Preliminary Ecuador Plant Design

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Executive Summary

The design team of AguaClara has come up with a preliminary design for a plant as per the request of Hugo Castillo. The plant is designed for a flow rate of 3 liters per second, and is powered by gravity. The plant is designed to treat turbid surface waters for distribution systems already in place. The Ecuador plant design contains two separate sedimentation tanks, three flocculator channels, and an entrance and exit channel. The plant has a footprint of approximately 10.5 square meters.

The following document contains an overview of the plant design, including drawings, dimensions, and overall process descriptions. It should be noted that this is a preliminary design and is subject to change as continuing research brings forth design changes.

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1. Design Overview

The automated design process breaks up the plant design into nine different elements: entrance tank, flocculator, inlet channel, sedimentation inlet slopes, sedimentation tank, settling plates (lamella), sludge drain, sedimentation effluent launder, and exit channel. Given a flow rate and specifications for the materials that will be used, the program is designed to make all necessary calculations and output dimensions for the plant. It is up to on-site engineers to conduct construction details and perform any surveying that may be necessary.

The following report outlines the different design elements and processes associated with the plant, including drawings with dimensions. Every element of the plant follows a variable naming guideline, which can be found online. However, in this report a description is given next to the dimension, with a rendered image showing those dimensions. Please note that the given dimensions are not an exhaustive list, but are a general overview to give an idea of what the plant will look like. Additionally, the given dimensions do not take into account wall thickness.

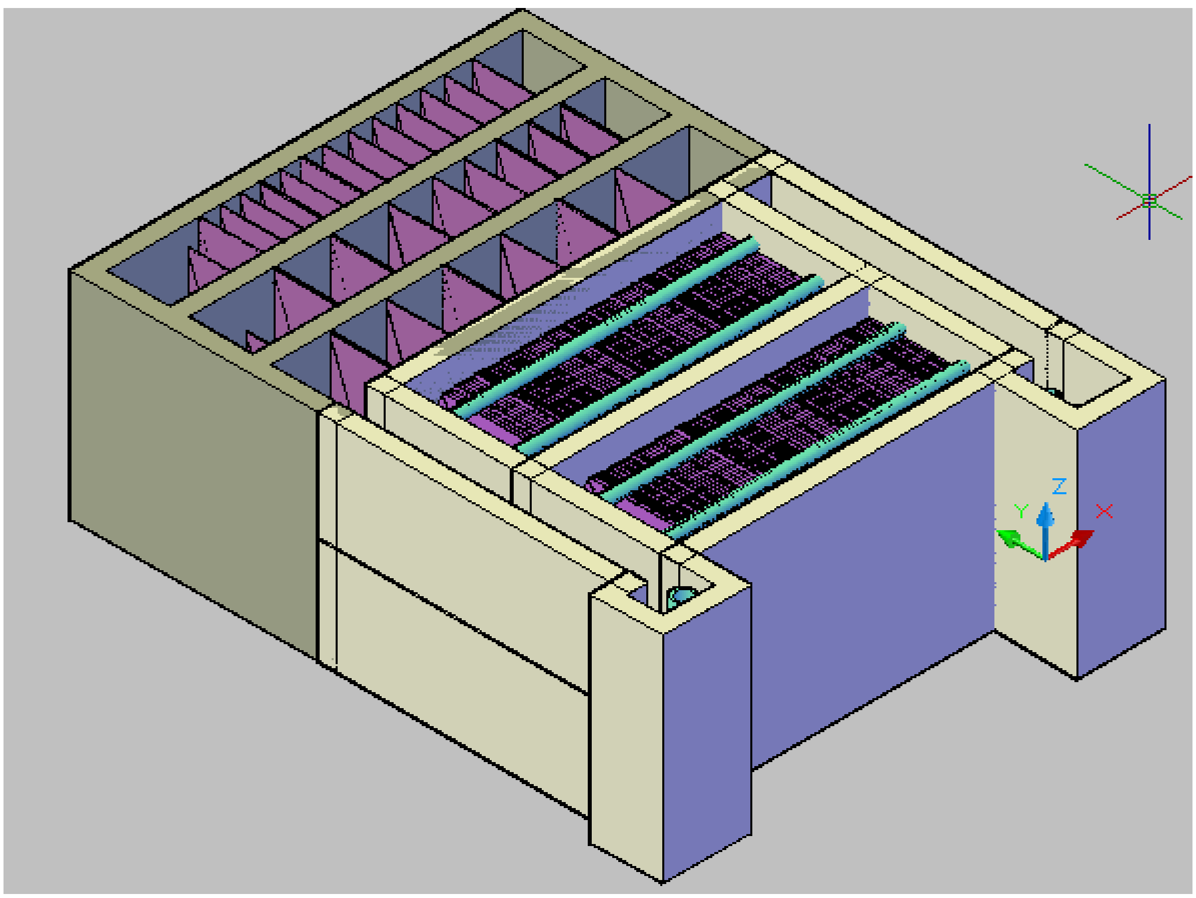

Figure 1: Ecuador Plant Design

2. Entrance Tank

The entrance tank feeds water from the source to the plant and causes rapid mixing to take place as chemicals are fed into the water. It is designed to be a single channel running the length of the flocculator, and includes a grit chamber. The plant is designed for 60mg/L of aluminum sulfate to serve as coagulant, however this concentration can be changed. The water then flows through a riser pipe called a linear flow orifice meter (LFOM) so as to create a linear relationship between the height of the water in the entrance tank and the flow rate through the plant.

The number of orifices and diameter of the orifices are calculated in the program, as well as the diameter of the riser pipe. The dimensions for the entrance tank are also given. The following are the particular dimensions for the plant's entrance tank:

Dimension	MathCAD Variable Name	
Length	L_{Et}	2.012m
Width	W_{Et}	0.45m
LFOM Pipe Diameter	ND_{Lfom}	12in
Height	H_{Et}	2.155m
Water Depth	ZW_{Et}	2.055m

Information regarding the process of feeding chemicals into the plant can be found online.

2.1. Grit Chamber

A grit chamber is added to the entrance tank to help with the issue of floating flocs (described later in the document). The grit chamber just takes up a portion of the entrance tank, and contains gravel at the bottom. The purpose of the grit chamber is to diffuse any dissolved oxygen accumulated in the water. The length of the grit chamber is given below.

Dimension	MathCAD Variable Name	
Length	L_{Grit}	0.823m

3. Flocculator

The flocculation tanks serve to mix the water with aluminum sulfate to promote flocculation. Flocculation is a simple gravity-driven process that creates flocs (collections of particles) which settle out in the sedimentation tank. The flocculator is divided into vertical channels by baffles and the water flows up and down through these channels.

Before entering the floc tank, the water is mixed with aluminum sulfate which acts as a coagulant. Each 180 degree turn through the flocculator encourages mixing and collisions of the particles. Each collision offers a small probability of sticking, and as a floc proceeds through the tank it increases in size. The larger it gets, the more likely it is to settle out in the sedimentation tank.

The flocculation program calculates the dimensions of the flocculator, the number of flocculation channels needed for adequate mixing, and the number and spacing of the baffles. Tapered flocculation is used in the design to promote faster collisions of particles at the beginning, and slower collisions towards the end. Research is currently being conducted to determine if tapered flocculation or equal spacing make a difference in the formation of flocs.

The baffles are composed of corrugated sheeting, constructed in a set number of modules. Separating the baffles into separate modules allows them to be removed easily, giving easy access for cleaning the tank. Details regarding the modules can be found below.

The following are the dimensions for the flocculation tanks:

Dimension	**MathCAD Variable Name**	
Width	$W_{FlocChannel}$	0.45m
Length	$L_{FlocChannel}$	2.01m
Number of baffles	$N_{FlocBaffles}$	92
Number of floc channels	$N_{FlocChannels}$	3
Local water depth at the beginning of the floc channels	$HW_{FlocStart}$	1.755m
Local water depth at the end of the flocculator	$HW_{FlocEnd}$	1.55m

3.1. Construction Suggestions

The baffles are designed to have varying length and spacing, so as to promote flocculation more efficiently. It is suggested that modules are created for the baffles based on design parameters. Typically PVC pipes have been used to connect the baffles together in a single module. If further information is needed on this type of construction it can be made available. The following is the suggested module arrangement for this plant, including the varying dimensions of the baffles:

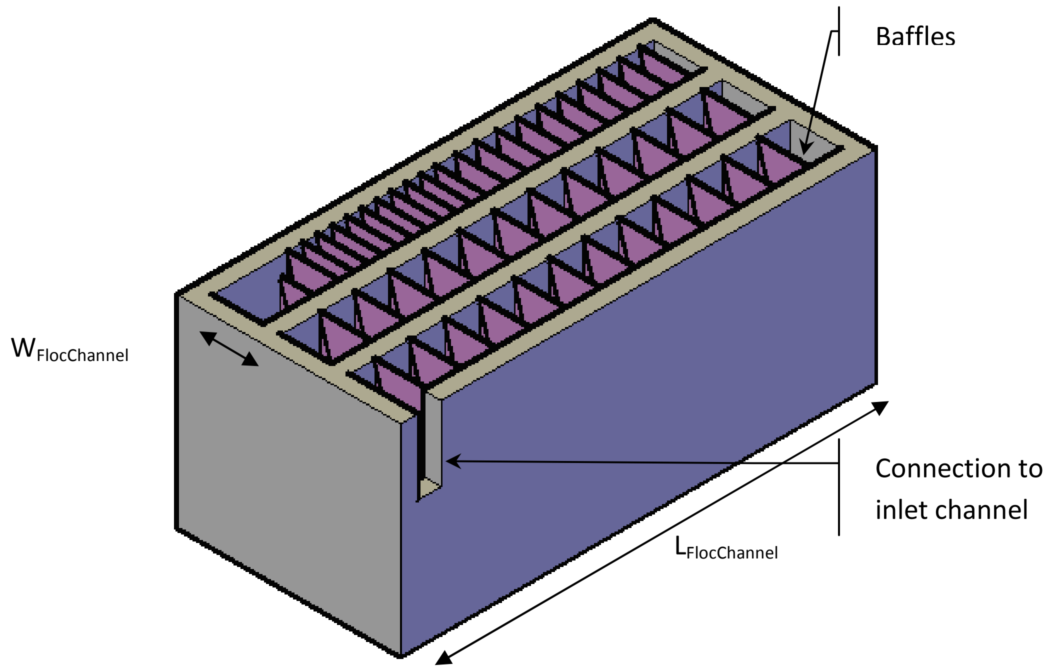

Figure 2: Flocculator Design

4. Inlet Channel

Water flows from the flocculator into the sedimentation tanks via the inlet channel. The channel runs along the inlet end of the sedimentation tanks, such that its length will be equal to the sum of the widths of the sedimentation tanks. The width and depth of the channel depend on the water level in the sedimentation tank, which is designed to be the same as in the channel and the flocculator.

The primary constraint for the inlet channel is the depth. The channel is designed to make sure that the water velocity in the channel is not high enough to break up the flocs formed in the flocculator. The following are the dimensions for the plant's inlet channel:

Dimension	**MathCAD Variable Name**	
Width	$W_{InletChannel}$	0.145m
Height	$H_{InletChannel}$	0.545m
Length	$L_{Channel}$	2.14m
Local water depth	$HW_{InletChannel}$	0.445m
Number of chimneys into each tank	N.SedInletPipes	2

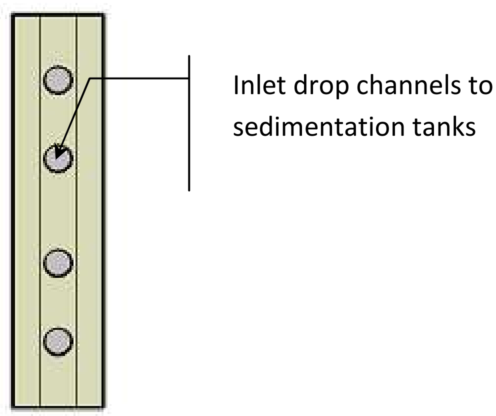

Figure 3: Inlet Channel – Top View

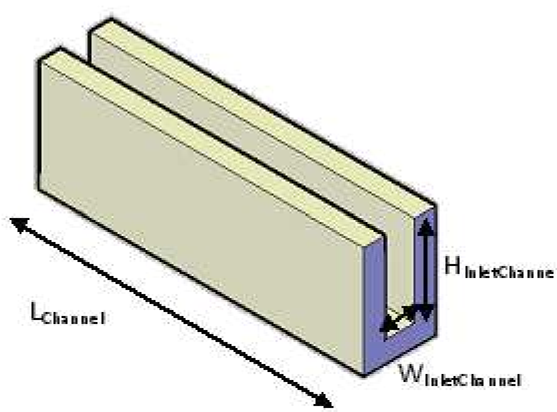

Figure 4: Inlet Channel – Isometric View

5. Sedimentation Tank

The following five sections describe the overall design of the sedimentation tanks. For reference, the following is a cross-section of the sedimentation tank.

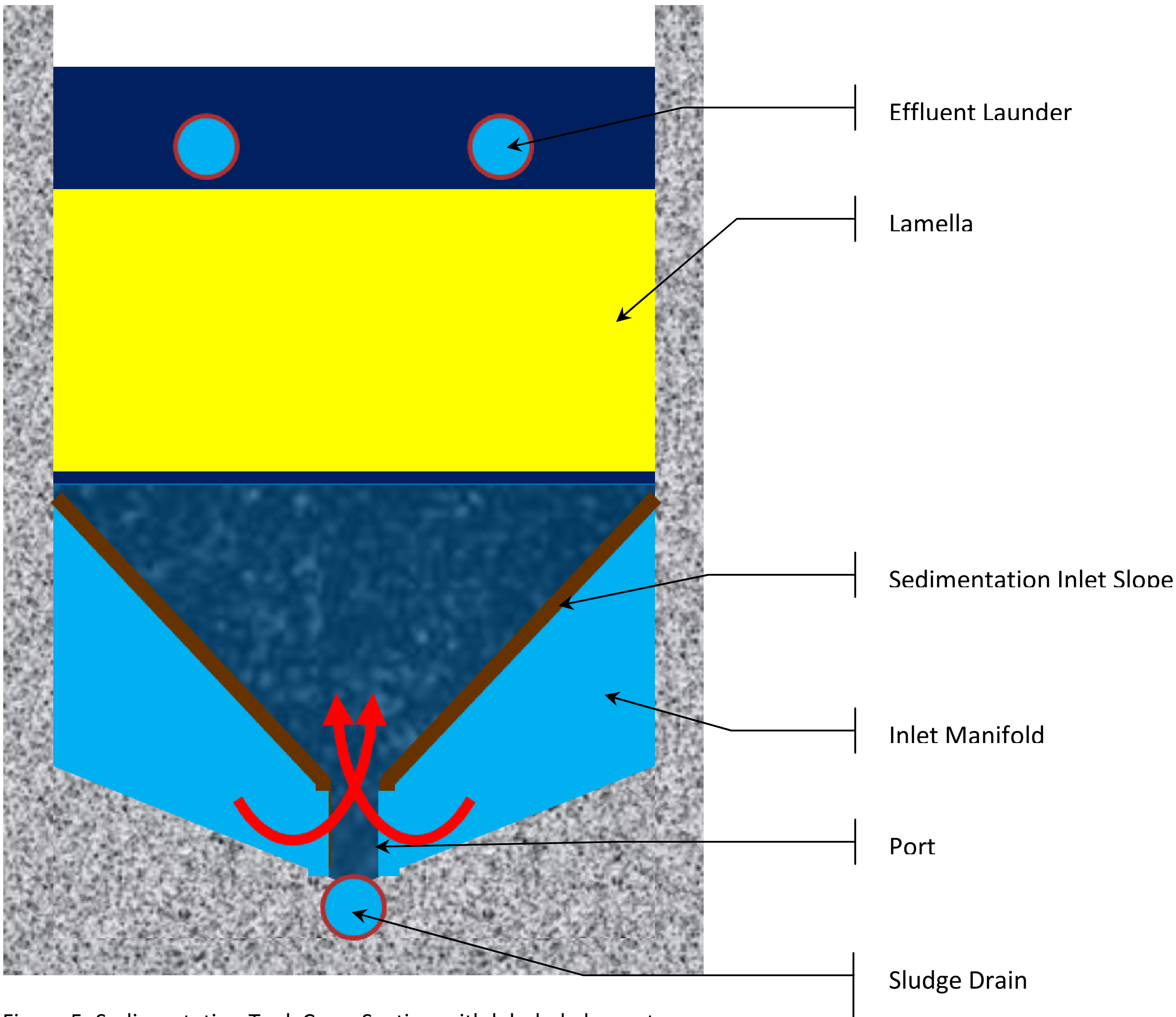

Figure 5: Sedimentation Tank Cross Section with labeled elements

Water flows through the inlet manifolds, out through the ports (as shown by the red arrows), up through the settler plates/lamella, and then out through the effluent launder. These processes are described in the following sections.

5.1. Inlet Slopes

Drop pipes leaving the inlet channel deliver water to manifolds in the bottom of the sedimemtatopm tanks, also known as the sedimentation inlet slopes. These manifolds run along the length of the sedimentation tank on both sides and uniformly distribute water to the entire bottom of the tank, thus creating a uniform flow of water out of the slopes through ports and into the tank.

One of the major concerns with this design is ensuring the water flows uniformly into the sedimentation tank and that the velocity does not get too high as to break up the flocs. However, the velocity must be high enough so that the flocs don't settle in the slopes and obstruct the ports through which the water flows out.

Due to the relatively low flowrate this plant is designed to handle, each sedimentation tank is small enough to just have one pair of inlet slopes running the length of the bottom. The design specifies only the area and number of exit ports. The shape can be determined later based on construction materials. However, the ports are recommended to be either square or rectangular.

The following are the dimensions for the design of the sedimentation inlet slopes.

Dimension	**MathCAD Variable Name**	
Top angle of the slope	$AN_{SedTopInlet}$	60 deg
Bottom angle of the slope	$AN_{SedBottom}$	10 deg
Vertical height of the slope	$Z_{SedSlopes}$	0.878m
Number of bays in each tank	$N_{SedBays}$	1
Number of ports in each slope	$N_{SedPorts}$	36
Area of ports	$A_{SedPort}$	29.3cm^2
Center to center spacing between ports	$W_{SedSlopePlate}$	30cm

5.1.1. Construction Suggestions

Previous communities have constructed the inlet slopes as plates made of ferrous cement. An example of this type of construction can be seen below in the Cuatro Communidades plant.

Figure 6: Photo of Inlet Slopes Construction

Ports are cut out of the slopes, and since the spacing between the ports is a constant (set as 30cm for this plant), the plates can be constructed so that each plate ends in a port. An illustration is shown below.

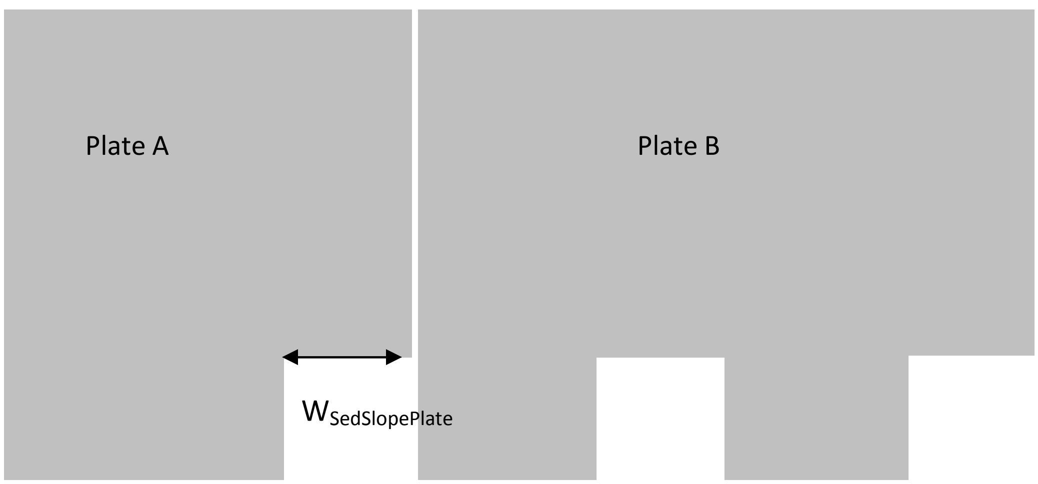

Figure 7: Port Construction and Layout Example

It is also important when constructing these slopes to make sure that the ports are so that they are not directly across from each other in the sedimentation tank. As the water flows out of the manifolds through the ports, collisions could occur if the ports are facing one another—staggering them will help eliminate this risk.

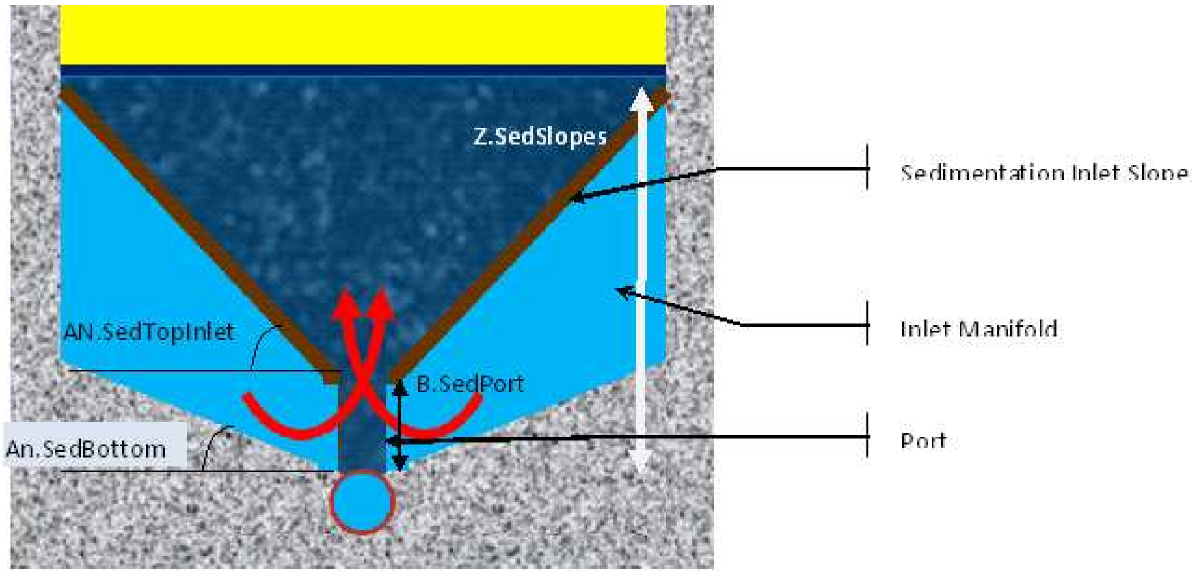

Figure 8: Inlet Slopes Cross Section

5.2. Sedimentation Tank

The design of the sedimentation tank is a critical piece of the design of the entire plant. Its properties, such as depth and critical velocity, are important in determining the dimensions and lamella spacing. The total required sedimentation tank area is determined by plant flow rate. The width of each tank is optional and normally determined by the material used for the lamella. The number of sedimentation tanks is set by the user, and has been set at two for this specific design. With two sedimentation tanks, one can be shut down for cleaning while the other remains in operation. The length of the tanks is chosen to produce the required total tank area.

The following are the dimensions for the sedimentation tanks.

Dimension	**MathCAD Variable Name**	
Number of sedimentation tanks	$N_{SedTanks}$	2
Height	H_{Sed}	1.65m
Length	L_{Sed}	2.01m
Width	W_{Sed}	0.92m
Local water depth	HW_{Sed}	1.55m

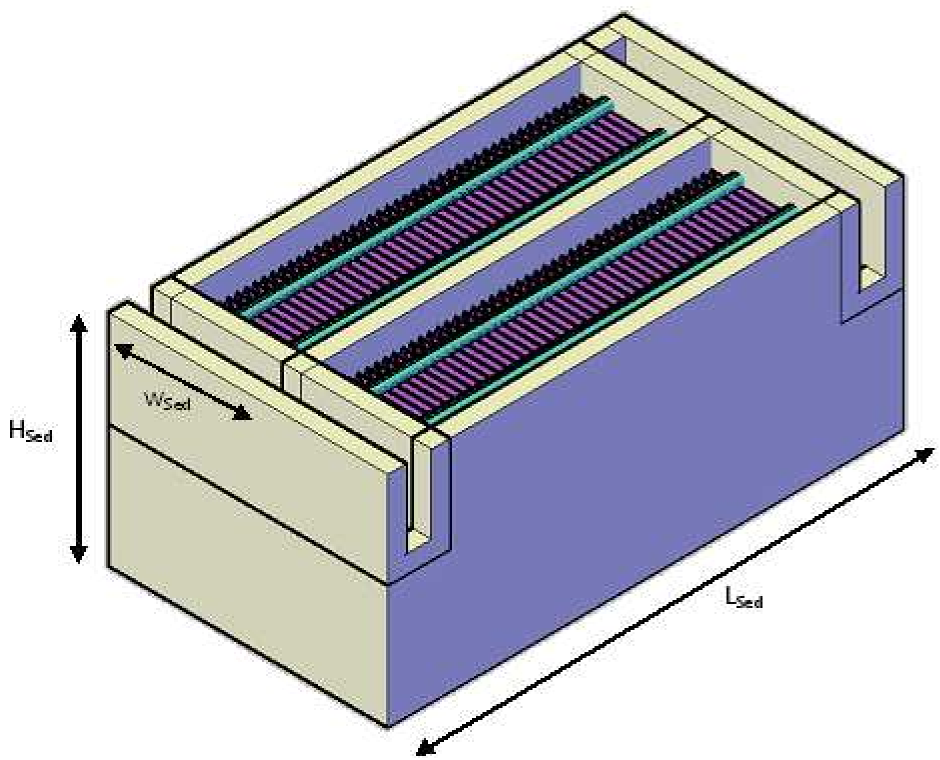

Figure 9: Sedimentation Tank

5.3. Sludge Drain

The sedimentation tank also includes a sludge drain for the settled flocs to be drained. The sludge drain runs along the bottom of each sedimentation tank and collects the flocs as they fall from the lamella and settle. The number of orifices in the sludge drain is determined by the length of the sedimentation tank and the spacing between each orifice, as defined by the user.

The following are the dimensions for the sludge drain.

Dimension	**MathCAD Variable Name**	
Number of orifices	$N_{SedSludgeOrifices}$	13
Diameter of orifices	$D_{SedSludgeOrifices}$	0.5in
Center to center distance between orifices	$B_{SedSludgeOrifices}$	15cm
Height of the sludge drain	$H_{SedSludge}$	5cm
Width of the sludge drain	$W_{SedSludge}$	4.1cm
Wall thickness of sludge drain	$T_{SedSludge}$	9.33cm

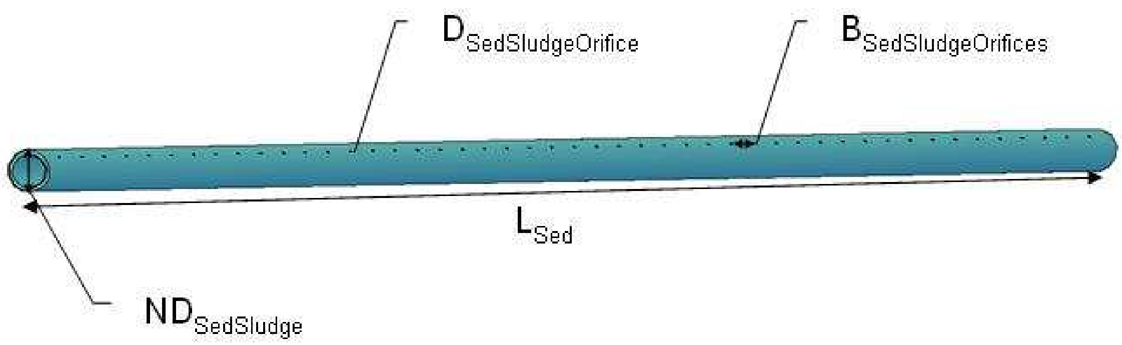

Figure 10: Sludge Drain

5.3.1.Construction Suggestions

The sludge drain is designed as part of the bottom of the tank, and is no longer a pipe as pictured above. This will eliminate any additional costs associated in purchasing more pipes. The sludge drain has previously been constructed out of ferrous cement and is formed into a cover that encases the channel. It should also be noted that the orifices in the sludge drain should be staggered with the ports in the inlet manifold. An example from a previous plant can be seen below.

Figure 11: Staggered orifice and ports

As seen above, no two ports are directly across from each other, and no single orifice is in the same streamline as a port. This is done to eliminate any additional pathways the water might flow, and to avoid breaking up the flocs as they enter the sedimentation tank.

5.4. Lamella

The lamella (sometimes referred to as plate settlers) are located within each sedimentation tank and serve to promote the settling of the flocs. Similar to the construction of the baffles in the flocculator, they are composed of corrugated sheets, however they are constructed at a specified angle. As water flows up through the sedimentation tank, the flocs will collide with the lamella, thus increasing the likelihood of settling.

The important parameters in the design of the lamella are the critical velocity (10m/day) and the upward velocity at the bottom of the tank (70m/day). The critical velocity is the rate at which a particle must fall to ensure that it settles out within the plate settlers. The upward velocity at the bottom of the tank is important for the formation of the sludge blanket, which can be incorporated into the sedimentation tank. Research is still being conducted on this part of the plant and details for the floc blanket will be sent separately.

Note that each sheet is referred to as a "plate" and the plates make up the entire lamella. The following are the dimensions for the lamella.

Dimension	**MathCAD Variable Name**	
Center to center distance between each plate	$B_{SedPlate}$	1.841cm
Length of the plate	$L_{SedPlate}$	0.469m
Number of plates	$N_{SedPlates}$	57
Angle of the plates	$AN_{SedPlate}$	60 deg

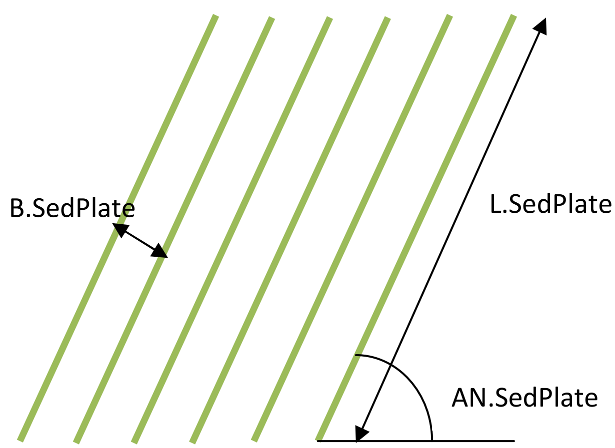

Figure 12: Lamella Design

5.5. Effluent Launder

The launder is the manifold that transports the clean water from the top of the sedimentation tank to the exit channel. The launder is located between the top of the lamella and the surface of the water in the sedimentation tank. There is one launder for every inlet slope. For this plant design there are two launders per sedimentation tank.

Orifices are drilled along the launder to carry the water through the manifold, similar to that of the sludge drain. Each launder will have two rows of orifices oriented along the side of the launder, making sure they are staggered so they do not align.

The following are the dimensions for the launders.

Dimension	**MathCAD Variable Name**	
Diameter of launder	$ND_{SedLaunder}$	3in
Number of orifices in launder (per row)	$N_{SedLaunderOrifices}$	30
Diameter of orifices	$D_{SedLaunderOrifices}$	0.313in
Center-to-center spacing between orifices	$B_{SedLaunderOrifices}$	0.1m

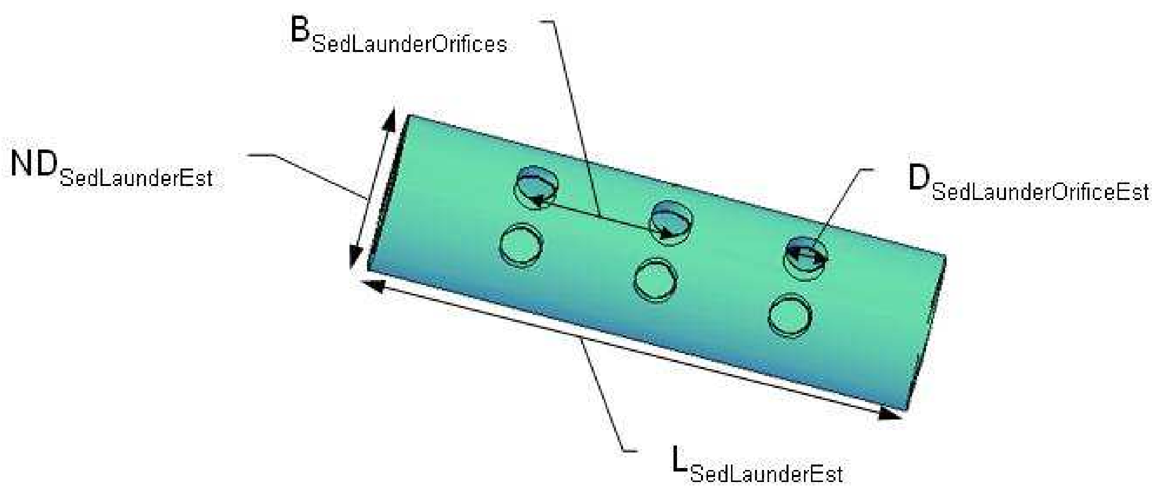

Figure 13: Effluent Launder Design

6. Exit Channel

The exit channel collects the water from the sedimentation tank effluent launders, and transports it out of the plant. Chlorine is added to the water at the end of the exit channel before the water flows through the outlet weir. The outlet weir controls the flow to the storage tank and determines the water level throughout the entire plant. The exit channel is very similar to the design of the inlet channel in layout, but different in functionality.

The following are the dimensions for the exit channel.

Dimension	MathCAD Variable Name	
Width	$W_{ExitChannel}$	0.145m
Height	$H_{ExitChannel}$	0.545m
Length	$L_{ExitChannel}$	2.14m

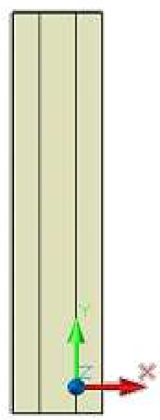

Figure 14: Exit Channel – Top View

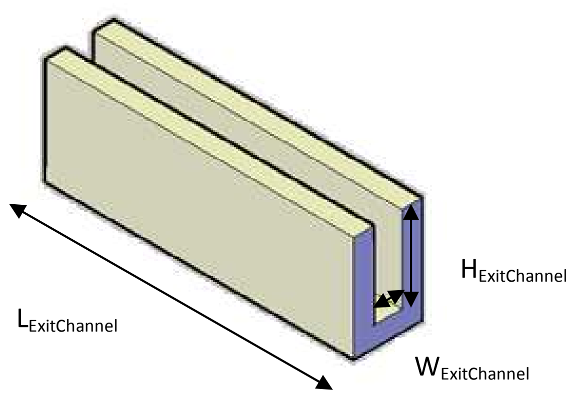

Figure 15: Exit Channel – Isometric View