Floc Probe, Fall 2014

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Abstract

The sedimentation tanks at AguaClara sustainable drinking water treatment plants are performing well, but they can perform better. When floc settles it becomes sludge. If there is sludge buildup in a sedimentation tank, a host of problems follow: uneven water flow through the sedimentation tank, impaired performance, anaerobic digestion, and methane production. However, if a sedimentation tank can be designed to prevent any flocs from settling, then the drinking water treatment process will never have to be stopped, and the sedimentation tanks will never have to be cleaned. AguaClara is investigating the creation/use of a “Floc Probe” to better understand floc behavior and achieve this improved tank design. The research tool will be used to survey currently functioning sedimentation tanks in Honduras to identify where sludge is building up. Sonar has been found to be a potential solution. Sonar can detect substances of varying densities as well as record at what depth the substance was found. This technology can therefore distinguish between flocs and sludge, and can also recognize the amount of sludge buildup.

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Introduction

It is difficult to know what is occurring inside a sedimentation tank, because it is too dark. Plate settlers block light from the top, and the remaining four sides are walled by concrete. Therefore, theoretical understanding based on models, designs and calculations is difficult to test. AguaClara's goal is to purchase or create a research tool, or '**Floc Probe**,' to give the AguaClara team an understanding of what transpires in a full-scale sedimentation tank during operation. With this tool, AguaClara can potentially design a sedimentation tank that would keep flocs consistently suspended and never require sludge cleaning. If all possible sludge accumulation can be prevented, then maximum performance from the sedimentation tank will be achieved. Therefore, the Floc Probe needs to be able to identify sludge buildup at the bottom of the sedimentation tank. Current research shows that sonar technology is a potential solution for this problem.

Literature Review

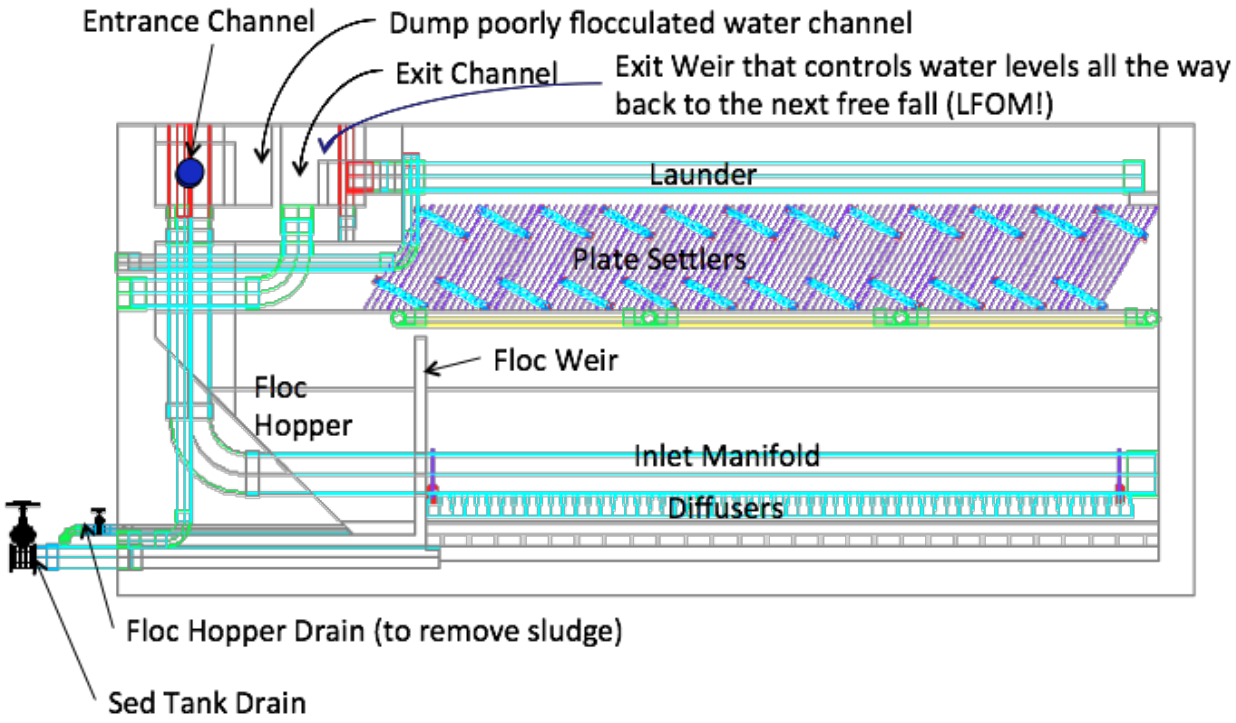
Sedimentation Tank and Floc Blanket

In an AguaClara drinking water treatment plant, the sedimentation tank comes after the flocculator, but before the filter(s). The tank consists of an inlet manifold with vertical diffusers to feed water into the tank, as a line source, from the flocculator. A semi-circular half-pipe exists underneath the vertical diffusers to serve as a jet reverser to keep the flocs in the tank suspended. Flocs are kept suspended in the sedimentation tank to create a floc blanket.

Cutaway view of the geometry of half of AguaClara's sedimentation tanks based off of experimental apparatus by Casey Garland. Note the formation of the floc bed.

A floc blanket is a dense, fluidized bed of particles that forms in the tank below the plate settlers and acts as an additional flocculator, providing more collision potential in the plant. As water from the flocculator travels from the diffuser and the jet reverser upwards towards the plate settlers, it passes through the floc blanket. Flocs in the water collide with the particles in the floc blanket and build larger particles that settle more easily. Also, the constant resuspension of flocs in the floc blanket reduces the buildup of sludge at the bottom of the tank, and also reduces the need for emptying and cleaning. Whenever flocs settle onto a surface, the compacted aggregate becomes sludge.

The plate settlers placed above the floc blanket settle flocs while allowing water to flow past and into the exit launders. Flocs that settle out due to the plates join the floc blanket. To maintain the level of the floc blanket, a floc weir is implemented. If the level of the floc blanket is higher than the floc weir, then flocs flow over the weir and into the floc hopper. The floc hopper is attached to the sludge drain that can be emptied periodically. This reduces the buildup of sludge in the sedimentation tank. To learn more about the sedimentation tank, follow this link and download the lecture notes on sedimentation.



A profile view of the sedimentation tank.

Failure Mode and Its Effects

Sludge buildup at the bottom of the sedimentation tank is the sedimentation tank's failure mode. If all aspects of the sedimentation tank are being executed perfectly, then no flocs should be settling at the bottom of the tank; all flocs should be constantly suspended.

Problems arise when sludge accumulates at the bottom of the sedimentation tank. The sludge degrades anaerobically, causing methane bubbles to form. These bubbles not only lead to foul smells, but also push flocs out of the sedimentation tank and into the exit launders. This increases the turbidity of the effluent water, which puts a higher strain on the filtering process.

A buildup of sludge also blocks the vertical diffusers, which are responsible for bringing water into the sedimentation tank. This leads to unequal flow through the diffusers causing water to travel through the remaining unclogged diffusers at higher velocities. This leads to two negative effects: flocs are pushed out of the sedimentation tank due to higher velocities and flocs settle where velocities are lower. Therefore, effluent water turbidity rises and more sludge is accumulated at the bottom of the tank.

Previous Work

No previous work has been done for this project.

Methods

The goal is to develop a method, using a device, to understand what is going on inside of a sedimentation tank. The team performed research to see if technologies already existed that could achieve this goal. After speaking with Professor Monroe Weber-Shirk and graduate student Casey Garland, and multiple internet searches, a list of companies and technologies was developed. As the semester went on, this list was constantly edited.

The Floc Probe team found a device called the Sultan Sonar System that was applicable to the team's needs. After speaking with the respective company, the team was told that a device could be lent for experimentation, free of charge.

Graduate student Paul Simonin in Natural Resources explained to the team what constraints to focus on with fishfinders that would work for this application. He also suggested to look into a GoPro camera and diver's light combination.

Results and Discussion

Five major technologies have been researched: Sultan Sonar System, fishfinders, diver's light and GoPro camera combination, ARIS 3000 (underwater sonar camera), and 4Deep Submersible Microscope.

Product Name	Sultan Sonar System	Fishfinder	Diver's Light and GoPro Camera	ARIS 3000	4Deep Submersible Microscope
Pros	Would be able to identify sludge accumulation and at what depth.	Inexpensive, has abilities similar to the Sultan Sonar System, and produces an image.	Easy to use, inexpensive, 1080p120 video, can control remotely.	Provide a live feed video without light.	Able to achieve detailed images, without light, of small sample spaces.
Cons	Device has to be parallel to surface being sampled. Can only perform point samples.	Will not provide quantitative data, easily disturbed by air bubbles.	Will not provide quantitative data, will not be able to remove unnecessary data. Questionably effective given poor visibility due to high density of flocs.	Too expensive.	Can't take images of large sample areas. Sample area being imaged must be free floating.
Price Range	$4000-$5000	$200-$2000	$700-$1000	$80,000	NA
Yet to be Discovered	If the sensor can detect sludge, which has a density close to water.	If it would be able to detect sludge.	Is there a way to see with a camera despite the high turbidities.	Is there a less expensive device that has similar technology?	NA

A quick reference table for the team's research.

Sultan Sonar System

The Sultan Sonar System seems to be the most promising option because it is affordable and is already used in the wastewater industry for similar purposes. The device operates by emitting high powered acoustic pulses that are reflected from the interface density selected.

These reflected signals are then processed using the company's software, which is able to discard reflections from lighter floating densities and stratified layers. This device would be able to identify accumulated sludge in the sedimentation tank and at what depth. However, there are two disadvantages: the device can only sample when the sensor is perpendicular to the surface it is sampling and it can only perform point samples. The angles would have to be perfect when using this instrument, the entire bottom of the tank cannot be surveyed in one sample, and plates will have to be removed for sampling. Also, experimenting will have to be done to see if the Sultan Sonar System is sensitive enough to detect the marginal density difference between sludge and water.

An image of the Sultan Sonar System.

Fishfinders

Fishfinders use sonar technology to locate objects. The device produces a sound wave that is sent through the water. At the source, the wave is narrow, but as it goes deeper in the water, it widens. If the sound wave comes in contact with something in its path, a part of the wave bounces back to the fishfinder. The device uses the time it takes for the wave to come back to its source to calculate the distance of the object. However, if an object exists directly under another object, both will be detected by the fishfinder. These detections are then put onto a screen to produce an image. The team hopes to use the fishfinder in conjunction with the Sultan Sonar System. With the fishfinder, the team might be able to produce a constantly updated image of the bottom of the sedimentation tank. With this image, the team would be able to detect the location of sludge buildup, and then point the Sultan Sonar System at the problem area to produce numeric data.

The team learned from Paul Simonin that for short distance detection, frequencies between 200 to 430 kHz work best for fishfinders. Also, if large areas need to be sampled in short distances, then wider angles return larger samples. Paul explained that fishfinders work by detecting densities that are different than water. In the case of fish, fishfinders detect the swim bladder that fills with oxygen to control the depth at which the fish swims. Therefore, experimenting will need to be done to see if fishfinders are sensitive enough to detect the marginal density difference between sludge and water.

Underwater Video Cameras

Diver's lights are extremely bright and are meant to be used in completely dark, turbid waters. GoPro cameras are waterproof, rugged, and provide high quality videos. A new feature also allows for the camera to be controlled remotely with a smartphone. If the team can attach both items to some sort of pole, this could prove to be the easiest solution. Experimenting will need to be done to see if the GoPro camera can create clear videos while being in water with floc concentrations between 2000 mg/L to 5000 mg/L.

The ARIS 3000 and Submersible Microscope have been ruled out. The ARIS 3000 was an interesting device, and could have fulfilled the team's objectives. The camera's optics require a minimum distance of 50 centimeters for a clear view. Objects closer than 50 centimeters become blurry due to a collapsing of the field of view. The camera has a range of 6 to 8 meters, depending on the settings. After reading about the device's capabilities and watching videos produced by the device, the team realized that the ARIS 3000 could be a viable solution if one was placed on either side of the sedimentation tank, thereby covering the entire view of the bottom. This way, the AguaClara team could observe any sludge buildup in real time. However, when a price quote for the camera was asked for, the team realized that the device was out of economical reach. With shipping, the device would cost $80,400.

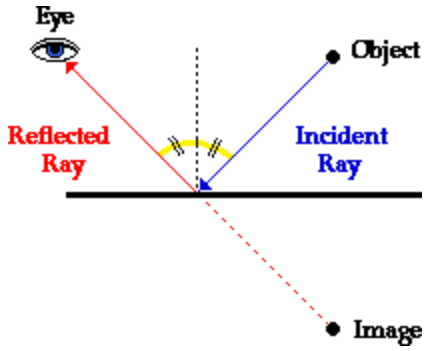
After researching the functions of the Submersible Microscope, the team realized that the magnitude of view was too small. By using lasers, the device analyzes small particles in a very small field of view. If the team wanted to research floc behavior in the floc blanket at a microscopic level, this device would be useful. With this problem's parameters however, there is no need for that much detail.

Future Work

Floc Probe

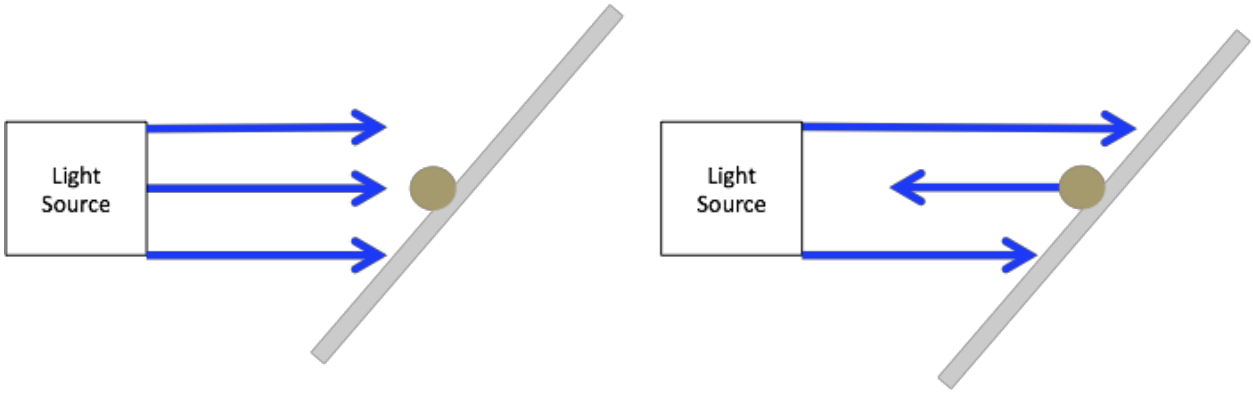
Work on designing, fabricating, and testing different floc probes.

Have some form of a light detector. If light is shined directly onto the angled concrete bottom of a sedimentation tank, no light should reflect directly back, because the angle of incidence is equal to the angle of reflection.



If there is nothing between the light and the concrete, then no light should reflect in the direction of the light source.

But, if an object was on the angled concrete bottom, then there is a possibility of direct reflection. Therefore, if a light sensor, like a photoresistor, was located next to the source of light, then a direct reflection could be detected and could prove the presence of sludge.



If something comes between the light and the concrete, then some amount of light will be reflected back to the light's source. If a light sensor is located somewhere near the light's source, then the light reflected can be detected. If light is detected, then it could indicate the existence of sludge on the bottom of a sedimentation tank.

Somehow collect a physical sample of water near the concrete bottom to prove the presence of sludge. If a sample could be collected with some sort of scraping device, the sample could be analyzed for densities that compare with sludge.

Research more technologies and methods that could be used for this project's goals.

Experimental Apparatus

Set up an experimental apparatus for testing the potential floc probes:

The team had to consider how to test any products and sensors acquired. The experimental setup must approximately reflect the appropriate dimensions that are being measured. Also,

many of the sonar technologies considered require a minimum distance to operate. Team members should explore the option of using the Defrees Hydraulic Laboratory due to the availability of several tanks that would be large enough to fit our purposes. Specifically, there is a sediment testing flume that would be appropriate for two reasons: 1) The flume is used for testing fluids experiments with sediment, meaning that adding sludge would not negatively affect the tank, 2) the bottom of the tank is sloped like AguaClara's sedimentation tanks.

Another possible experimental apparatus involves using a 200 liter drum and stone patio pavers. The 200 liter drum would be used to represent the depth of a sedimentation tank, and the stone patio pavers would be used to represent the sloped, concrete bottom. Benefits associated with this apparatus revolve around ease. A smaller environment is easier to control, and therefore easier to adjust. Even though the length of the sedimentation tank would not be emulated with this apparatus, the objective of single depth sampling would still be achieved.

Followup for Future Floc Probe Members

One of the more promising products that the team explored during the Fall 2014 semester was the Sultan Sonar Probe from Hawk Measurement Systems. At the time of writing this report, the floc probe team provided Hawk with a shipping address, and is waiting on the delivery of the Sultan probe.

Team members have been in contact with Steve Varholy, the Regional Business Manager for the Northeastern United States. His contact information is listed below.

Steve Varholy
Regional Business Manager
(Northeast USA, Eastern Canada)
Ph: +1-978-595-6464 / +1 888 429 5538
Fax: +1 978 304 1462
Email: steve.varholy@hawkmeasure.com

In addition to Steve, the team was also put in contact with Rod Carroll, a sales representative at RL Stone who distributes Hawk products. Rod has worked in the Ithaca area, and has installed Hawk products at the Ithaca Drinking Water Treatment Plant. Steve suggested that team members contact Rod when they receive the Sultan Probe for instructions on use and setup. Rod's contact information is listed below.

Rod Carroll
Ph: 315-479-7979
Email: Rodc@rl-stone.com

It is suggested that future team members stay in contact with both Steve and Rod, who will provide valuable guidance in effectively utilizing the Sultan Probe. Additionally, team members may want to contact Rod and go on a tour of the Ithaca Drinking Water Treatment Plant to learn how they use Hawk's products.

References

Use Citation Machine APA Format

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