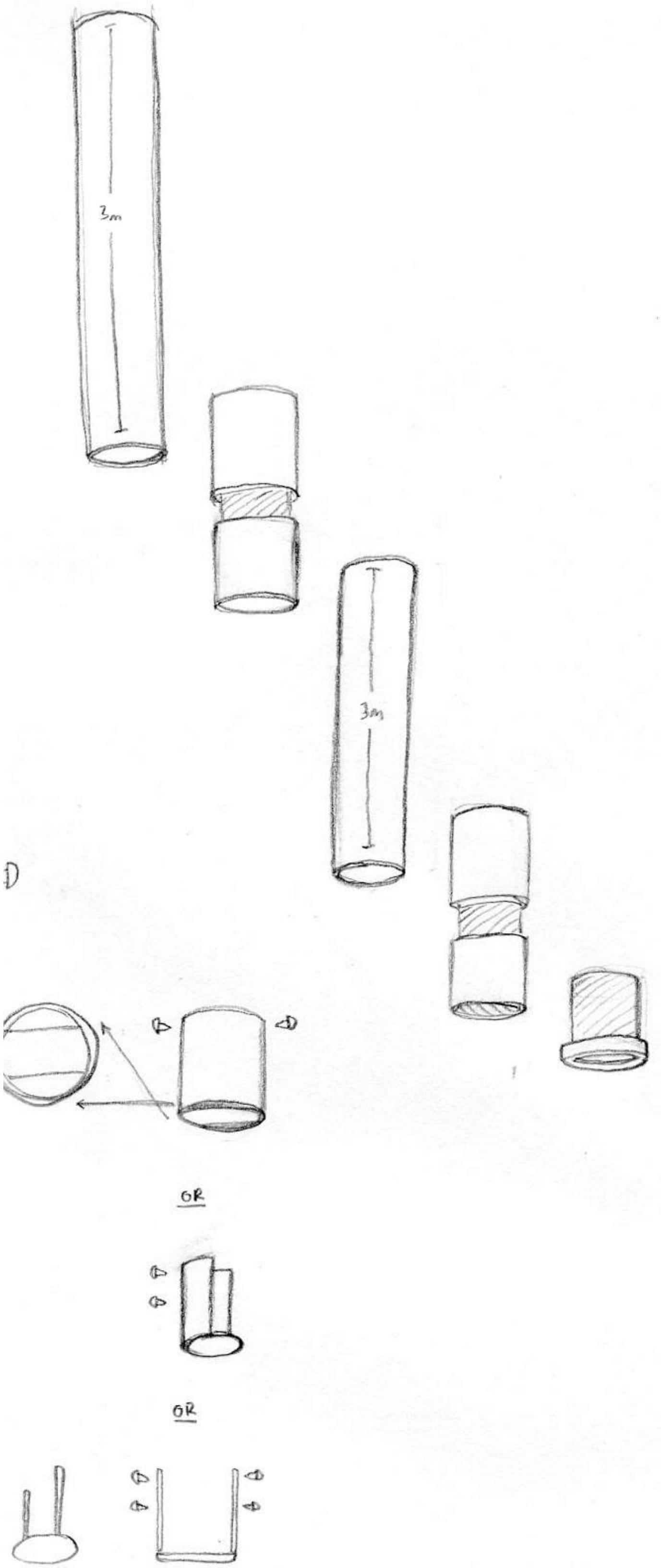


Figure 5: Sketches of the final tube and lens design, with three possible reflective head designs below (these three options were scrapped and redeveloped later on). The two 3.5 foot PVC pieces shown are joined by a union piece, with another union attached to the end of the second piece, which is where the glass lens will be screwed in. The bottom of the sketch shows three options for creating and connecting the reflective surface to put at the bottom of the probe. The top of the three is closest to the design we eventually decided on.

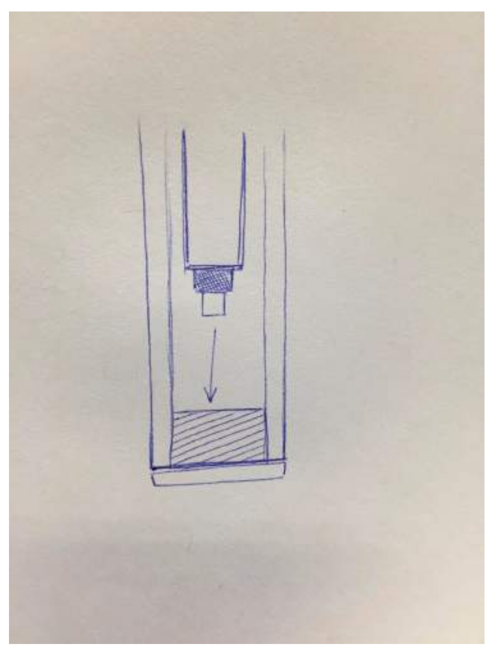
After the basic design was decided on and the materials were obtained, the team began fabrication. A union fitting was secured to one of the 3.5 foot PVC pipes (inner diameter 1.5”). A threaded union connection was secured to the end of the other 3.5 foot piece, into which a threaded metal piece capped with a glass lens (and hexagonal lens frame) was screwed. The watertightness of this connection was ensured by putting Teflon tape around the threads. The union attached to the first PVC pipe will allow for easy extendibility of the probe – the two pipes can easily be connected and separated. A piece of 1.9” (outer diameter) PVC pipe was then cut vertically to make it openable. It was fit snuggly over the hexagonal lens piece and reinforced with three flat head screws.

During construction of the probe, some challenges arose. First, the 2” tube was not large enough to fit around the hexagonal sight, but cutting the vertical slit down the pipe allowed for attachment. Second, when the flat head bolts were drilled into the sides, they pierced the tube, thus compromising the watertightness of the apparatus. However, reinforcing the threads of the screws with Teflon tape has restored watertightness, at least temporarily. If watertightness were to become an issue again after repeated use, it would be smart to get a new union piece to drill into more conservatively. One important element to emphasize for this process is the 2” limit imposed by the existing opening in the settled water channel. This fact makes buffers or nuts impractical when considering methods to uphold both the ultimate diameter restrictions and the innermost wall’s watertightness.

Another challenge arose when the snake camera would get caught on the lip of the hexagonal lens inside the pipe. This made it difficult to align the camera to peer straight down into the pipe. To counter the camera’s lightness and tendency to lodge at an angle, a ring of duct tape was added around its head and then pushed snug into a smaller pipe. The spongy nature of the duct tape catches on the inner diameter of the smaller pipe, and the camera now looks straight ahead.

Image 1 (left): Borescope snake camera with pipe casing. At the bottom of the image is where the camera head is held snug with duct tape ring.

Figure 6 (right): Sketch of snake camera in probe tube. The threaded hexagonal lens of the probe pictured at bottom. Snake camera head is shown, being held in place by duct tape ring (colored in on right), which is lodged into the smaller PVC tube.



Another big challenge to the probe's functionality was the fact that the boroscopic camera with built in LEDs created a glare when looking through the lens into the tank. This is caused by light refracting through the thick glass in an otherwise dark environment. To counter this effect, lights should be placed on the other end of the lens, shining in from the exterior. This semester, the team was not able to decide how to attach this light source and what type to choose. Two proposed design solutions will be presented later in this report.

In the team's final constructed design, a transparent pvc sheet was cut to allow light to pass into the pipe from the outside source. This sheet was sprayed with a "frosting" spray for an opaque effect so the light would not directly interfere with the view of the user and the camera. Black lines were then drawn horizontally to give a way to judge the level of turbidity due to depth. Gripping tape for the operator to hold was the final physical element added. Ideally, this would be purchased athletic gripping tape like that used for tennis racquets. For the team's purpose this semester, we used black electrical tape.

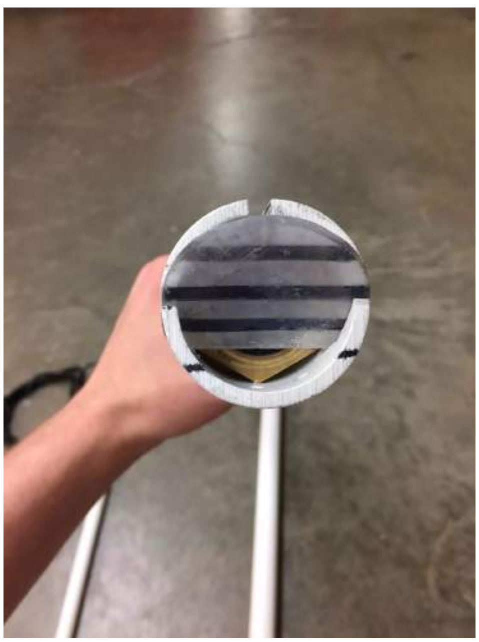


Image 2: Top view of the probe head. The opaque, striped plastic piece is lodged into the head of the probe at a 45-degree angle. The hexagonal lens is visible in this image, under the opaque plastic.

The team initially thought the final probe head design would be what is shown on the top of the next page (Figure 7). However, that design puts too much space between the hexagonal lens and the reflective plug. Visual and image-based confirmation of turbidity can only happen when that distance is on the order of half of an inch, according to Professor Weber-Shirk. The team went forward in cutting down the head to accommodate that constraint. Professor Weber-Shirk later advised that this plugged half inch space would get clogged with sludge, making meaningful data extraction unlikely. This challenge forced the team to reevaluate the design and propose alternatives. The decided alternative was to have the reflective surface set at an angle for the sludge to slide down. This can be seen in Image 2 above and will be discussed further in this section.

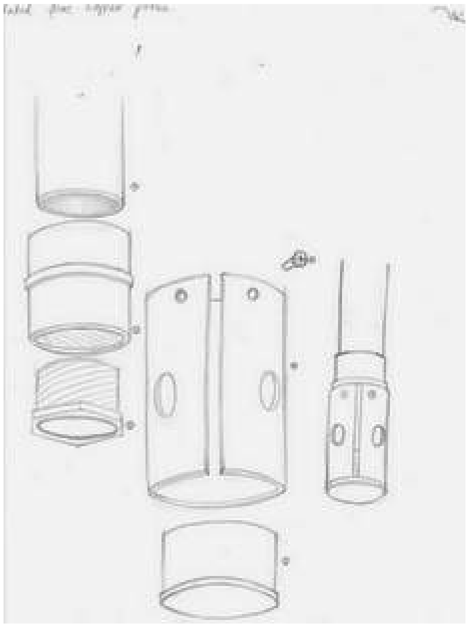


Figure 7: The team's initial "final" design of the head of the probe. On the left is the hexagonal lens piece with union. In the middle is the slitted larger PVC piece with circular holes cut in it to allow for water flow through. The plug is below it. On the far right is what the head looks like when fully assembled.

However, upon further review and input from Professor Weber-Shirk, the design was altered considerably.

A new design was then fabricated that leaves about a half inch of space between the lens and the surface. The surface is now open-faced and slanted to ensure that sludge will slide down and not get stuck there. This idea is similar to some our our first design ideas, which can be seen in Figure 4. The slanted reflective surface has three black stripes on it to make judging the turbidity clear. It has also been "frosted" with a spray to make it opaque. This will scatter the light from the LED more evenly and prevent it from directly interfering with the view of the user or camera.

The opaque plastic piece is lodged into the probe head at about a 45-degree angle. The head also has small holes around the top to increase water flow through the analysis area.

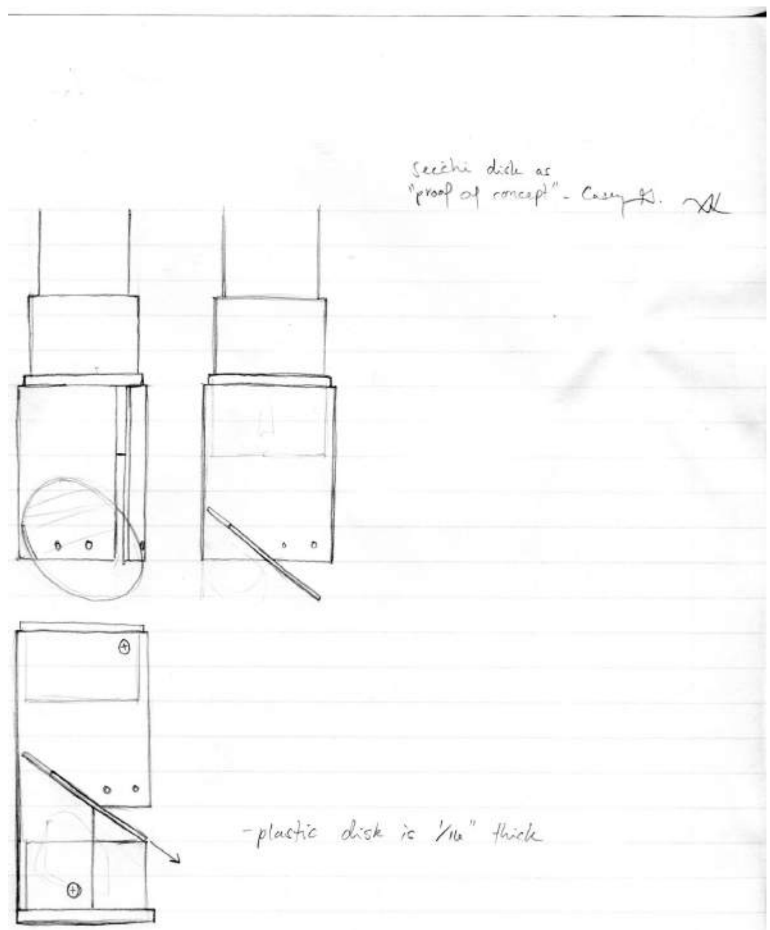


Figure 8: The image on top shows two perspectives of the most recent head model.

The bottom image is one possible design alteration in which an LED is secured in the chamber beneath the slanted sheet.

Image 3 & 4: Physical replications of the (Figure 8) design as it is currently.

Image 5 & 6: The complete unassembled probe.

Analysis

Image 7: View looking down the entire probe tube. The black stripes of the opaque piece are visible at the bottom.

The material and general construction have been finalized, but with recently discovered challenges relating to the light source, designs will need to be altered. The analysis of the probe's effectiveness from the operational perspective has mostly depended on visibility when looking down the tube and successful watertightness. Though the screws did puncture the wall of the tube, watertightness has been ensured by teflon tape around the flathead screws. This does, however, create the need to keep the screws as they are and rewrap the teflon tape if they are removed. Though the borescope camera is waterproof, watertightness of the entire tube is necessary to maintain visibility and a clear lens. Placing a light on the external side of the lens will improve the operator's visibility, and visibility for the camera and its accompanying software. The glare dilemma creates a task for future work regarding the placement of a light source.

The snake camera's images could also be useful for recording and tracking quantitative turbidity readings. Recent CEE research has been done on transferring image data to turbidity readings, which would enable the probe operator to record a body of this information. Many new analyses could result from that.

Conclusion

Image 8: Assembled probe in relation to a 6” user.

The team has tested several designs for visibility into the floc hopper, so an operator can determine when it needs to be drained. The probe is watertight and disassemble-able for easy transport, but with recently discovered challenges, the design of the probe head lighting needs to be altered to optimize visibility. The snake camera itself has capabilities for easy image data recording and reading via a borescope camera and mobile device/PC.

The final probe design can be easily replicated with minimal technological intervention. As of now, the head of the probe is made up of a larger piece of PVC piece, slit lengthwise to conform to the hexagonal structure of the lens. This slit piece secures the slanted surface that aids in measuring turbidity through light reflectance readings. The team has investigated the alternative head design with an opaque slanted surface so that sludge will not get trapped, obscuring the operator's view and interfering with meaningful image interpretation. The borescope snake camera will be safe from surrounding water and held stationary by the smaller internal PVC pipe.

Future Work

The team finalized fabrication of their redesigned probe, but unforeseen challenges have forced the team to consider new options relating to the light source. Alterations will consist of methods to secure the LED light(s) opposite the opaque slanted sheet. More detailed work with the borescope camera will take place simultaneously. The main challenges going forward will be ensuring the LED’s effectiveness and making the camera images translatable into turbidity data via light-testing.

Two possible solutions are a waterproof LED candle held in the chamber of the head design (as in the bottom of Figure 8) and waterproof mini balloon LEDs. The candle is a potential option because it is remote operated, thus reducing the need to remove the screws securing the probe head. However, the singular source of light may not project ideal clarity at the probe end. The mini balloon lights on the other hand offer multiple points of light, but the method of securing them may be a dilemma. A redesign is not necessary if these can be anchored in the current model.

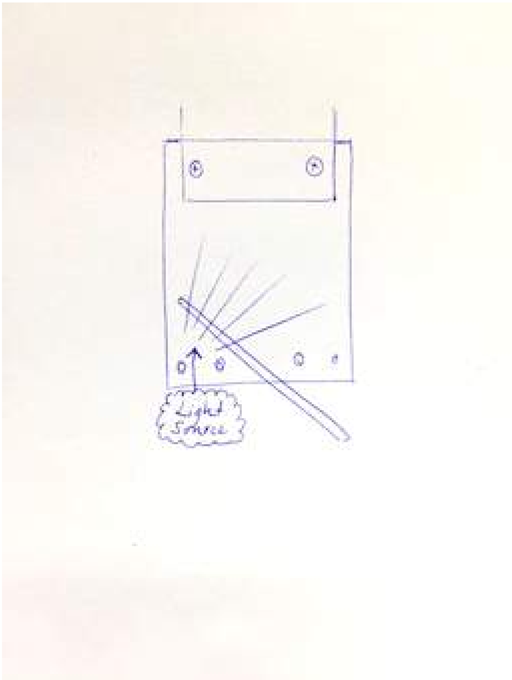


Figure 9: Future work involves finding and securing an external light source to the current model.

Link to candle LED:
http://www.100candles.com/i-6201/Remote-Controlled-Submersible-LED-Light?affId=121&gclid=CKfr44XercUCFSYV7AodRVAAKw

Link to balloon LEDs: http://www.amazon.com/Vktech-Waterproof-Balloons-Lights-Decoration/dp/B00C1XK15S