Reengineering the GSAP Microflush Toilet

A Major Qualifying Project Report Submitted to the faculty of
WORCESTER POLYTECHNIC INSTITUTE
In Partial Fulfillment of the Requirements for the
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In
Mechanical Engineering

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Abstract

Sustainable, low-cost, odor-free private 'Microflush Toilets' are currently being deployed in Ethiopia by the Global Sustainable Aid Project. This key aid project is ongoing since 2009, with continued work to steadily improve the toilet's functionality and ease the flow of the education programs that are built around them. This MQP aims to redesign the vermiculture Digester of these toilets to improve functionality, longevity, and simplify construction. Additionally, the first wordless instruction manual for toilet installation was created, which will aid in comprehension on-site and raise accessibility as a teaching tool. A similar manual will be created to cover a student-created recycled plastic mesh filter to be installed in the toilets to tackle a lack of materials in Ethiopia.

Acknowledgments

I would like to first and foremost thank my advisor Dr. Aaron Sakulich for his constant support on this solo MQP. For our weekly meetings, for keeping me on track, for listening to my ideas, and for making this project an enjoyable experience overall. To this he would reply "don't thank me, you did all the work!" but I do sincerely appreciate him for advising me this past year.

Thank you to my other advisor Dr. Robert Krueger for getting me involved with the Development Design Lab and for answering my many questions.

A big thank you to my summer research partner Fatimah Wattar for co-designing and prototyping our recycled plastic mesh. Also to Dr. Achirri Ismael for his continued support of the project and enthusiasm in answering my questions.

Thanks to the Lab itself for sponsoring this MQP and involving WPI with such an inspiring project. Also to the GSAP for beginning the work on the Microflush technology, USAID for its continued sponsorship, and to CRS & Tom Hollywood for pushing this project into Ethiopia and other nations in need.

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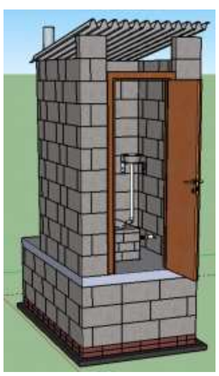
Introduction

All of Ethiopia suffers from poverty and poor sanitation, and therefore the country is supported by both development and humanitarian assistance programs from agencies worldwide. The main efforts in Ethiopia are aimed at fighting against poverty, working towards sustainable economics, protecting the environment, and increasing employment. Over 20 million Ethiopians live under the poverty line. Catholic Relief Services (CRS) has identified several causes including weak local infrastructure and inadequate on and off farm livelihoods. In addition to low incomes, only 7% of the population have access to basic sanitation services, with many humanitarian efforts hoping to change that as well. When looking at the effects of low sanitation, the most detrimental to human life is bacterial diarrhea, which leads to disease and death. Family-owned latrines improve personal cleanliness thereby reducing these rates, especially among children.

Reflecting the efforts being made on both fronts, the Global Sustainable Aid Project (GSAP) in collaboration with benefactors CRS & USAID, has designed and established the MicroFlush Toilet System in the hopes of creating a sanitation economy, enabling communities around the world to have a self-sustaining cycle that improves the quality of life for its people. The system can add health, wellness, and other value to a basic rural Ethiopian household, as it has in other places it has been deployed.



These toilets were first designed in 2009 in the S-Lab at Providence College by the late Dr. Stephen Mecca. It is an off-grid, sustainable, eco-friendly, low-cost, odor-free private toilet that reuses a few ounces of greywater from a previous user's hand wash to isolate waste and flush. They have been proven to be an effective sustainable sanitation solution for the developing world, having already been deployed successfully in many countries. CRS's implementation of GSAP toilets in Ethiopia has been challenged due to material unavailability and unfinalized retrofit designs that are not consistently documented. [1]

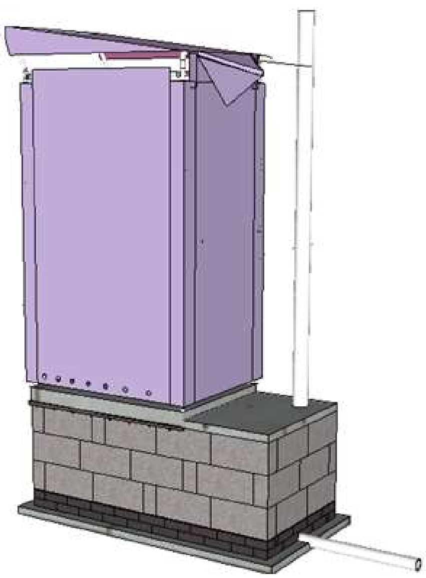
Numerous projects are working towards aspects of sanitation in Ethiopia, with a focus on the GSAP Microflush Toilet system. WPI and the Harar Catholic Secretariat (HCS) are in the process of completing many sub-projects that improve the current deployment efforts of MicroFlush Toilets, including creating manuals for the sub-assemblies, improving construction education programs, and compiling better Bills of Quantities (BoQ). This Major Qualifying Project will serve as one piece of the puzzle in the success of Microflush Toilets in Ethiopia.

[1] Figure 1: GMF Model Render from *globalsustainableaid.org*

Background

Ethiopia is the country in which the GSAP Microflush (GMF) Toilet Program is being developed, a landlocked nation in Sub-Saharan Africa. There are several large cities, but the majority of the population lives in small farming villages with many different sub-cultures and languages. There are many economic and humanitarian crises in Ethiopia, the lack of sanitation being the driving force behind the GMF toilet system. As in any developing nation without plumbing, hygiene can become a real problem, stemming into many problems for the country's people, including the spread of disease, especially those that affect the digestive tract, leading to nutritional crises and hunger amongst children and adults alike.

The sponsor of the WPI Institute of Science and Technology for Development (InSTeD) program is the United States Agency for International Development (USAID), which "emphasizes three strategic priorities within its WASH (Water Sanitation And Hygiene) investments: sustainability, sanitation innovation, and local ownership". This strategy is also implemented by the project's second sponsor, Catholic Relief Services (CRS). This approach leads their projects to not only improve health but also develop rural Ethiopians' livelihoods with opportunities to grow their wealth.



GSAP Microflush (GMF) toilets are environmentally friendly latrines that combine two main technologies: a filtered digester bed and the titular Microflush valve. The valve was developed by the S-Lab of Providence College. It uses a "pour flush" model where the previous user's handwashing water cleans the valve and flushes the waste through the aforementioned filtration layers.

Functionally, what makes the GMF toilet successful is its lack of smell. This is due to the most important part of the system, the Digester bed. This multi-layered structure separates the solid and liquid waste, separating the design from a typical latrine. The waste falls onto layers of soil and straw that create a vermiculture bed that is populated by earthworms. This compost is supported by a filter layer that lays over top a few spacer bricks to create a gap above the ground. In the current design, there is a concrete slab laid on the ground to support the Digester. It is poured at an angle that supposedly directs the liquid waste into a PVC pipe on the back of the structure that leads to the Soak Pit. The digester and soak pit are built underground which also helps reduce the smell. The Soak Pit is a round hole filled with rocks, designed to intake the liquid and better dissipate it into the ground around it.[2]

[2] Figure 2: GMF Model from *Mecca, GSAP Microflush Toilet Instructions*

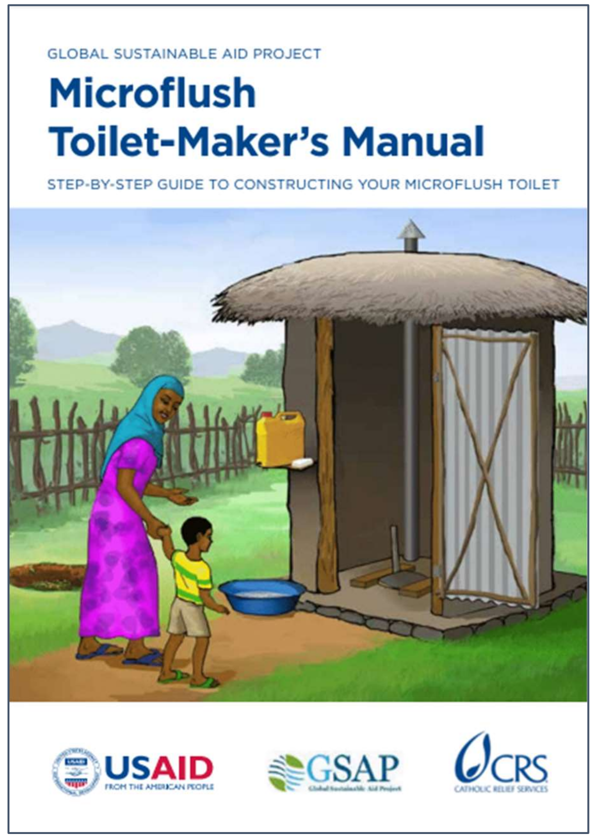
The Microflush Toilets already have successful results in Ghana, Haiti, Nicaragua, and 14 other countries with GSAP expecting the technology and the multiple models to scale even larger. This system, coupled with local skills and materials, has empowered thousands of households worldwide to own off-grid sanitation.

Since 2021 the WPI Development Design Lab has taken over the GMF Toilet project from the S-Lab, with a focus on deploying them in Ethiopia. There has already been an IQP that assessed the longevity and durability of the toilets, as well as faculty-run efforts to improve the process in Ethiopia. There has also been a major focus on the Digester Bed due to it being the most important component of the design. Also due to the wire mesh in the original design being unavailable or expensive in Ethiopia, these screens are readily available in other countries in which the toilets have been deployed. GSAP came up with a second option in place of this wire mesh filter: a slab of porous concrete. This solution has proved concerning to the CRS and WPI, due to the potential of the porous concrete clogging when exposed to solid waste. Multiple teams from the Development Design Lab have researched its effectiveness and alternative materials to replace it. This MQP was started as an extension of the research project over the summer that developed a recycled plastic mesh to be installed above the slab, to prevent excess clogging. [3]

GSAP hosts Microflush toilet-maker training sessions, which certify residents of target countries to become "Makers". These Makers are often skilled laborers and artisans but can be anyone interested. They are taught everything about the toilets' construction, eventually being able to lead their own small companies which install the toilets in their local communities. This certification program has been difficult to maintain and has some areas that are currently being enhanced by WPI's focus on Monitoring, Evaluation, Accountability, and Learning (MEAL) to assist with assessing and developing continuous improvements to the program. To train Makers there are manuals and curricula that have been developed to create a learning system with tiers for people to start from nothing and become experts on GMF Toilets, who are eventually able to teach their own training courses. This system creates a circular economy which enables the toilets to have an even wider expanse of deployment and success.

[3] Figure 3: Photo of Completed Toilet from *Mecca, GSAP Microflush Toilet Instructions*

The “GSAP Microflush Toilet-Maker's Manual: A Step-by-Step Guide to Constructing Your Microflush Toilet” is one of the main publications created in English to serve certified Makers. It contains written instructions and justifications that Makers can reference in the field, for those who have already completed hands-on training. There is a separate facilitator's guide that is used to conduct Microflush training, and this Maker’s Manual does not cover everything that is taught during the sessions. Within the manual are tables detailing learning objectives, materials, and times to complete each step. There are sections that go over each overarching step in toilet construction, but they each do not detail everything that must be done, mostly including dimensions and the justifications behind each step. There are some diagrams and photographs to accompany paragraphs of text but it is by no means a construction booklet. [4]



A factor at play in implementing Microflush toilets is the largely illiterate population in Ethiopia plus the lack of English speakers and readers. Humanitarian outreach has found one solution to be wordless instruction and communication using graphic illustration. Methods that have had great success with illiteracy and construction, certainly exist already as many such interlingual programs have been successful. Common examples of consumer-based companies using wordless instruction manuals include IKEA and LEGO, which effectively guide everyday people to build sturdy products. The most accessible way is to make a construction guide, is a diagram-based wordless format, completely removing language barriers.

[4] Figure 4: Cover Page from *GSAP Microflush Toilet-Maker’s Manual*

Methodology

Goal

Microflush toilets are being ineffectively implemented in Ethiopia due to several factors. The GSAP maker's manual does not illustrate the actual building practices being used on-site. The current manual caters to the educated makers that lead the construction projects, but not the builders themselves, due to additional sections that detail inapplicable portions of the process, the layout being unconcise and unorganized, and the entire guidebook is written in English. The manual also includes components that are hard to come by or add excess cost to the toilets and does not offer alternative solutions. The design of the digester bed has been modified to include a porous concrete layer which has been the center of some difficulties with construction as the concrete is more prone to clogging and long-term failure. The retrofit and redesigns created will be reflected in the new manual. The goal of this MQP is to overhaul the Digester Bed in order to ease implementation of GSAP Microflush Toilets in Ethiopia.

Objectives

1. Create a wordless instruction manual for Ethiopian builders
2. Reengineer the design to better utilize resources and simplify construction
3. Create a manual for a recycled plastic mesh retrofit

Methods

1. Create a wordless instruction manual for Ethiopian builders

For the first objective, the GSAP maker's version of the guide was read through and notated based on relevancy to the wordless manual. Each step in construction to be included in the wordless instruction manual was isolated. It was important to determine what steps within the guide are out of date and not applicable to the builders in Ethiopia, as well as identify components of construction that can be redesigned as part of the following objective. Questions were directed to Dr. Achirri Ismael since he observed the actual construction of the toilets during his time in Ethiopia, and he was able to clarify how the practices differed from what was illustrated in the maker's guide. As this MQP is being co-advised by Dr. Robert Krueger, the lead of the InSTeD program, he was consulted to offer insight when it came to the design itself as well as coordinating with the design specialist hired to create the graphics for the manual, Mr. Patrick Charles Brown.

A written guide was created to detail the construction steps using reference images of the previous CAD models with feedback and alterations needed to be made. This document was sent to Mr. Brown to create the models necessary for each step.

The original guidebook was written to reflect the construction methods used in Ghana and some of the formatting and layout was helpful in creating the wordless manual. The new manual will encompass the changed designs such as the redesigned filter stage containing a porous concrete slab instead of wire mesh and any differences identified by the interviewees. It is a step-by-step guide for builders on site to visually learn how to construct a Microflush toilet, guided by the trained builders monitoring the site.

2. Reengineer the design to better utilize resources and simplify construction

For the second objective the Digester design was gone through and evaluated based on function and assembly, alongside creation of the wordless manual. Within the design there are some components that will be prioritized, such as the filter layers, while others may be determined to serve to clear purpose imperative to the design's function. The Digester must separate the liquid waste from the solid waste, anything that overcomplicates this purpose, without justification written in the Makers Manual, will be reviewed. This redesign was proposed to Dr. Krueger and then implemented into the wordless instruction manual.

3. Create a manual for a recycled plastic mesh retrofit

For the third objective, there had already been work completed as a summer lab position, which precedes this MQP. Previously, a retrofit design for the porous concrete filter option was created and finalized by Julianna Ziegler and Fatimah Wattar. Recycled plastic bags, cut into strips, were braided and woven together to create a large mesh filter that is laid over the porous concrete to prevent assumed clogging issues. Any unfinished work on the final protype is to be completed. [5]

As this component must be made prior to installing the full toilet, a separate manual was created for this plastic mesh filter in a wordless format similar to the one detailed above, by compiling images of the prototype as well as using digital drawing software to detail the steps of creating the component. It serves as a new solution to the porous concrete slab filter and is available to be distributed as part of this new handbook.

[5] Figure 5: Plastic Mesh Section Photo from *Julianna Ziegler*

Results

In order to address the first objective to create a wordless instruction manual for Ethiopian builders, the original manual was reviewed. It appears to be more of a justification or conceptual guide to the toilets than a manual for assembly. There are some shortcomings that were addressed by creating a wordless construction guide. First, the manual is in English, making it inaccessible to anyone who cannot read the language, which is most Ethiopians. Second, the guide is not laid out in an instruction guide format. There are paragraphs, tables, and the occasional photograph. This does not work in the field as there are not enough pictures to fully detail the construction steps, and the instructions describe but do not spell out the exact steps in building a toilet. Third, there are inconsistencies between this manual and a step-by-step guide created in 2013 that contains CAD images of each construction step.

The manual was fully analyzed and the following specific problems were identified:

The water table test is impractical as locals should know if their water table levels are below or above two meters. In addition, the manual does not specify where this additional test hole should be dug, and digging such a test hole the way it describes could be skipped in most Ethiopian villages which are not prone to flooding.

There are images displaying how deep to install the Digester bed based on three different water tables that may be confusing to readers since three separate exact measurements of depth are overcomplicated for such an application. As long as the water table is below two meters, the toilet should be installed fully below ground. There are better images displaying the different hole depths in the 2013 Manual compared to the Makers manual.

The soak pit is not detailed well. There are not good images illustrating the three depth options for the pit in accordance with the water table.

There are only written instructions for how to build the base of the Digester. The manual uses written dimensions and explains the materials like bricks that can be used, but not how to lay them out in an appropriate way. Also, there is very little detail included regarding the space left in the foundation for the soak pit pipe.

The two options to build the main Digester filter are well-detailed ,but there are no diagrams to display what the final bed looks like. It also appears that the walls should be built before the filter layers are installed, but this is not detailed until the next section. There is no explanation of how the filter system works, although other design decisions, like the digester's purpose as a whole, are fully detailed in previous sections.

The rocks placed in the soak pit and how to cover it are detailed well, but how to connect it to the digest bed is unclear.

There are several options listed for materials that can be used to build the Digester walls but there are no guiding images to detail their construction. There are also no methods of consistency in the exact brick layout, only a description of how to use a level to check that the corners are straight. There is an outdated picture claiming to be a completed Digester but the organic layer currently used in the Digester is not present. Some of the bricks are different sizes, which is never mentioned in the manual. [6]

The remaining parts of the manual are not covered as part of this MQP, including the user interface, the Microflush toilet valve, SaTo pans, squat fixtures, superstructures, and toilet blocks. There is also a section detailing the earthworms and one detailing accessibility all of which are not included in the Digester Manual.

The next stage in creating the deliverable for this objective, the wordless instruction manual, was creating the Digester Bed Manual Framework, Appendix A. Using both the Makers Manual and CAD guide, a step-by-step document was created. This document was created with the intention of sending it to a professional CAD artist, Patrick Charles Brown, to make the models and images needed for the manual. The redesigned portions of the GMF toilet are included as part of this framework and are reflected in the final Wordless Manual.

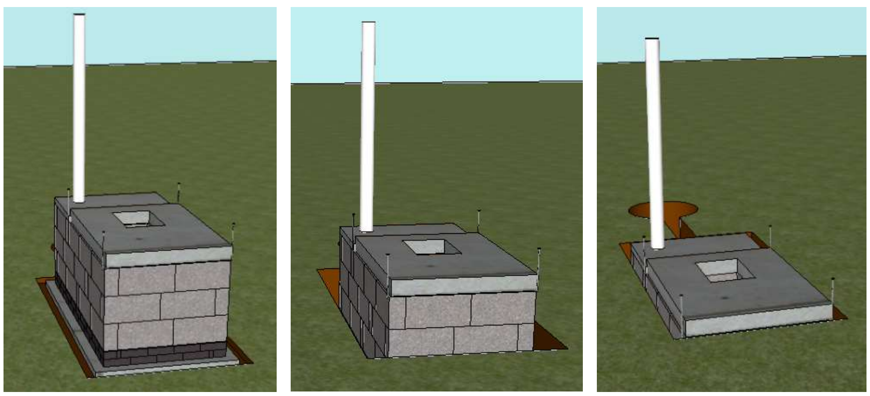
The document in Appendix A compiles details about creating the desired images for the wordless manual. There are 13 building steps in the Digester framework. It is formatted starting with the building steps and written descriptions of the visual to accompany it. The materials and tools needed for each step are also included, which were added to the pages in addition to the main illustration. Next, images were found from the original CAD guide that are similar to the desired illustrations, along with critiques on those images to clarify what needs changing.

The framework was then sent to Mr. Brown who sent back many of the images requested. The images were then compiled in order in Appendix B. The wordless manual only reflects the Digester bed and work will continue by others beyond this MQP.

[6] Figure 6: Outdated Completed Digester Walls from *GSAP Microflush Toilet-Maker's Manual*

In order to address the second objective to Reengineer the design to better utilize resources and simplify construction the Digester was fully analyzed from an engineering standpoint. During the evaluation of the older manuals and throughout the wordless manual creation, the function of each component as well as the difficulty level of the construction was analyzed. Several components were reviewed from an engineering standpoint and new designs for three portions of the Digester were identified. This MQP has design limitations, specifically in individual hands-on experience with constructing the toilets. There is no accessible documentation on design intent and flaws in practice and therefore there may be some oversights with the reengineering.

One of the most complicated aspects of constructing Microflush Toilets is determining the depth at which to install them. There are currently three installation depths, for water tables of less than 1.5m they are built on the surface, for between 1.5m and 2m they are half buried, and for deeper than 2m they are completely below the surface of the earth.[7]



Explaining the water level test in a wordless format takes several pages, almost as though it could be its own manual. This step seems to be a residual from when these toilets were deployed in wetter climates such as in Central America, which could explain its importance and inclusion in the original process. In Ethiopia, where most villages are in very dry environments, this step is obsolete as the water table is almost guaranteed to be below two meters. Changing this step to reflect these points simplifies the manual as well as the installation.

The solution is to change to two options instead of the aforementioned three: One is to dig the full depth of the Digester Bed measured based on the blocks being used as the walls, approximately 3-4 blocks deep. The second option is to install the entire structure on the slightly dug-into and leveled ground when the water level is known to be high or the ground is too rocky to achieve full ground installation. There are maps of Ethiopia and all countries that document the water table depths, and an easily readable one could be created with two colors distinguishing the high and low water tables. (Wikipedia, Hydrogeology of Ethiopia 2022)

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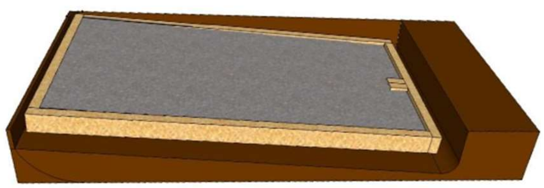
[7] Figure 7: Three Water Table Depth Options from *Mecca, GSAP Microflush Toilet Instructions*

The main structure that could be completely removed is the rock-filled pit that sits at the back of the Digester and is completely covered by dirt. This structure does not appear to have any additional benefits or function than just letting liquid waste seep into the earth. It seems that its purpose was to collect the redirected liquid and disperse it through the different levels of rock sizes, reducing smell by covering it up with dirt. A pipe leads the waste from the concrete slab to the pit which is only a few inches in diameter, too small to allow good flow into the pit. Although this seems like an important feature, after analysis, there is a much simpler way to accomplish the same purpose.

The solution is to entirely remove the soak pit from the design and change the base concrete slab as detailed below. [8]

The slanted nature of the bottom slab makes it complicated to pour and to build the Digester walls on top. In addition, the rectangular nature of the Digester likely leads to the liquid pooling in the corners instead of going into the pipe that leads to the Soak Pit.

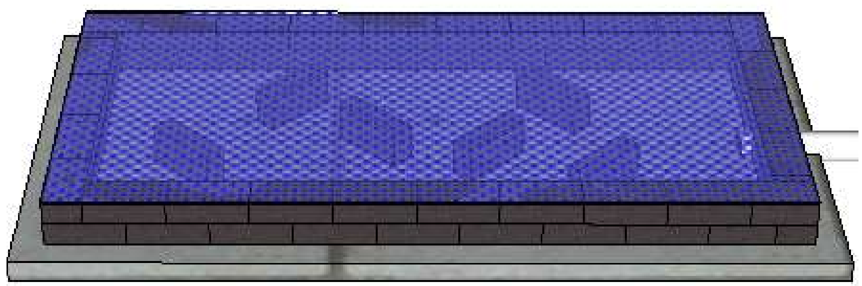


The solution is to change the bottom of the Digester into a bed of gravel and rocks. Instead of getting stuck when flowing into the soak pit pipe, the liquid waste will just seep right into the ground through the gravel and rocks below the Digester filter. The Digester walls will be built on top of this layer just as before. There is no apparent reason why the bottom of the Digester pit must be solid concrete, as it does not provide any structural function. A gravel base in the Digester pit will allow liquids to seep into the earth, a simpler and more effective way of meeting the goal for which the soak pit was originally designed. [9]

[8] Figure 8: Model of Rocks in Soak Pit and Photo of Soak Pit Tube from *Mecca, GSAP Microflush Toilet Instructions*
[9] Figure 9: Model of Slanted Bottom Concrete Slab from *Mecca, GSAP Microflush Toilet Instructions*

In order to address the third objective to create a manual for a recycled plastic mesh retrofit a computer drawing software with a touchscreen and stylus was used. The steps were designed as part of the summer research project previously completed, and now compiled into a usable format. The guide can be found in Appendix C.

There are 25 steps, divided into three distinct sections. The first section details preparing the plastic bags into weaving loops, by cutting off the excess, folding them into sections, and cutting them into six loops per bag. The second section details braiding the loops using a standard three-strand braid, connecting extensions with loop-to-loop knots until the target length is reached, the width of the digester bed. The third section details the weaving of the entire mesh. Fitting the braids vertically on the frame, then weaving and connecting loops until the mesh is complete. This plastic mesh is installed similarly to the old method of wire mesh and mosquito netting. It will be placed in between the first and second layer of bricks that make up the digester walls. The mortar will hold it in place between the bricks, while there are also support bricks placed to hold up the middle. [10]

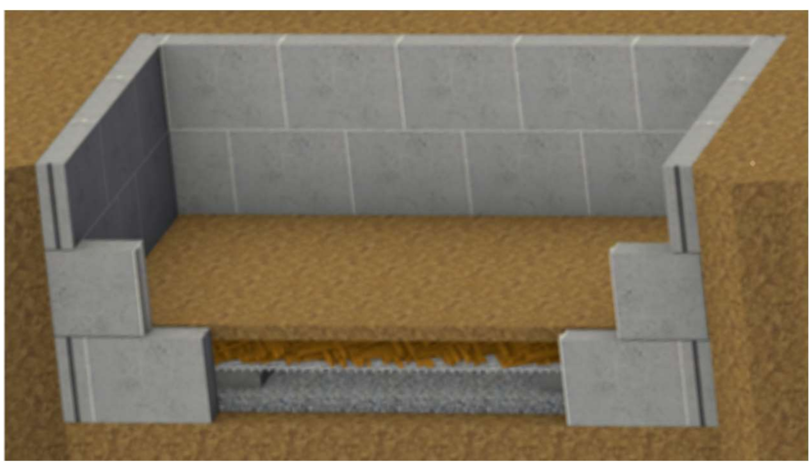


[10] Figure 10: Model of Wire Mesh Insert Construction from *Mecca, GSAP Microflush Toilet Instructions*

Conclusion

This MQP is just a piece of the puzzle in regard to the GSAP Microflush Toilet Project. It tackles the current issues facing implementation in Ethiopia; a lack of materials and simple instructions that can be universally used. Creating a wordless manual for the entire toilet will drastically improve the building process and make these toilets even more sustainable and accessible. Starting with the Digester, the main component of the toilet's function and success will lead to more manuals being created by the team in the future. This project created such a manual as well as re-engineered the digester, simplifying it down to its most necessary components and aiding in the versatility of the design. Included in this redesign is a crafted mesh filter using recycled plastic bags, designed previously but documented in a manual as part of this MQP.

Continued work on GMF Toilets is already underway, with some next objectives including expanding these wordless manuals to encompass the rest of the toilet design. Testing of the re-engineered digester should be done on-site in Ethiopia, as well as distribution of the plastic mesh manual to the communities who will create and sell them to toilet manufacturers. Eventually, a complete version of the wordless manual should be distributed to the Makers and other people constructing these abroad. Although the GSAP Microflsuh Toilets are over a decade in the making, they will continue to improve sanitation in developing nations, this MQP was completed in the hopes of pushing them in an even better direction.[11]



[11] Figure 11: CAD Render of Final Redesigned Digester from *Patrick Charles Brown*

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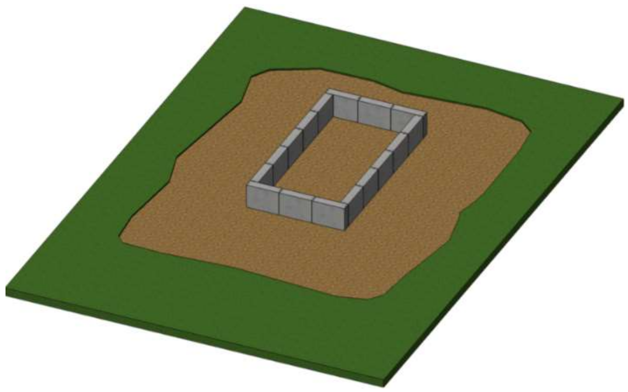
Appendix A: Digester Framework

Key:

#. Text in standard font is a description of what is shown in the figure

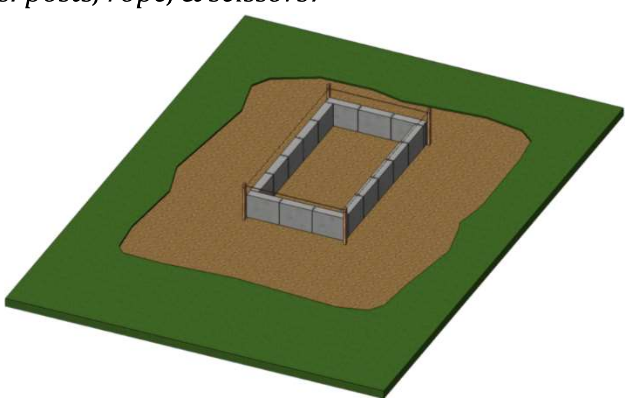
- *Text in italics font describes what figure should eventually be produced*
  - *Tools: what tools should be displayed on the corner of each page*
- Text in red is a question or criticism about a particular step

1. Prepare and level patch of ground
   - *Patch of land stripped of grass*
     - *Tools: shovel & level*
2. Lay out blocks in correct size and formation
   - *Patch of stripped land with bricks in layout*
     - *Tools: 16 bricks*



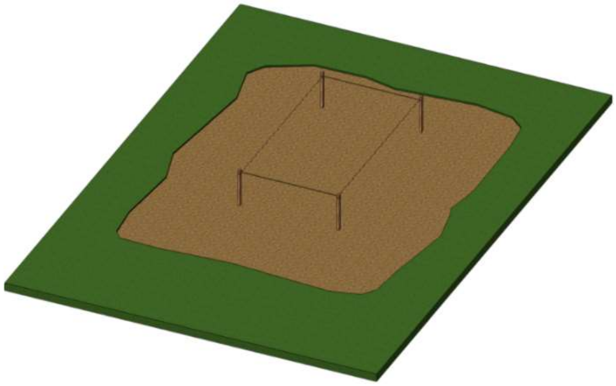
- Zoom in on bricks and the land around it smaller
- For this and following images: Zoom in on important, center area of image - more action, less landscape

3. Place corner sticks and rope to mark dig area
   - *Same as before, adding rope and posts to corners*
     - *Materials: posts, rope, & scissors?*



- Zoom in on bricks so rope and posts are more clearly visible
- Add photo of string and posts to left

4. Remove blocks
   - *Rope and string left behind without blocks*
     - *Materials: none*

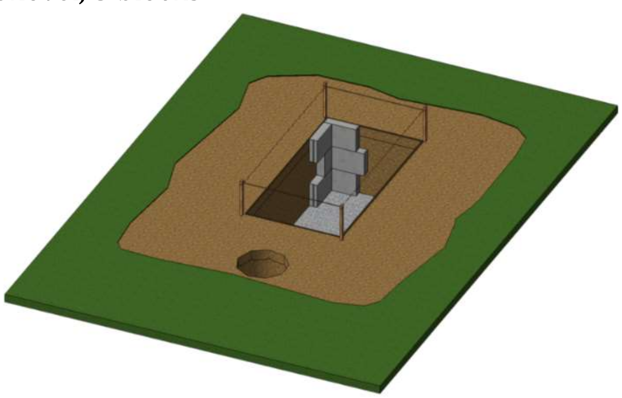


   - Perhaps add blocks off to side to demonstrate them being removed?

5. Dig rectangular hole to specified depth based on water table

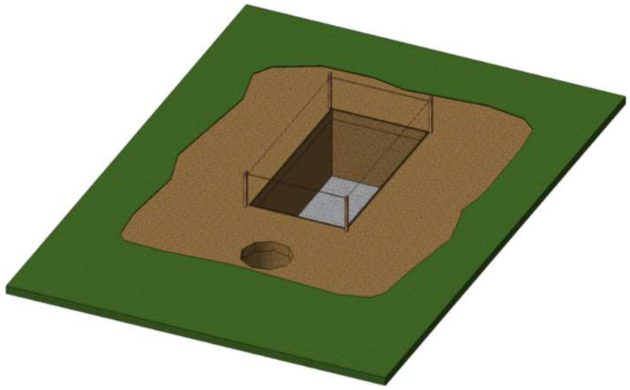
   High → no dig, just level area with shovels
   - *Raw earth ~ 1 cm deep with shovel hovering*
     - *Tools: Shovel*

   Low → dig to 3 blocks deep
   - *Hole being dug with shovels, three blocks stacked in corner to surface*
     - *Tools: Shovel, 3 blocks*



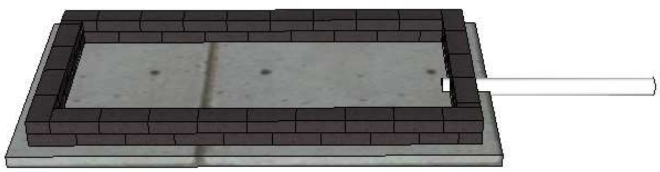
   - *Like this but as a cut away view, only 3 blocks demonstrating height without the extra blocks that create a corner, without the soak pit hole and with no gravel at the bottom of the hole just raw earth*

6. Pour a layer of gravel at the bottom of hole, remove sticks & rope
   - *Shows 3 previously demonstrated heights of holes, without measuring blocks, with gravel/rocks being poured into them to form bottom layer*
     - *Tools: rocks/gravel & shovel*



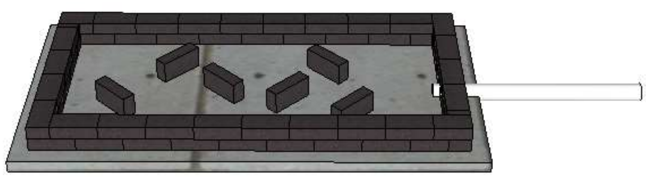
- *3 images, and change to cut away view, remove the sticks & rope to demonstrate they are no longer being used, no soak pit*

7. Lay first layer of blocks with cement mortar
   - *New view, instead of 3 views as before, simplify to just digester, unearthed*
   - *Blocks form first layer of digester bed walls*
     - *Tools: 16 blocks, cement mortar, trowel*



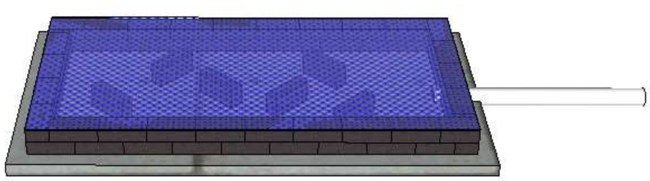
   - *Blocks instead of bricks and on top of gravel foundation, remove pipe*

8. Lay support blocks for digester bed
   - *Same as previous, adding 4? Support blocks spread out*
     - *Tools: Blocks*



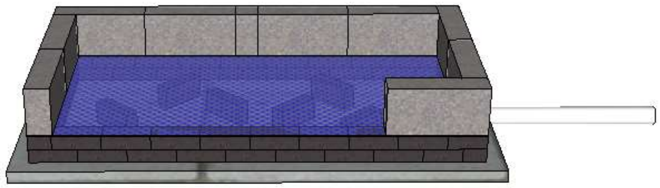
   - *Same adjustments as previous step*

9. Lay Plastic Mesh layer on top of blocks
   - *Same as previous, adding plastic mesh on top of blocks, small amount of concrete glue*
     - *Tools: plastic mesh, concrete, trowel*



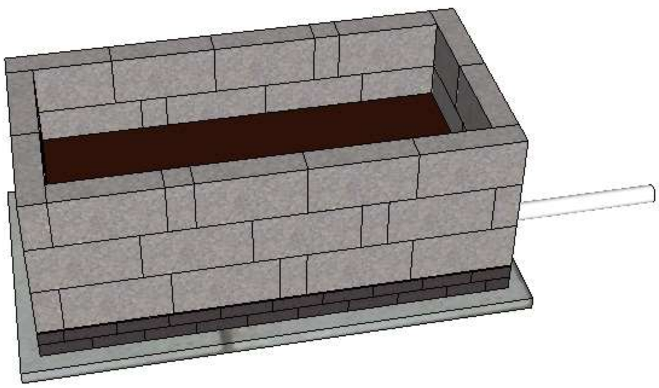
   - *Same adjustments, with additional change to an opaque white mesh*

10. Lay first layer of digester wall overlapping the mesh with cement mortar
   - *Layer of blocks overlapping the mesh and the bottom layer of the blocks*
     - *Tools: 16 blocks, concrete mortar, trowel*



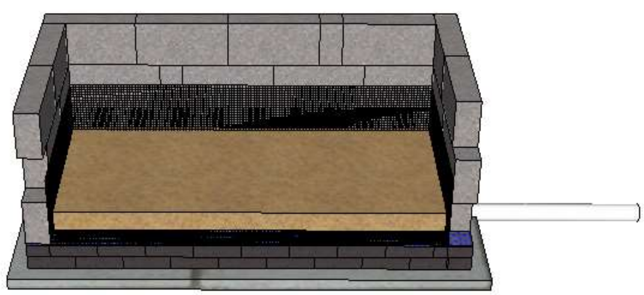
- *Same adjustments, and ensures block's overlay of mesh is demonstrated with partial cut away view?*

11. Create one more layers of blocks to form digester walls using cement mortar
    - *Full walls, 3 blocks tall, demonstrating correct layout*
        - *Tools: 16 blocks, concrete mortar, trowel*



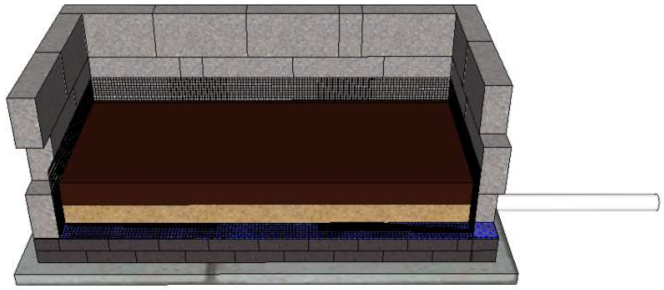
- *Must demonstrate the proper block layout & include visible mortar, still be empty aside from plastic mesh*

12. Fill with layer of hay
    - *Layer of hay overtop the plastic mesh, inside the digester walls, cut away view*
        - *Tools: Hay*



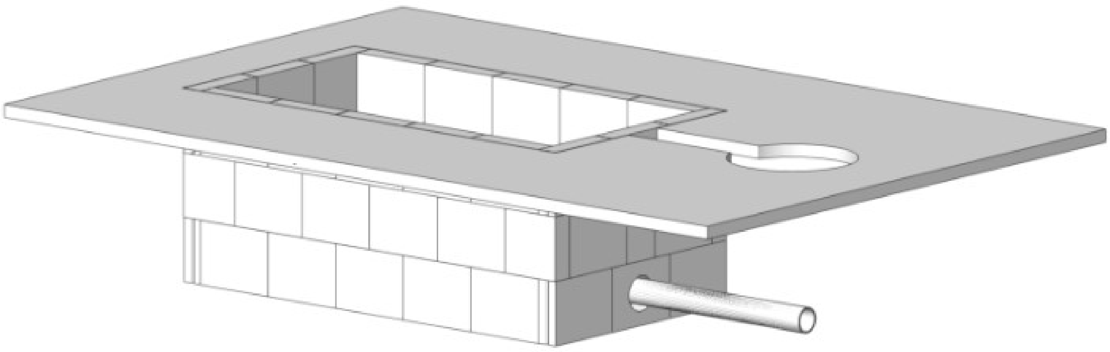
- *Include hay being poured into digester, and less blocky if possible*

13. Fill with layer of soil
    - *Layer of soil overtop the hay layer, inside the digester walls, cut away view*
        - *Tools: Soil*



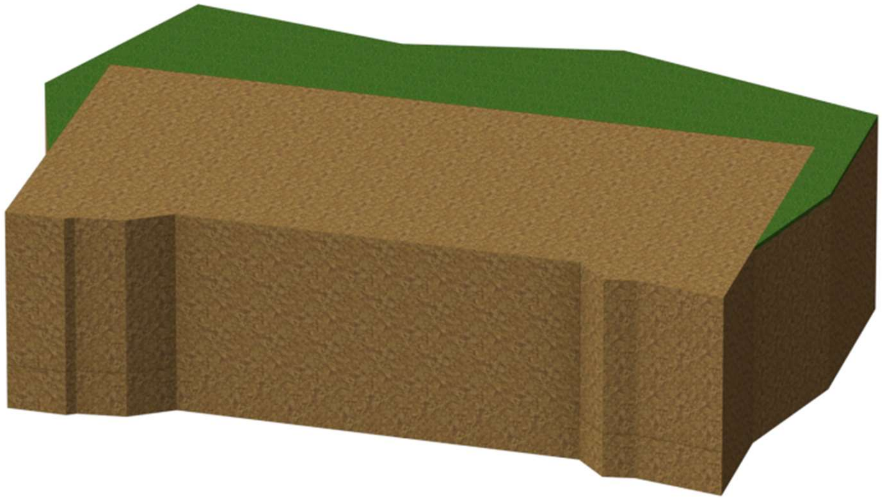
- *Change to lighter brown color, like dirt (same color used for dirt everywhere else in the manual)*

14. Final product:

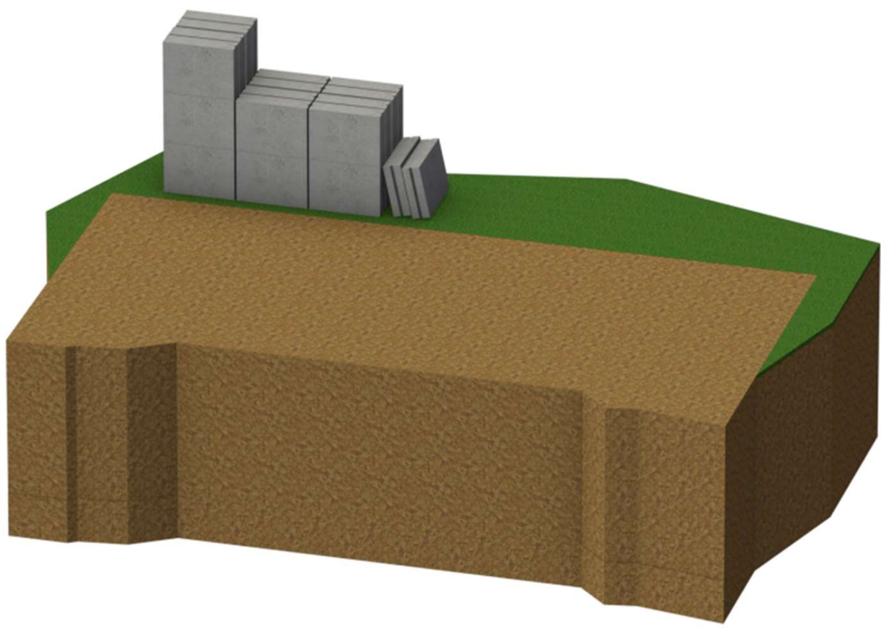


- *Make sure the blocks are all the same size, including partial blocks*
- *Exclude soak pit hole and pipe*

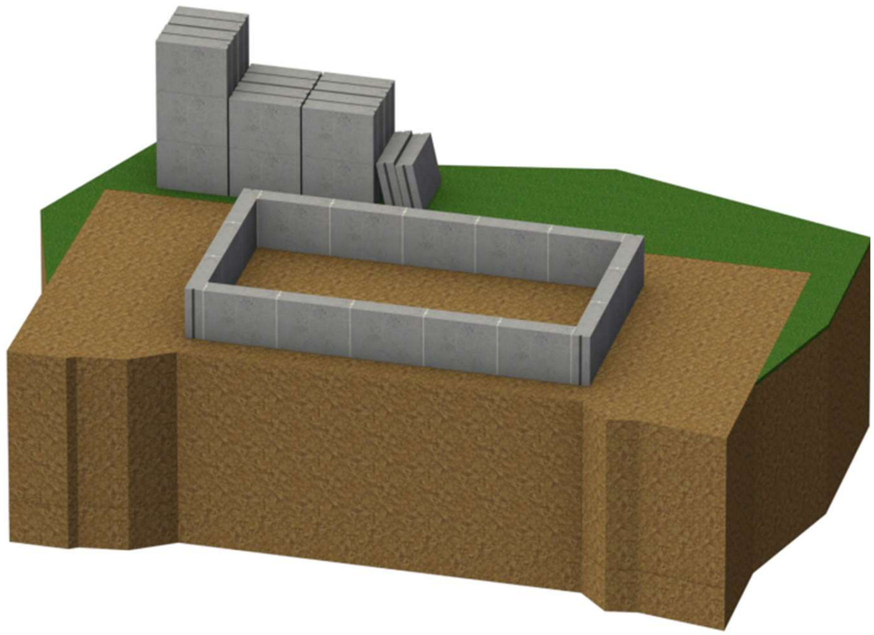
Appendix B: Wordless CAD Manual Draft - Annotated



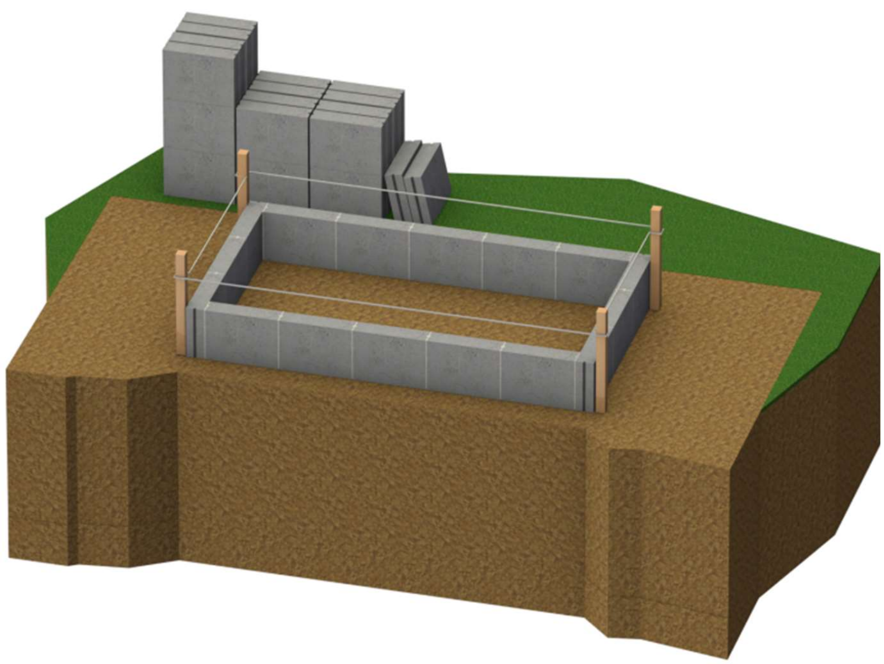
0. Plain Ground
    - *Might not need to include this diagram.*



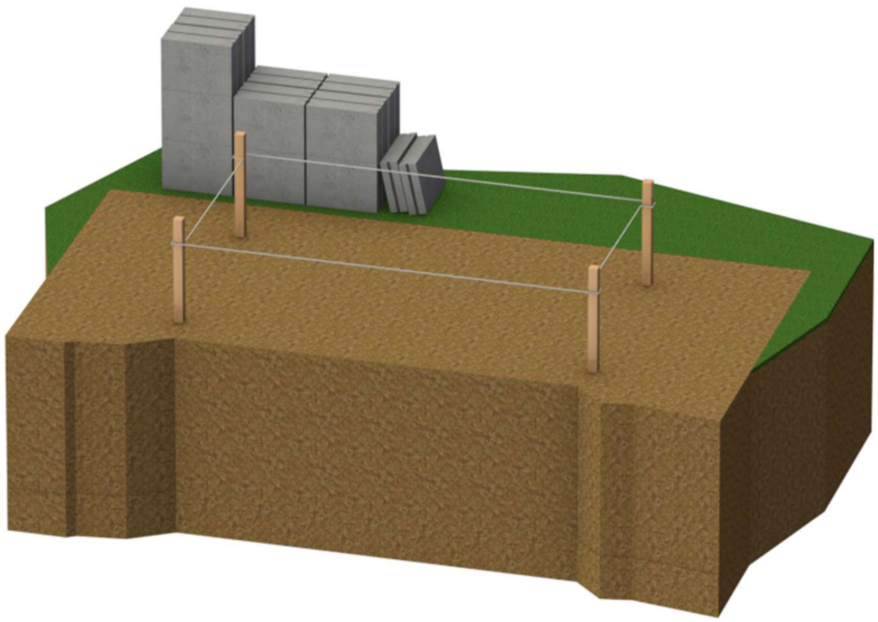
1. Prepare and level patch of ground
    - *Add shovel to corner of diagram.*



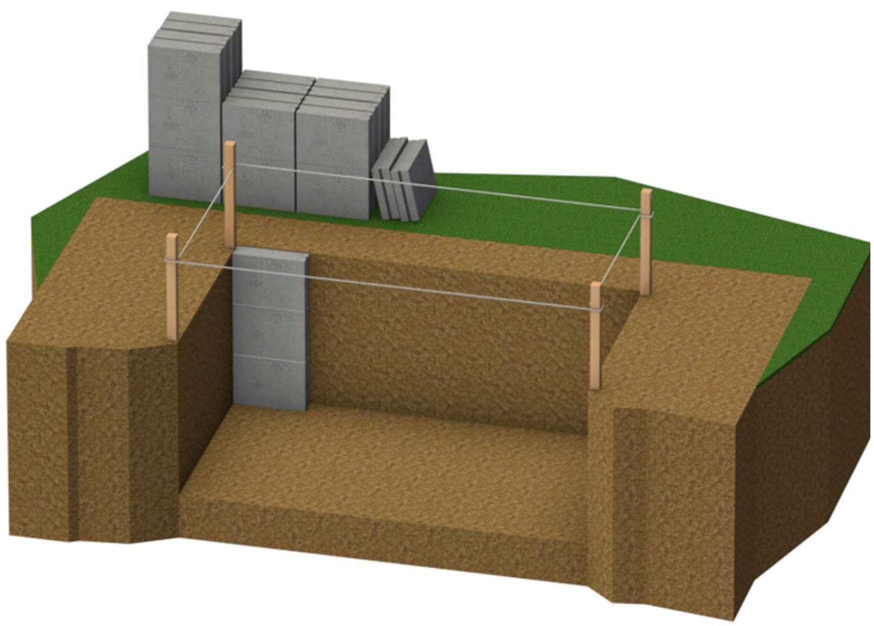
2. Lay out blocks in correct size and formation
    - *Remove bricks from pile as they are laid down, reduce by 16 here. Remove mortar.*



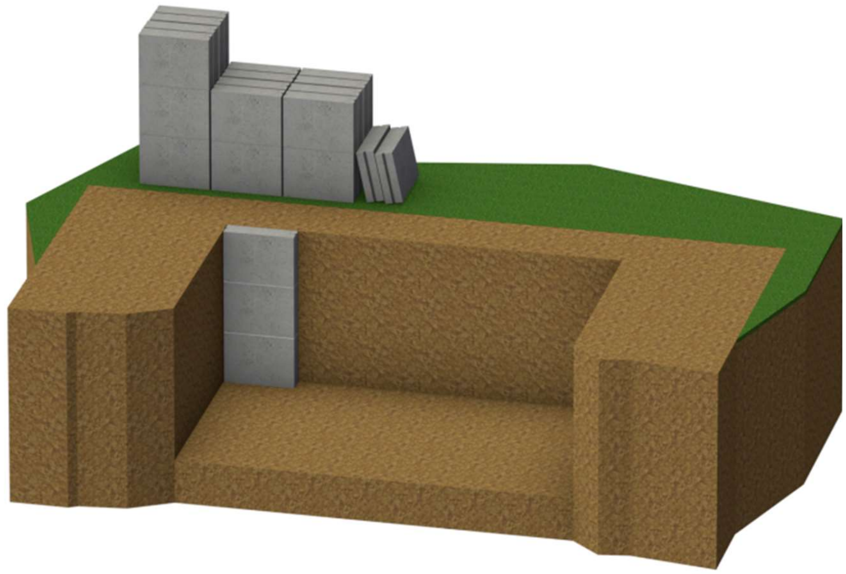
3. Place corner sticks and rope to mark dig area
    - *Same as previous step and add posts and rope to corner of diagram.*



4. Remove Blocks
   - *Return blocks to pile.*

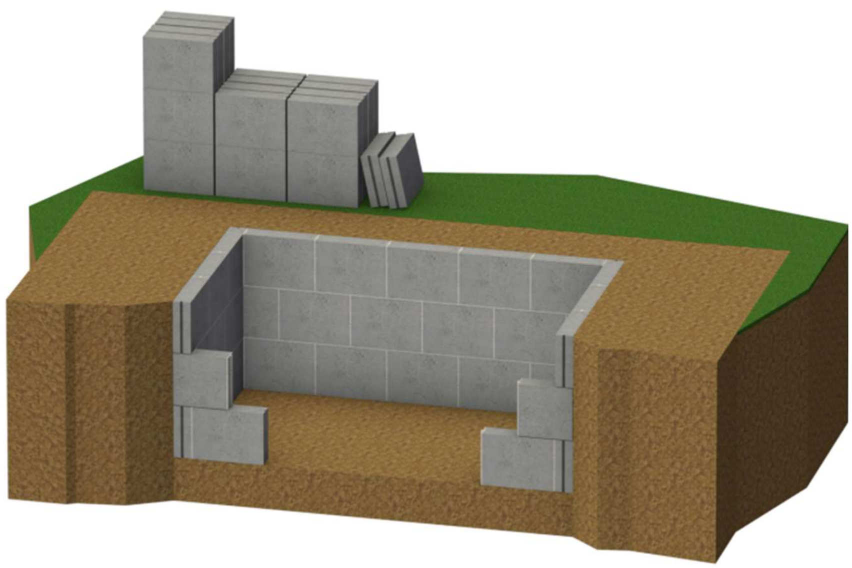


5. Dig rectangular hole to three blocks deep
   - *Take 3 blocks from the pile, remove mortar lines.*



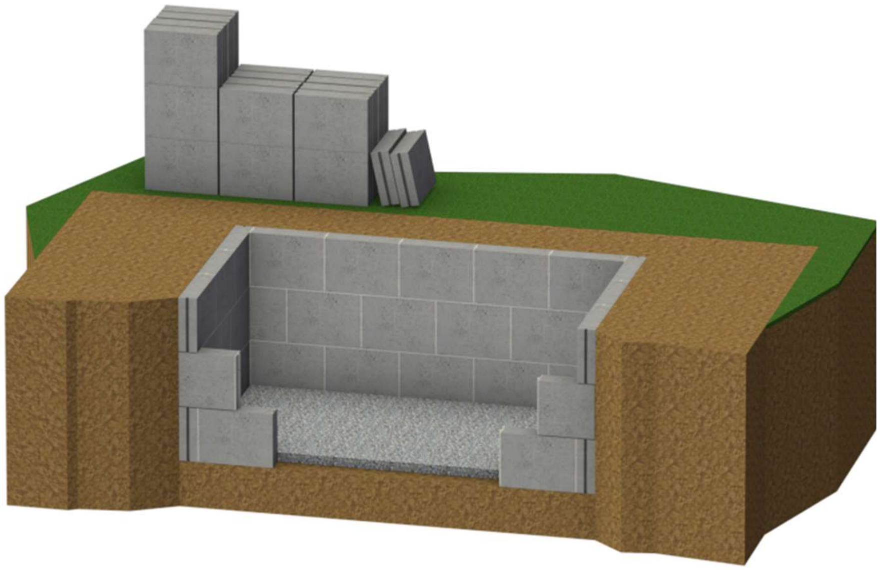
6. Pour a layer of gravel at the bottom of hole, remove sticks & rope

- *Remove measuring blocks and add gravel, include gravel as a tool in corner of diagram*



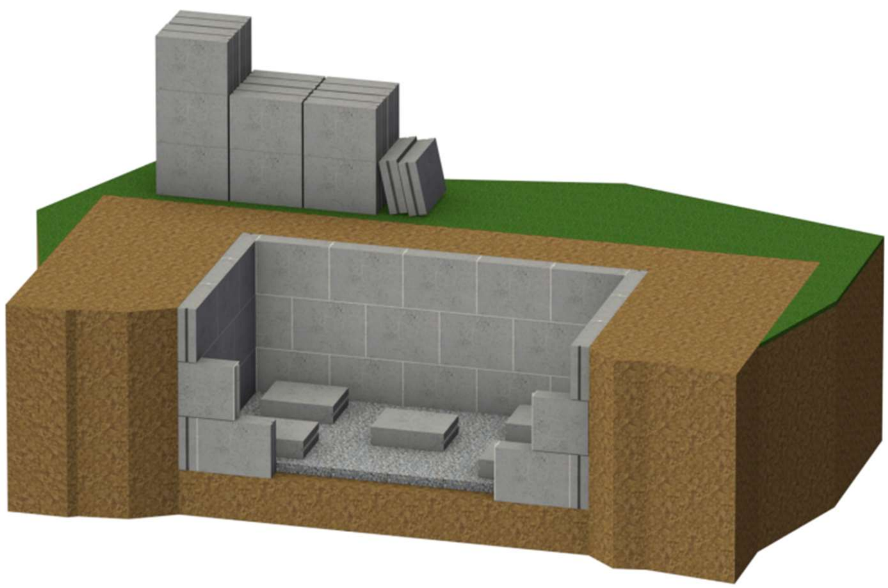
7. Lay first layer of blocks with cement mortar

- *Only put first layer of blocks, include gravel beneath them, remove 16 blocks from the pile again, include mortar and trowel as tools*



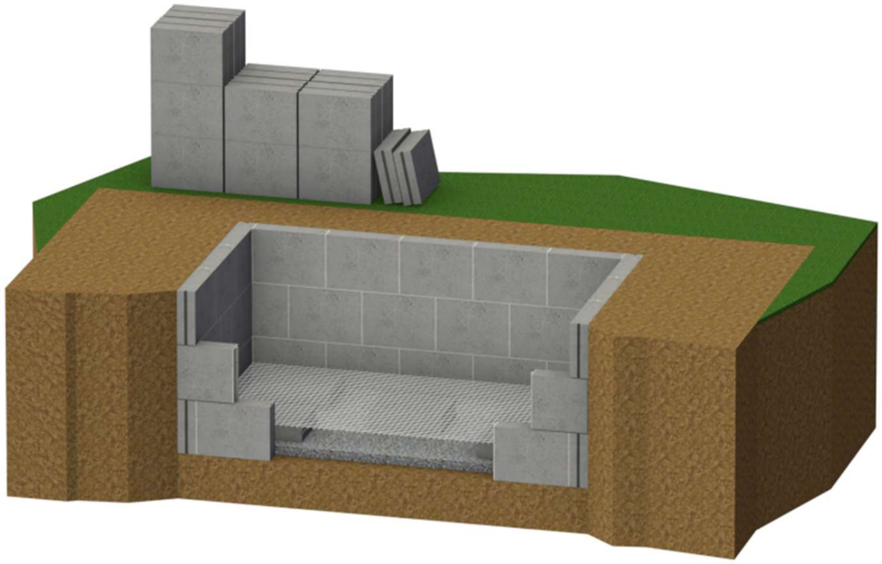
7.5 Gravel?

- *There should already be gravel as previously mentioned.*



8. Lay support blocks for digester bed

- *Maintain only first layer of blocks creating a cut away view at the vertical seam, remove front two visible blocks. Orient the support blocks vertically. Remove 5 blocks from the pile.*



9. Lay Plastic Mesh layer on top of blocks

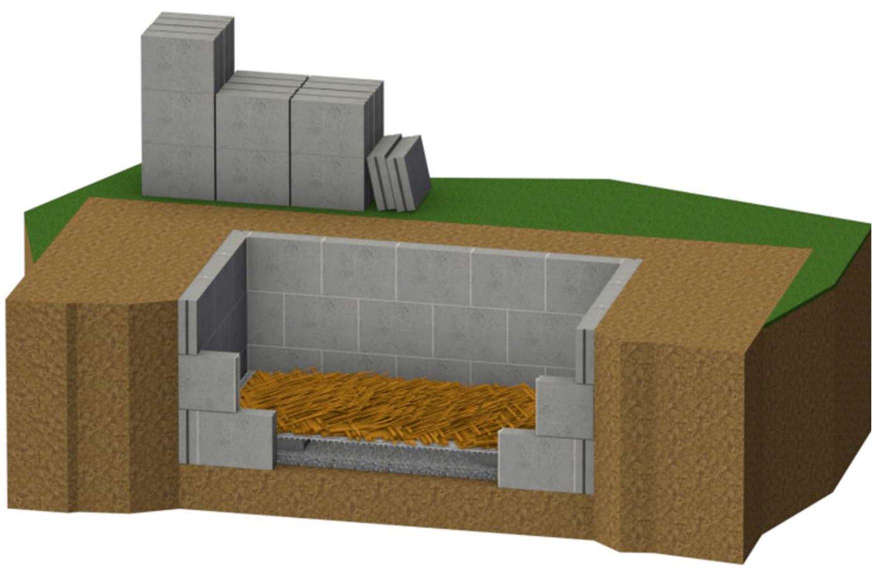
  - *Make mesh more opaque, lay it over the first block layer*

10. Lay first layer of digester wall overlapping the mesh with cement mortar

  - *Diagram missing, ensure plastic mesh is visible between first and second layer, no cut away view here, full block layout visible, remove 16 more blocks from pile*

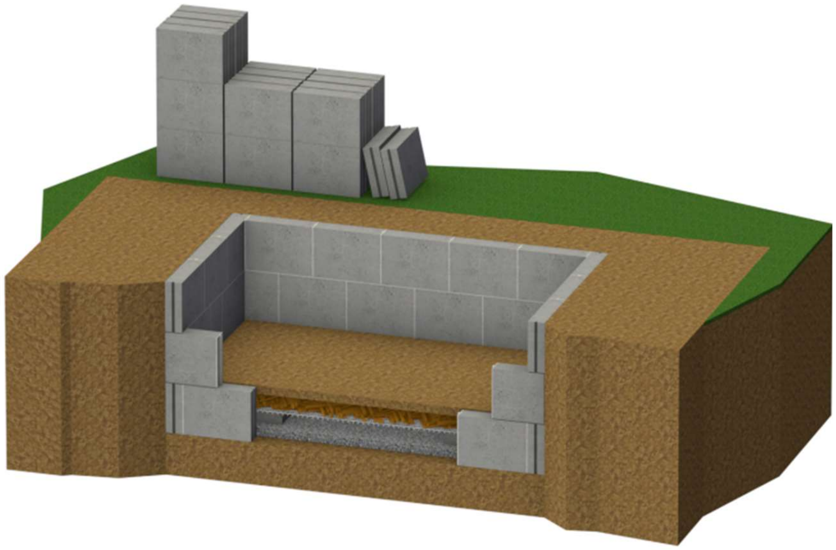
11. Create one more layers of blocks to form digester walls using cement mortar

  - *Same as above, no cut away view, remove remaining blocks from pile*

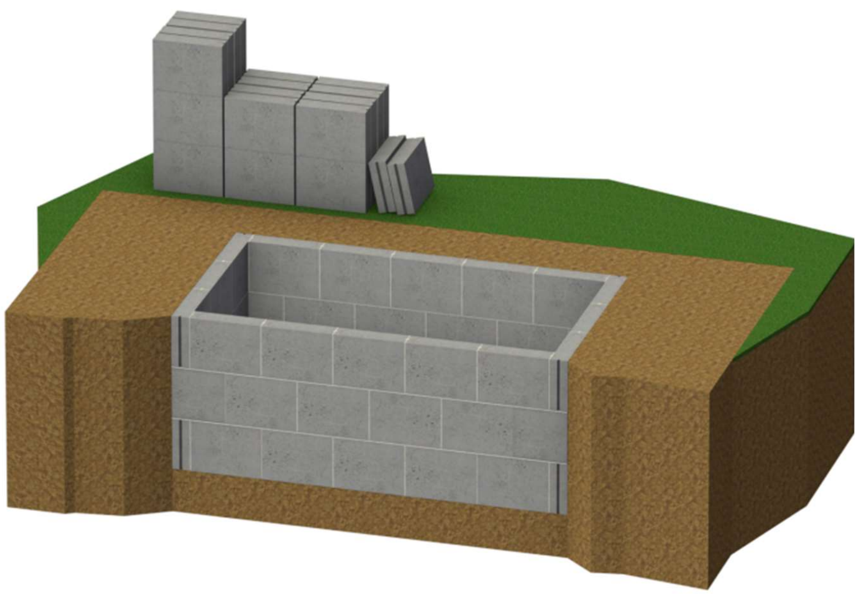


12. Fill with layer of hay

  - *Begin cut away view here, cropping at vertical seam, no block pile from here onward*



13. Fill with layer of soil
    - *Adjust like previous step*



14. Final product:
    - *Good besides block pile*

Appendix C: Recycled Plastic Mesh Guide