Small Scale Plant Model Team, Spring 2015

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Abstract

The Small Scale Plant Model Team of Spring 2015 worked to design a clear and portable model of the AguaClara water treatment plant. The current small scale plant model is cumbersome to travel with and difficult to understand for those unfamiliar with AguaClara technologies. After repairing the previous model, the team identified promoting education and awareness the primary purposes of the new model. Representing the water treatment plant in a clear and critical way will be the main objective of the Small Scale Model Team. After a semester of material testing and prototypes, the new small scale model will be completed over summer and fall 2015.

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Introduction

Understanding how water flows through an AguaClara plant can be difficult for people who are unfamiliar with AguaClara technologies. Having a three-dimensional model as a visual and spatial tool can make the education process easier. The main goal for the Small Scale Plant Model Team is to design and create a model that is professional and easy to understand for a wide audience, from potential investors to college students.

Literature Review

Overview of Plant Technologies

https://confluence.cornell.edu/display/AGUACLARA/Home

This page of the AguaClara website offers an overview about the research occurring in Cornell. It provides a basic overview of the AguaClara technologies.

History of Plants

https://confluence.cornell.edu/display/AGUACLARA/Project+Sites

This page of the AguaClara website lists the twelve plants in Honduras and India. The page includes the design flows in L/s, population served, and other important informations. So far, the average flow capacity is 13.75 L/s, which, when compared with existing plant designs, is closest to the capacity of 12 L/s. The team decided the 12 L/s plant design best represents the existing AguaClara plants and will be used to design the new small scale model.

Plant CAD Drawings

http://designserver.cee.cornell.edu/Designs/etflocsedfi/5363/12Lps/Index.html

This page features PDFs, AutoCAD drawing files, and Word documents that describe plants with a 12 L/s flow rate, including many dimensional and technical specifications. Various diagrams and figures illustrating plant processes have aided the team's spatial understanding of the plant. The Spring 2013 team used the drawing (.dwg) file featured on this design page to create laser cutting templates for all flat planes in the water treatment plant. These pieces were scaled using AutoCAD and Rhinoceros, an architectural modeling software.

Plant Component Templates

https://confluence.cornell.edu/display/AGUACLARA/Small+Scale+Plant+Model+References

All small scale plant model component templates created by the Spring 2013 team can be found in PDF form on the team's wiki page. The files were created in Rhinoceros by the team from existing AutoCAD design files. The team has processed and uploaded top views of the plant in both 1:20 and 1:30. These PDFs can be found under the "References" heading. Preliminary component templates of the models can be found under the heading "Component Templates (1:20)." The templates are scaled by a factor of 1:20.

Spring 2013 Report

https://confluence.cornell.edu/download/attachments/207948359/SSPMFinalReportSpring2013.pdf?version=1&modificationDate=1368162794000

The Spring 2013 Small Scale Plant Model Team began the process of building a model. The team chose the 1:20 scaling factor for the model. The scaled model depicted specific technologies in the AguaClara. It was compact and readily transportable. The team also laid the groundwork for the construction of the model by developing templates in AutoCad so that it can be assembled with plexiglass pieces. A mock up model of the plan was constructed from cardboard, and it included the main base of the plant, flocculator and filter.

Summer 2013 Report

https://confluence.cornell.edu/download/attachments/207948359/FinalReport.zip?version=1&modificationDate=1376074025000&api=v2

Summer 2013 team saw the completion and 3D printing of model components. The team finalized the work started by the Spring 2013 team and completed the model by first editing all of the templates to account for the finite thickness of plexiglass and then formatting them to be used for water cutting instead of laser cutting. The team also prepared a manual for future small scale models to be built in a timely manner using existing templates.

Fall 2013 Report

https://confluence.cornell.edu/download/attachments/207948359/Aguaclara_FinalReport_Fall2013.pdf?version=1&modificationDate=1387119166000&api=v2

Members of the Fall 2013 team focused on introducing 3D printing technology and components into the existing plexiglass/acrylic model. Team members focused on exporting the AutoCAD plant model into the program Rhinoceros and created a physical model by using 3D printing and laser cutting technologies. The report shed light on ways to improve the model, such as using alternative media to convey plant process (Maya, Video) and scripting a 3D model to create a one-button workflow.

Fall 2014 Report

https://confluence.cornell.edu/download/attachments/207948359/FinalReport_SmallScalePlantModel_Fall2014.pdf?version=2&modificationDate=1419482712000&api=v2

The Fall 2014 team focused on using AutoCAD to automate the 3D printing process for the plant model. The team worked to achieve the one-button workflow, from MathCAD to AutoCAD to 3D printing. The report highlighted several issues. For example, multiple ways to mesh solids with MathCAD or AutoCAD, components of the model were too thick or too thin, and a model base was needed.

Methods

This semester, the Small Scale Plant Model Team simplified the design of the model to improve model clarity and ease of travel. Team members referred to the blueprints and CAD models of existing AguaClara plants to design the new model. The broad objective of the model is to show how water flows through the plant in a simple way. Representing water levels and having removable tanks in the model would help viewers to better understand the plant. Through experimentation,the team determined the best material to represent water.

Understanding Plant Lineage

The team began the semester by documenting past AguaClara plants, in order to better understand the evolution of AguaClara design and technology. For example, the first plant in Ojojona, Honduras was a relatively small open-air facility. Over time, the design of the treatment plants have developed to include interior shelter, stacked rapid sand filters, and living quarters for the plant operator. These changes were implemented due to advances in AguaClara technology, changes in municipal flow rates, and plant operator feedback. The document, “How Water Flows Through the Plant”, describe how AguaClara treat its water in detail, from water collection to distribution. The purpose of this exercise was to research AguaClara plant lineage and identify the basic concept of each treatment plant component.

Repairing the Existing Model

The current small scaled model was damaged due to wear and constant air travel. Most of the pipes connecting the filter box to the stacked rapid sand filter have broke off. Referencing Rhinoceros files made in previous semesters, new pipes were 3D printed in Rhodes Hall and installed in the current model. The group referred to pictures of the previous model, shown in Figure 1, when repairing the pipes and other unstable parts with super glue. Styrofoam pieces were also added to the bottom of the pipes for extra support and protection. An emergency repair kit, which includes super glue, sandpaper, and extra pipes, has been added to the current model container for future travel and wear.

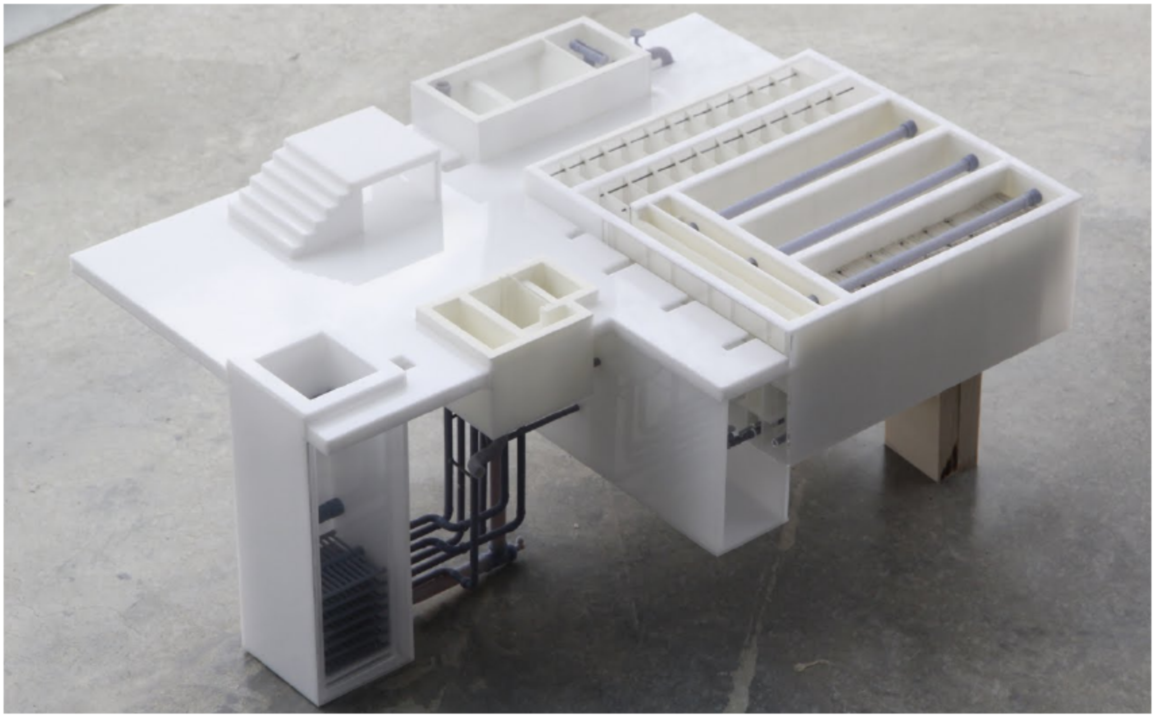

Figure 1:Picture of the Original Small Scale Plant Model.

Sketch Model

After the repairing the existing model, the Spring 2015 team began the process of designing a new, more user-friendly model. The previous teams faced some difficulties with the existing model, including fragile pipes and an unstable base. As such, the team decided to simplify the model components and design composition for the new model. The new design would be smaller, stabler, and easier to understand. The team sketched out preliminary ideas, as seen in Figure 2, with the goals and changes in mind. Different sketches were drawn to identify the best model composition. The final plan for the new model is shown in Figure 3. The model would be based on the 2014 plant in Moroceli, Honduras because it incorporated AguaClara's most recent technologies and represented the general design of AguaClara infrastructure in Honduras. The team also had access to the full blueprints of the Moroceli treatment plant.

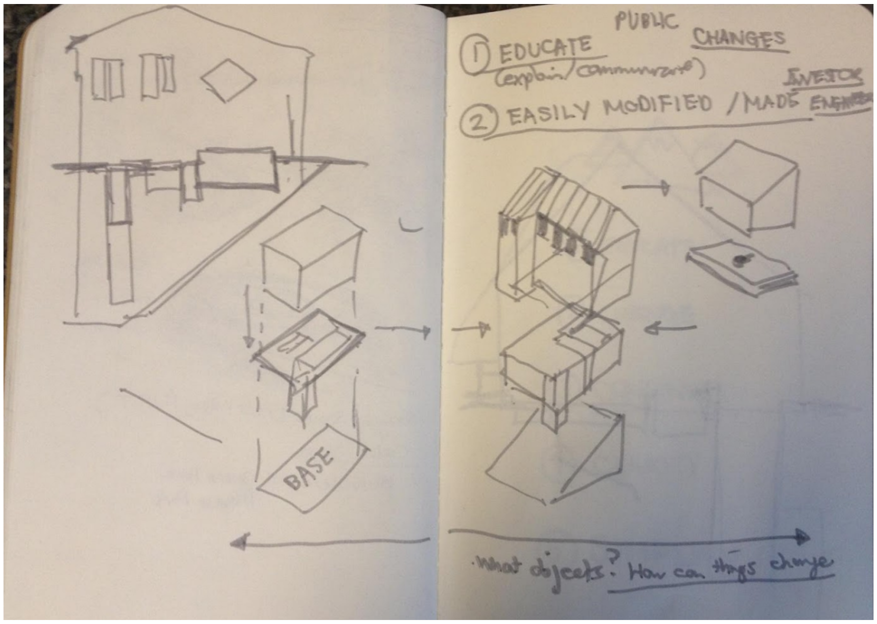

Figure 2: Sketches of Possible Final Model

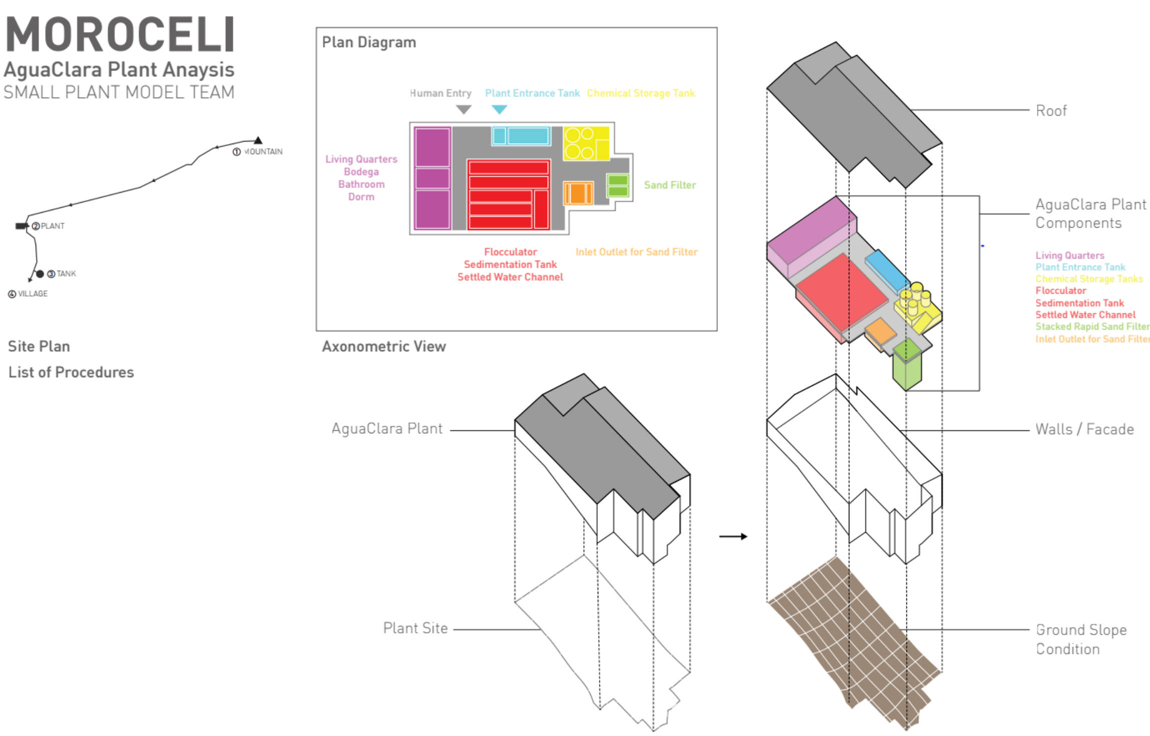

Figure 3: Plan for New Model

Glycerin Soap Model

Following the initial design sketches, the team began to build mockups of the AguaClara water tanks in the new model design. The team casted the various parts of the plant in clear soap to show inner workings of the plant. The soap would take the general form of each tank component, and corresponding pipes would be embedded in the soap forms. The soap blocks would also represent relative water levels in the each plant component. Different soap transparencies would be used to model actual water quality in the plant. The soap components were designed to be removable from the new model, as shown in Figure 4. It would allow viewers of the plant model to examine each AguaClara component in detail.

While working with glycerin, the team ran into some difficulties. The material was more opaque than imagined, and the soap blocks were malleable and heavy. The team decided to change the material to resin to solve the transparency problem.

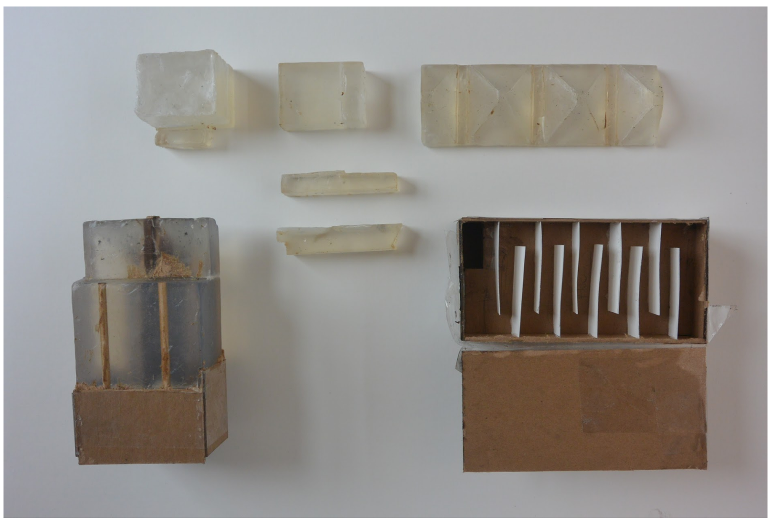

Figure 4: Trial Glycerin Soap Model Components

Epoxy Resin Model

Resin is a type of plastic used to cast objects and sculptures. The transparency level of resin casting is much higher compared to glycerin soap, and the finished product has a smooth finish, which is desirable for travelling. The team decided to use epoxy, a type of ultra-strong bonding agent, as the casting material after researching about different types of resin. Like glycerin, epoxy comes in a variety of transparencies. For the new model, the team would use epoxy ranging from clear to cloudy yellow to represent the water qualities at different points in the treatment plant. For example, water in the entrance tank would be casted in the cloudy yellow resin, while the exit tank water would be in clear resin. This would provide visual representation of the water in actual plants.

While testing the epoxy casts, the team had some trial and error. The first epoxy cast utilized Smooth-On EpoxyACast 650, which did not suit the cardboard mold that was used. The resin outcome turned amber yellow, as shown in Figure 5. Afterwards, The group changed the type of epoxy to Smooth-On EpoxyACast 690 and poured it into foam and 3D printed molds. The resin reacted with the foam mold. The resin bubbled and the product turned very opaque, as shown in Figure 6. The epoxy did not react with the 3D printed molds, but the cast was irretrievable from the mold, as seen in Figure 7. After some research and experimentation, the team found that vaseline and beeswax can be a releasing agent for epoxy. Figure 8 shows the resin cast that was poured into a 3D printed mold coated with vaseline.

Figure 5: Epoxy Cast Smooth-On 650 with Cardboard Mold

Figure 6: Epoxy Cast Smooth-On 690 with Foam Board Mold

Figure 7: Epoxy Cast Stuck Inside 3D Printed Mold

Figure 8: Epoxy Poured into 3D Printed Mold with Vaseline Release

3D Modeling

Following the initial water mold tests, the team decided to concentrate on building a comprehensive digital model of the Moroceli plant, in order to visualize the plant's relationship to the ground and site. While representing the water tanks accurately was essential to the new small scale model, building a solid foundation for the new model was equally important. A 3D model of the Moroceli treatment plant was built in Rhinoceros, referencing the 2D Moroceli blueprints, as shown in Figure 9. After important lines and details were extracted from the blueprint, walls and surfaces were extruded by cross referencing different combinations of the plan and section drawings. The ground and foundation were generated from the ground lines from CAD plan. The model did not include minute details, such as the structural column grade and the toilet in the bathroom.

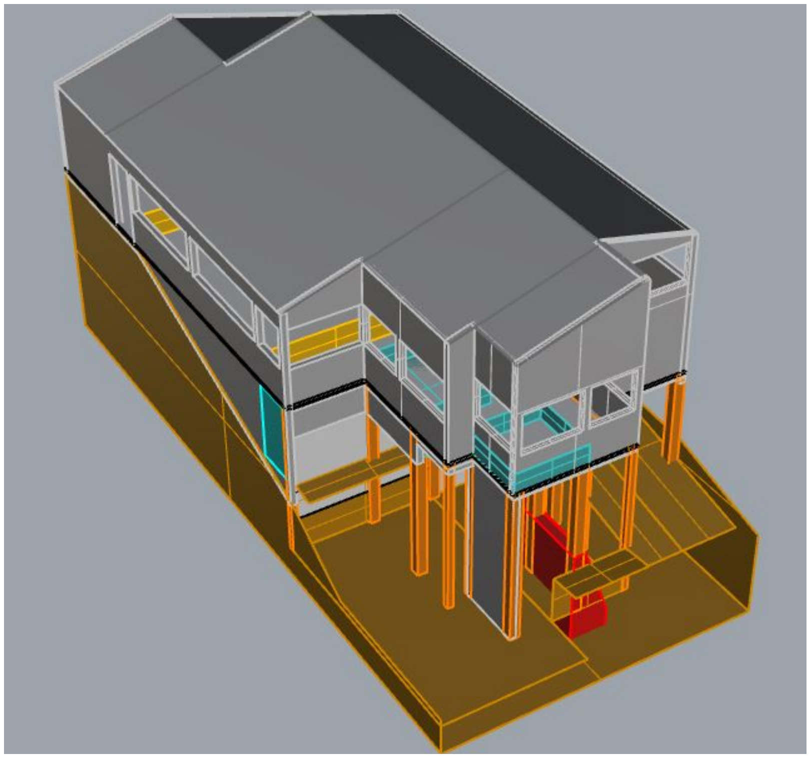

Figure 9: 3D Model Plan Created Using Rhinoceros

Building Plant Model

The new model is expected to be 12 x13 x 28 inches. It would consist of five components: the soil foundation, the concrete foundation, the water treatment system, the building, and a protective outer box. The soil would be made out of wooden sections with carved in slopes and details. The concrete level would sit on top of the wood, and it would be made out of either Rockite, a concrete like material, chipboard, or wood. The walls, including the tank and exterior ones, and the ground of the water treatment system would be made out of white Plexiglass. The mold for the water casts would be 3D printed. The actual cast would be made out of Epoxy with 3D printed pipes suspended inside. The building would be wood, and the roof would be Aluminum cuts. An outer box made out of foam would be included to protect the model from scratches and minimize shock.

AutoCAD to 3D Printing

Previous 3D printed objects have been rendered in Rhinoceros. The team worked to link AutoCAD with 3D printing by creating a basic objects and printing them. Research was done to learn more about meshing surfaces and solids in AutoCAD. Other ways of making pipes were experimented with to simplify the printing process. For example, extruding a solid from a 2D donut shaped surface and then mesh the object. The team also worked on simplifying the meshing process of a tank.

Analysis

Goals of the Small Scale Plant Model Team this semester were to create a portable model of a AguaClara plant and to incorporate components that may influence the design of future plants. On top of replicating the Moroceli plant with minor changes, the team wanted to show it could be more than just a water treatment plant. By building gardens and trees surrounding the structure, it could become a community icon for the village. This addition to the model would influence the viewer's perception of AguaClara plants, which can in turn influence the design of future AguaClara sites.

Conclusion

The Spring 2015 team worked on creating a smaller model of the AguaClara plant that is simplier and easier to travel with compared to the current one. The team worked with different casting materials and molds to represent water in the model. Epoxy in 3D printed containers covered with vaseline is a good combination for water casting. The team also worked on simplifying the meshing process in AutoCAD, which is required for 3D printing. The team found that pipes extruded from a donut foundation is easier to mesh relative to subtracting a cylinder within another cylinder.

Future Work

Future Small Scale Plant Model Team should continue experiment with meshing in AutoCAD and connect it with 3D printing. The Spring 2015 team was unable to complete the model. However, there are 3D plans of the model future teams could follow to complete it. AguaClara technologies are also changing rapidly. Future teams should work on modify the composition of the small scaled plant to better incorporate the changes.