DECEMBER 9, 2014

Photo Courtesy of Cheryl

MAINPAT REFUGEE CAMP

WASTEWATER DESIGN AND WATER SAMPLING PLAN

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Definitions

- Arsenic- a chemical commonly found in groundwater sources that can be harmful or deadly if present in high concentrations.
- Nitrates- inorganic compounds often originating from fertilizer or other agricultural products
- Typhoid Fever- an infection that causes diarrhea and a rash -- most commonly due to a type of bacteria called Salmonella typhi (S. typhi).
- Total Coliform Count- a water quality test procedure that gives a general indication of the sanitary condition of a water supply.
- Turbidity- the cloudiness or haziness of a fluid caused by large numbers of individual particles.

Acknowledgments

We would like to express our gratitude to Dr. Bridget Bero, Department Chair of Civil Engineering, Environmental Engineering, and Construction Management. She has been an immense help throughout the semester and has provided invaluable advice to our team.

We would also like to thank Cheryl Dilks, our primary project client. She has provided us with an abundance of information on Mainpat including pictures and site descriptions of Mainpat Refugee Camp. In addition, Alan Francis, an instructor here at NAU, has provided the team with blueprints and critical information about Mainpat, India.

Alarick Reibolt, the “Head Field Sampler” and our team’s technical advisor, has also contributed to this project. His input and suggestions have helped our team throughout the semester.

Finally, we would like to thank Dr. Charles Schlinger and Mark Lamer who have given us constructive criticism throughout the capstone course. Their comments and criticism have been important to us and we have taken them into account throughout the duration of this project.

1.0 Project Description

Mainpat Tibetan Refugee Camp is located in the state of Chhattisgarh, India. The initial population of the camp was 2000 in 1962; the current population is 1,825 residents. The elevation of the camp is approximately 3500 ft. above sea level making it the highest area in the state. The nearest town to Mainpat is the town of Ambikapur, which is located 45 km away and can be seen in Figure 2. The closest town with an airport is Varanasi, at a distance of 300 km. The location of Mainpat can be seen as the letter A on the above map, Figure 1.

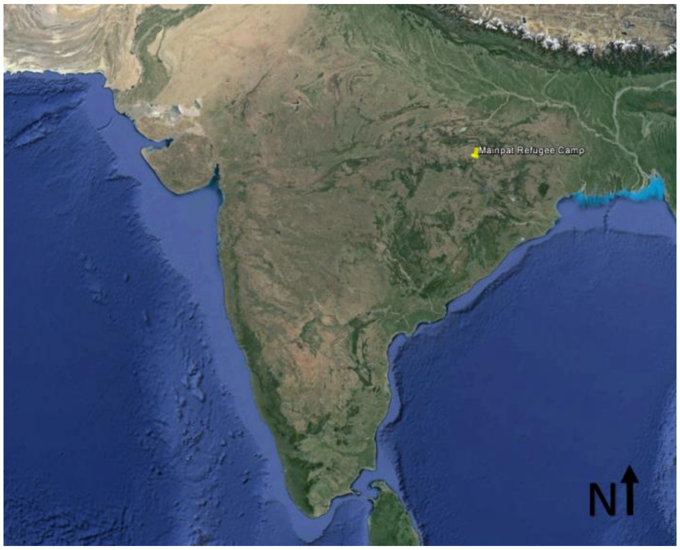

Figure 1: Camp Location (Google Earth)

Figure 2: Location of Ambikapur (Google Earth)

The settlement is split into 7 different camps within a radius of 25 km, and the average distance between each camp is 5 to 6 km. Camp 1 is the central location of the town and contains the school, settlement office, co-operative society, workshop and health clinics. The camps' number of households can be seen below in Table 1.

Table 1: Number of Households per Camp (Dilks, Cheryl)

Camp	**One**	**Two**	**Three**	**Four**	**Five**	**Six**	**Seven**	**Total**
Number of Households	99	55	28	48	17	17	30	**294**

Education for the settlement consists of one Crèche (Day Care), four kindergartens, and one middle school located in Camp 1. For healthcare, Mainpat has an allopathic dispensary and a Tibetan herbal medicine clinic. The settlement also consists of three monasteries.

Each of the camps has a group leader who report to the settlements representative. The representative for the settlement then reports to the Central Tibetan Administration with information on the settlement. A map showing the relative locations of the seven Mainpat camps is provided below in Figure 3.

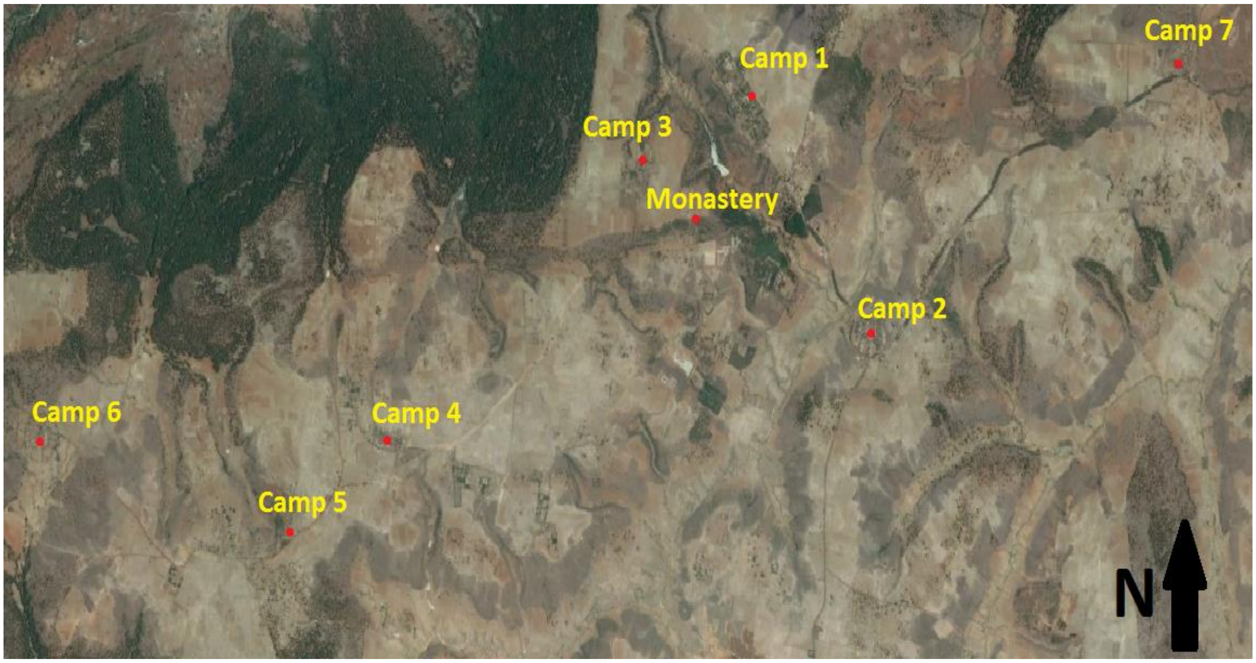

Figure 3: Mainpat Camps Location (Google Earth)

Water supply for the camps consists of seven wells located at each of the seven camps. Water is taken from the ground using an underground electric pump. The electric pump pumps the water through piping to an above-ground water storage tank. The water storage tank then feeds the surrounding residents, using gravity for transportation. In Mainpat, India the main monastery located in camp 3 is under construction by the local Rinpoche.

The department of Civil Engineering, Environmental Engineering, and Construction Management at NAU has been involved with Mainpat Refugee Camp for around two years. Last year Cheryl Dilks, a former NAU student, traveled to Mainpat Refugee Camp and informed the university of her findings. She noticed two overarching problems at the camps. The first problem was an outbreak of typhoid fever at all seven camps. The second main problem was the lack of wastewater containment at the monastery in Camp 3. Our team was assigned to address these problems and implement a possible solution. This report addresses these two solutions in two components:

1) Wastewater Design at the Monastery
2) Sampling Protocol for the Seven Camps

The first part of the project, per Cheryl Dilks' request, was to design a wastewater removal method for the Monastery at Camp 3 of Mainpat. In addition, the wastewater system needed to be culturally acceptable to Mainpat residents. Residents currently use a flat toilet that is flushed with a bucket, which can be seen in Figure 5. Previously, Mainpat residents stored wastewater in a septic tank. However, the septic tank has recently been unattached from the building and does not connect to the incoming piping from the monk's quarters. The location of the existing septic tank in relation to the monastery can be seen in Figure 6.

Figure 4: Uncontained Waste (Dilks, Cheryl)

Figure 5: Monastery Toilet (Dilks, Cheryl)

The effluent coming from the monk's quarters was then flowing into an open field behind the monastery, which can be seen in Figure 4. This uncontained waste can create an unsanitary environment and spread waterborne illnesses, as well as possibly contribute to the recent typhoid fever outbreak at Mainpat.

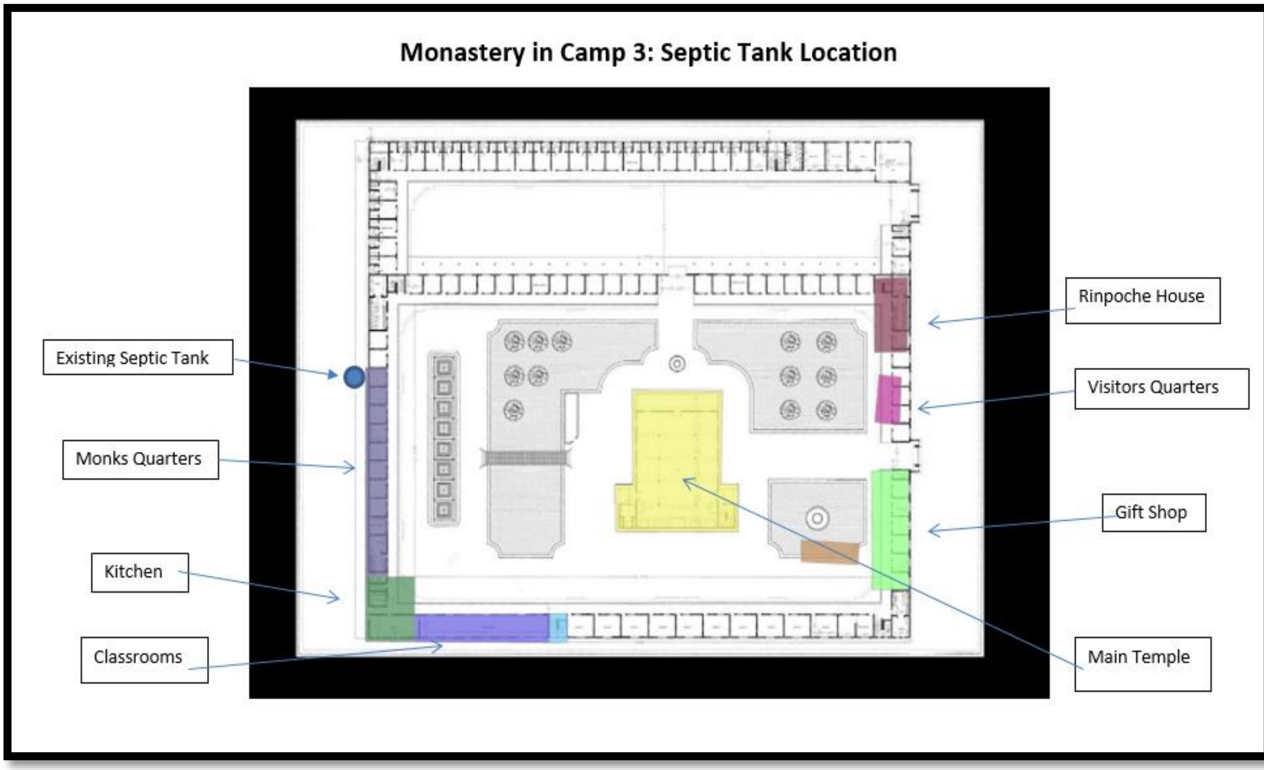

Figure 6: Monastery in Camp 3 Septic Tank Location (Dilks, Cheryl)

The second part of this design report is to address this recent outbreak of typhoid fever that has spread across the community of Mainpat. A sampling protocol has been created for the field samplers traveling to Mainpat in December 2014. The field samplers will be testing for five water quality parameters in Mainpat's water supply. The five parameters are:

1) Total Coliform Count
2) Turbidity
3) Nitrates
4) Arsenic
5) Lead

These parameters were chosen because they provide a good indication to the overall health of the water supply at Mainpat. The sampling protocol, located in Appendix A of this report, provides a detailed explanation of why each water quality parameter was selected for testing. It also provides *all* necessary information for the field samplers.

2.0 Background Research

In order to perform a wastewater disposal method research must be gathered. The research conducted will include soil analysis, wastewater design, and small scale wastewater treatment systems.

2.1 Wastewater Information

The average per capita use of wastewater per day in the United States is around 100 gallons. In India, however, per capita use per day is about 31 gallons. Therefore all designs needed to be based off this number when performing technical calculations for Mainpat's wastewater system (5).

2.2 Soil Analysis

A soil analysis found that the soil at the Mainpat camp was ferric luvisols, per the map in Figure 7. Luvisols are characteristic to low leveled forested regions. They are identified by alluvial horizons and illuvial horizons with an accumulation of silicate clay. Other properties include a leafy humus horizon and a separate mineral horizon. Luvisols fall into the category of silt loam, based on USDA classification. This means the soil is primarily silt (0.002-0.02mm). This soil has a percolation rate of a moderate 2.5 gal/ft^2/hour. Determining the percolation rates of the soils at Mainpat was an important consideration, especially if a leach field was to be implemented in the final design.

FIGURE 3
Dominant soil map of India

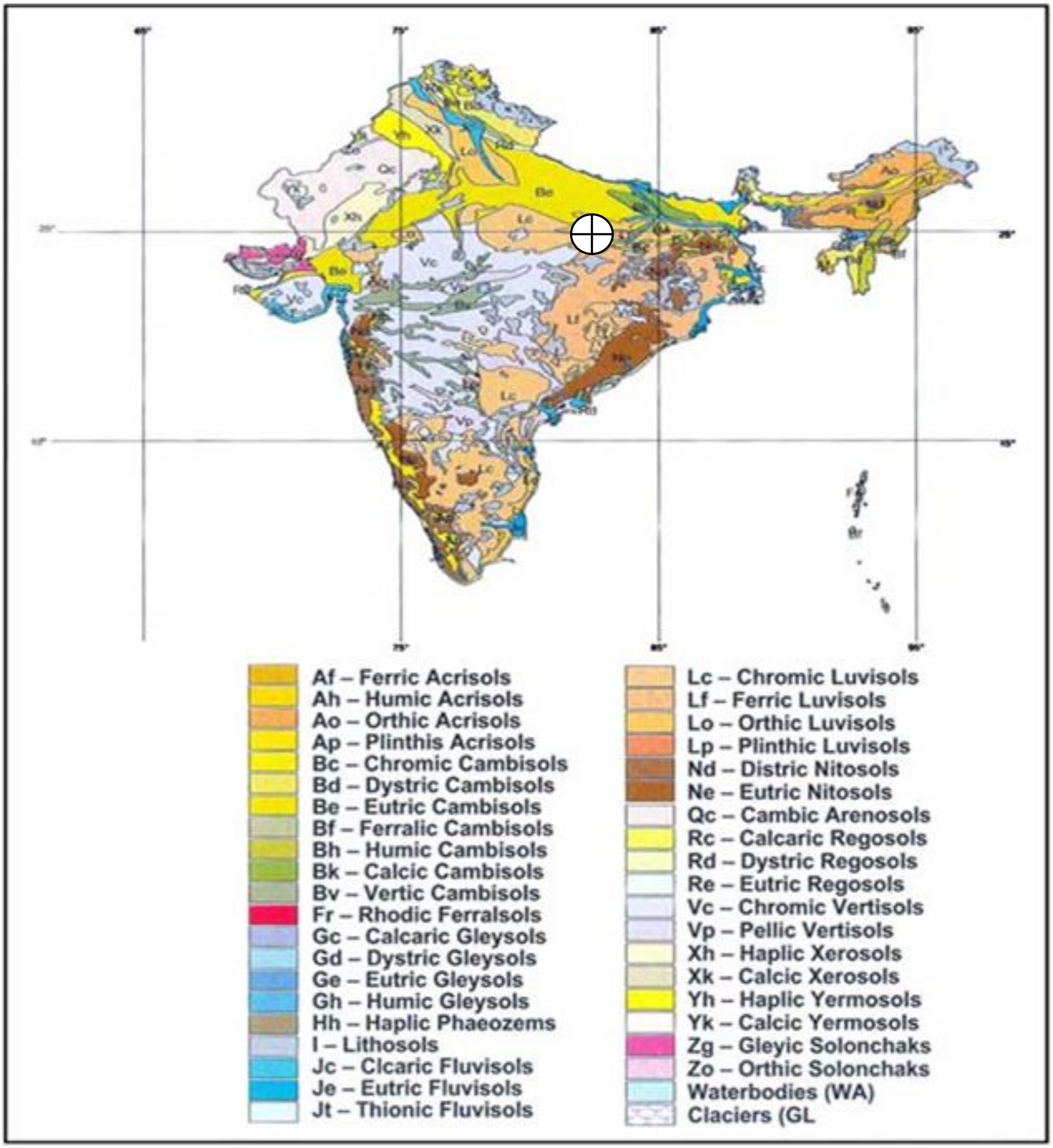

Figure 7: Soil Analysis (Simonson, R)

2.3 Wastewater Disposal Options

Three different categories of wastewater disposal options were considered: physical, chemical, and biological. Each category was broken into the main options for wastewater removal. The options mentioned are from the textbook "Water and Wastewater Engineering: Design Principles and Practice" (Davis, 2002). It is important to note that these wastewater treatment options are usually employed on a municipal scale.

Physical

-Sedimentation (Clarification) - Using a large body of water to remove solids with the use of gravity. The suspended solids eventually will reach the bottom of the tank or pond. Tanks with clarifiers have a way to remove the sunken solids.

-Screening- Utilizes a screen in order to collect larger waste from the stream. The screen then needs to be manually cleaned.

-Aeration- The process of adding oxygen into the bottom of a tank to remove stagnant gases. This also increases the rate of digestion by aerobic bacteria.

-Filtration- Using a very fine membrane filter to remove the finer particles in the wastewater. This process is done after the wastewater has been treated.

-Flotation and Skimming- The process of removing solids and oils by releasing air bubbles into the bottom of the tank making the solids and oils float. The solids and oils are then collected by a skimmer on the top of the tank.

-Degasification- The use of a vacuum to remove the gasses from the wastewater, thus improving the removal of gases such as dissolved nitrogen.

-Equalization- A process to ensure the incoming wastewater is at the same velocity of the outgoing treated wastewater. This reduces the chance of a surge which can overload the treatment process.

-Incineration- An incinerating toilet is a toilet with a built in incinerator that burns the waste until all water content is out. The ashes that come from the incinerating toilet are sterilized and can be disposed of. The downside to using an incinerating toilet is the need of a fuel source to incinerate. If the human waste becomes a contributing factor to the health of the camp and incinerating toilet option should be considered to insure total sterilization.

Chemical

-Chlorination- Using the addition of chlorine to disinfect the municipal wastewater. Chlorine penetrates and kills many infectious agents, thus making the water potable.

-Ozonation- Using a machine to create ozone hat can be injected into the wastewater. The ozone oxidizes with bacteria, molds, organic material and other pollutants.

-Neutralization- Using an alkaline reagent to adjust the pH level of the wastewater. The adjusted pH levels make the wastewater much easier for removal of the solids.

-Coagulation- With the use of a coagulating agent the solids of the wastewater are coagulated for easier removal. Some common coagulants are alum or aluminum sulfate.

-Adsorption- The removal of the interface between two-phases such as gas-solid or liquid-solid.

-Ion Exchange- Using the addition of a chemical exchanger to demineralize the wastewater for further treatment.

Biological

-Activated Sludge Treatment Methods- Removing waste with the use of a bacteria floc that feeds on the waste and filters the wastewater.

-Trickling Filtration- Using a bed of filter that can be compose of gravel, plastic, ceramics, moss, and lava rock to grow a bacteria film on. The waste is filtered through the media and decomposed by the bacteria.

-Constructed Wetlands- Similar to the aerobic lagoon a constructed wetland is basically a lagoon but with added plant life. The plant life is added to the aid in the decomposition of the human waste. The decomposition is added by microorganisms attaching themselves to the plant life's roots and breaking the organic matter down. As the plants breakdown they turn into a carbon source to further filtrate the human waste out.

-Lagoons- A lagoon is a shallow treatment pond that naturally breaks down organic waste through the use of microorganisms. It contains aerobic and anoxic zones for the bacteria to feed on the waste. Some factors that influence the design of lagoons are: the intensity of sunlight, the amount of rainfall, and the wind velocities in the area.

-Septic Tanks- The septic tank design was based on the existing septic tank that was in place. The option of using the existing tank was considered but decided against due to its failure. The basic design of a septic tank is an underground tank that decomposes the human waste with the aid of microorganisms while getting rid of fluids through leach lines. Leach lines are lines that reach out from the septic tank and flow into the underground soil. For this fluid disposal to be possible a certain rate of percolation has to be achieved by the local soil. In our soil analysis this percolation rate was met.

-Composting Toilets- The design of a composting toilet would incorporate the use of a large holding tank with a breathing valve. The basic design is to collect the human waste in a large tank and with the help of added microorganism (for decomposition) and wood chips (for added air space) the waste will decompose to a fraction of its original size. After the waste is fully decomposed the now fertilizer can be used in local gardens.

3.0 Monastery Wastewater Treatment Options

After analyzing the different disposal methods mentioned before, treatment options were selected that could be implemented at the Monastery. Because many of these options are large scale, high cost, and better suited for municipal facilities they cannot be readily implemented at the Monastery in Camp 3 of Mainpat.

3.1 Design Options

The five designs proposed to treat the wastewater effluent coming from the monastery's monk quarters were: Septic Tank, Composting Toilet, Incinerating Toilet, Aerobic Lagoon, and Constructed Wetlands. Table 2 was constructed to outlay the benefits and downsides to each option.

Table 2: Pros and Cons of Disposal Options

Monastery Wastewater Disposal Options		
Option	+	-
Septic Tank	• Relatively Cheap • Easy installation	• Previous Failure
Composting Toilet	• Low Cost • Possible usage of previous septic	• High Chance of Failure in Future.
Incinerating Toilet	• Clean • Set up anywhere	• High Cost • Maintenance
Aerobic Lagoon	• Low cost • Low maintenance • No Electricity	• Smell • Water Requirement
Constructed Wetland	• Low cost • Low maintenance • No Electricity	• Smell • Water Requirement

3.1.1 Septic Tank

The septic tank design was based on the existing septic tank that was in place. The option of using the existing tank was considered but decided against due to its failure. The basic design of a septic tank is an underground tank that decomposes the human waste with the aid of microorganisms while getting rid of fluids through leach lines. Leach lines are lines that reach out from the septic tank and flow into the underground soil. For this fluid disposal to be possible a certain rate of percolation has to be achieved by the local soil. In our soil analysis this percolation rate was met.

3.1.2 Composting Toilet

The design of a composting toilet would incorporate the use of a large holding tank with a breathing valve. The basic design is to collect the human waste in a large tank and with the help of added microorganism (for decomposition) and wood chips (for added air space) the waste will decompose to a fraction of its original size. After the waste is fully decomposed, the now fertilizer can be used in local fields.

3.1.3 Incinerating Toilet

An incinerating toilet is a toilet with a built in incinerator that burns the waste until all water content is out. The ashes that come from the incinerating toilet are sterilized and can be disposed of. The downside to using an incinerating toilet is the need of a fuel source to incinerate. If the human waste becomes a contributing factor to the health of the camp and incinerating toilet option should be considered to insure total sterilization.

3.1.4 Aerobic Lagoon

A lagoon is a shallow treatment pond that naturally breaks down organic waste through the use of microorganisms. It contains aerobic and anoxic zones for the bacteria to feed on the waste. Some factors that influence the design of lagoons are: the intensity of sunlight, the amount of rainfall, and the wind velocities in the area.

3.1.5 Constructed Wetlands

Similar to the aerobic lagoon a constructed wetland is basically a lagoon but with added plant life. The plant life is added to the aid in the decomposition of the human waste. The decomposition is added by microorganisms attaching themselves to the plant life's roots and breaking the organic matter down. As the plants breakdown they turn into a carbon source to further filtrate the human waste out.

3.2 Preliminary Design Decision Matrix

A preliminary decision design matrix was composed based on the five disposal options. Each option was then analyzed in five criteria: initial cost, ease of maintenance, aesthetic appeal and safety, and cultural acceptance. Each criteria was given a value based on the importance. The higher the value given, the more important the criteria. The design option was given a value out of the total value for that criteria. A total was then composed and the highest value shows the best option for wastewater disposal.

Initial cost

This criterion is worth 25% of the total weight of the decision matrix. It is important that the wastewater treatment option is cost effective for both the university and Mainpat residents. The evaluation of this criterion is on a scale from 1 to 3 as follows:

1=Very high cost

2=Average cost

3=Low cost

Ease of Maintenance

This criterion is worth 20% of the total weight of the decision matrix. Mainpat residents should be able to maintain their treatment system in the coming years, without external support. It is crucial that the residents are self-sufficient in managing their wastewater. Therefore, the ease of maintenance is an important criterion in deciding which design to implement. The evaluation of this criterion is on a scale from 1 to 3 as follows:

1=Extensive maintenance required

2=Average maintenance required

3=Little maintenance required

Effectiveness

This criterion is worth 20% of the total weight of the decision matrix. Obviously, the wastewater treatment option must be able to perform its job. It is crucial that the wastewater is separated and/or treated appropriately to mitigate the risk of waterborne illnesses. The evaluation of this criterion is on a scale from 1 to 3 as follows:

1=Low effectiveness

2=Average effectiveness

3=High effectiveness

Aesthetic Appeal and Safety

This criterion is worth 10% of the total weight of the decision matrix. The aesthetic appeal takes into account how visually pleasing the design is and whether it produces some sort of odor. The safety criterion refers to any potential dangers the treatment system might pose to Mainpat residents. The evaluation of this criterion is on a scale from 1 to 3 as follows:

1=Very aesthetically unpleasing and/or unsafe for residents.

2=Average aesthetic appeal and/or average safety.

3=Aesthetically pleasing and/or very safe.

Cultural Acceptance

This criteria has a weight of 25% of the total weight in the decision matrix. The cultural acceptance is an important criterion in choosing a design because the people of Mainpat need to be comfortable using a specific wastewater treatment option. They must be familiar with how to use the technology that may be implemented at their monastery. The evaluation of this criterion is on a scale from 1 to 3 as follows:

1=Not culturally acceptable.

2=Likely to be culturally accepted.

3=Very likely to be culturally accepted.

Table 3: Preliminary Decision Matrix

Criteria Weighting	Option 1: Composting Toilet	Option 2: Incinerating Toilet	Option 3: Septic Tank	Option 4: Constructed Wetlands	Option 5: Aerated Lagoon
Initial cost (25%)	3	1	2.5	1.5	1.5
Ease of Maintenance (20%)	3	1	2	2	2.5
Effectiveness (20%)	3	3	2	1	1
Aesthetic Appeal and Safety (10%)	2.5	2	2	3	2
Cultural Acceptance (25%)	2.5	1.5	3	2	2
Total (3)	**2.83**	**1.63**	**2.38**	**1.78**	**1.78**

Rationale for numbering system:

Option 1: Composting toilet

-Initial cost: Initial cost for the composting toilets was given a value of 3. A 240 gallon composting bin costs only $199.99 (10). This low amount of cost with no required excavation gave the highest possible score.

-Ease of maintenance: Composting toilets were given a 3 for ease of maintenance. This high value was given due to the fact that the only required maintenance is having to add an accelerator and emptying the composter bin when needed. In addition, the relatively low amount of fluid content makes it easier to operate the composting toilet.

-Effectiveness: When sized to handle a certain load, composting toilets are very effective, giving it a score of 3. Mainpat's mean annual temperature is around 75 degrees Fahrenheit, which is ideal for composting toilets. It allows for a fast degradation of solid waste, therefore accelerating the rate at which composting occurs.

-Aesthetic Appeal and safety: The composting toilet was given a value of 2.5 for aesthetic appeal and safety. This value for aesthetic appeal was assigned due to the two bins that will be located outside the building. Therefore, nobody in the monastery will see the bins making the composting toilet have virtually no effect on aesthetics. In addition, there is no odor released from the system. The safety value is high because the waste is sealed in a container.

-Cultural Acceptance: Composting toilets were given a 2.5 for cultural acceptance because the residents can still use the existing toilets. The only change would be to the outside of the monastery. The only reason the composting toilet was not given a perfect 3 is because the composting byproduct might not be completely familiar to Mainpat residents.

Option 2: Incinerating Toilet

-Initial cost: An initial cost of $61,600 for 28 propane units not including the venting installation was figured (3). This high cost gave the incinerating toilet an initial cost value of 1.

-Ease of maintenance: The incinerating toilet was given a value of 1 of ease of maintenance due to the usage of propane. The units use gas parts, which are harder to find in India, and an increased amount of maintenance is required to ensure safety of all residents.

-Effectiveness: The effectiveness of the incinerating toilet was given the value of 3. The high value is due to the overall incineration of human waste. Incineration will guarantee the removal of harmful pathogens, regardless of local climate.

-Aesthetic Appeal and safety: Incinerating toilets were given a value of 2 for aesthetic appeal and safety. The aesthetic appeal would be only lowered by the smoke emitted by the toilets. Safety could be an issue depending on proper installation and maintenance, or lack thereof.

-Cultural Acceptance: The cultural acceptance of an incinerating toilet was given a value of 1.5 because of the use of propane to burn the waste and the sitting toilet. The toilets in that region are standing so sitting toilets could cause cultural issues.

Option 3: Septic tank

-Initial cost: The initial cost of the septic tank was given a value of 2.5. This value is high due to the possible use of the existing septic tank. Also a large septic tank cost and installation ranges from $8,000 to $100,000 depending on size and existing conditions (18). The removal of the previous septic tank will also need to be considered.

-Ease of maintenance: The septic tank given a value of 2 for ease of maintenance. This is due to the required emptying of the septic tank annually. Since the previous failure of the septic tank, maintenance could have been the reason of failure, thus bringing the value lower.

-Effectiveness: The effectiveness of the septic tank was given a value of 2 due to the failure of the previous septic tank. The value of the septic tank would have been a 3 if previous failure had not occurred.

-Aesthetic Appeal and safety: The aesthetic appeal and safety for the septic tank is valued at 2. The safety of the septic tank is questionable with the previous septic tank failing and human waste being left to drain into an open field. The aesthetic appeal of a septic tank is high because a new design would have been fully covered.

-Cultural Acceptance: Since the existing waste disposal method was a septic tank, the cultural acceptance was given a value of 3. Mainpat residents have used this type of treatment method in the past and had no previous complaints.

Option 4: Constructed wetlands

-Initial cost: The initial cost of the constructed wetland was high due to the addition of the plant life. The weed beds added cost in the range of $10.00 to $30.00 per square foot (19). Since a large amount of plant is required plus the cost of construction and liners the constructed wetland was given a rating of 1.5.

-Ease of maintenance: Constructed wetland require an annual cleaning of plant life. This would require a team to remove all of the unnecessary plant life and bring cost up. However, the maintenance is annual so the constructed wetlands gets a slightly improved score of 2.

-Effectiveness: The effectiveness of the constructed wetland was given the lowest value of 1. This low rating is due to the lack of rainfall in the region. Constructed wetlands need sufficient rainfall in order to operate properly. In addition, all plant life would most likely be lost due to the low amount of moisture in the region.

-Aesthetic Appeal and safety: The aesthetic appeal and safety was given an overall rating of 3 for the constructed wetland. Constructed wetlands contain various plants that are generally pleasing to look at. The safety rating is high because a fence would surround the wetland. With the safety of a fence the constructed wetlands could not be entered by curious Mainpat residents.

-Cultural Acceptance: Since the constructed wetlands would be a newer design to this area of India the cultural acceptance was given a value of 2. The design would allow the use of existing toilets and piping, however the entire wetland might look out of place to local residents.

Option 5: Aerated Lagoon

-Initial cost: The initial cost of the aerated lagoon was given a 1.5 rating due to the high cost of the added lagoon aerators being $5,166.45 per each lagoon (11). The added cost of the construction and bed liners gave the aerated lagoon a high initial cost.

-Ease of maintenance: Aerated lagoons have very little required maintenance giving it the score of 2.5. The only maintenance required is the occasional changing of the beds and disposing of the dried waste.

-Effectiveness: The effectiveness of the aerated lagoon was given the lowest value of 1. This low rating is due to the lack of rainfall in the region. Lagoons require sufficient rainfall in order to operate properly. Without this moisture, the solid waste eventually dries and becomes odorous. This can become very problematic for the people of Mainpat.

-Aesthetic Appeal and safety: The aesthetic appeal and safety was given an overall rating of 2 for the aerated lagoon. Aesthetically, the lagoon will not look nice because the solid waste will sit there and look unpleasing. Without enough fluids the lagoon would begin to resemble a fecal pit. However, the safety rating is high because it would be surrounded by a fence to prohibit curious Mainpat residents from entering.

-Cultural Acceptance: Since the aerated lagoon would be a newer design to this area of India the cultural acceptance was given a value of 2. The design would allow the use of existing toilets and piping, however the lagoon might look out of place to local residents.

Based on the criteria of this preliminary decision matrix, the highest rated design option is the *composting toilet*, with a value of 2.83 out of 3. Before beginning the design of this composting toilet, however, a secondary decision matrix was required. This secondary decision matrix would explore more specific options for the composting toilet. The next section of this report details this decision matrix and explains more specific designs of the composting toilet.

4.0 Secondary Design Options

The composting toilet option was further divided into two possible designs: a community composting unit and individual composting units

4.0.1 Community Composting Unit

The community composting unit is an above ground single two-cell unit. This means all human waste from the Monks Quarters is collected into the same composting cells. The two-cell design offers the ability to rotate the usage of the cells. One cell can then be maintained and cleaned, while the other cell is in use. This community design also allows the ability to use the existing sewage piping and toilets.

4.0.2 Individual Composting Units

An individual composting unit consists of seven below ground two-cell units. Every four rooms of the Monks Quarters would be connected to a two-cell unit. The two-cell units could then be rotated for maintenance and cleaning. Each of the seven units would be located in the ground behind the Monks Quarters. The individual composting units would require excavation.

4.1 Secondary Design Decision Matrix

A secondary design matrix was composed based on the two composting toilet disposal options. Each option was then analyzed in four criteria: initial cost, ease of maintenance, aesthetic appeal and safety, and cultural acceptance. Each criterion was given a value based on its importance to the overall design. The higher the value given, the more important the criteria. A total was then calculated for both design options to determine which composting toilet design to implement.

Initial cost

This criterion is worth 25% of the total weight of the decision matrix. It is important that the wastewater treatment option is cost effective for both the university and Mainpat residents. The evaluation of this criterion is on a scale from 1 to 3 as follows:

1=Very high cost

2=Average cost

3=Low cost

Ease of Maintenance

This criterion is worth 25% of the total weight of the decision matrix. Mainpat residents should be able to maintain their treatment system in the coming years, without external support. It is crucial that the residents are self-sufficient in managing their wastewater. Therefore, the ease of maintenance is an important criterion in deciding which design to implement. The evaluation of this criterion is on a scale from 1 to 3 as follows:

1=Extensive maintenance required

2=Average maintenance required

3=Little maintenance required

Aesthetic Appeal and Safety

This criterion is worth 20% of the total weight of the decision matrix. The aesthetic appeal takes into account how visually pleasing the design is and whether it produces some sort of odor. The safety criterion refers to any potential dangers the treatment system might pose to Mainpat residents. The evaluation of this criterion is on a scale from 1 to 3 as follows:

1=Very aesthetically unpleasing and/or unsafe for residents.

2=Average aesthetic appeal and/or average safety.

3=Aesthetically pleasing and/or very safe.

Cultural Acceptance

This criteria has a weight of 25% of the total weight in the decision matrix. The cultural acceptance is an important criterion in choosing a design because the people of Mainpat need to be comfortable using a specific wastewater treatment option. They must be familiar with how to use the technology that may be implemented at their monastery. The evaluation of this criterion is on a scale from 1 to 3 as follows:

1=Not culturally acceptable.

2=Likely to be culturally accepted.

3=Very likely to be culturally accepted.

Table 4: Secondary Decision Matrix

Criteria Weighting	Option 1 (Community Composting Unit)	Option 2 (Individual Composting Units)
Initial Cost (25%)	2.5	1.5
Ease of Maintenance (25%)	3.0	2.0
Aesthetic Appeal and Safety (20%)	1.5	2.0
Cultural Acceptance (30%)	2.0	1.0
Total	**2.28**	**1.58**

<u>Rationale for numbering system:</u>

Option 1: Community Composting Unit

-Initial Cost: The community composting unit was given a rating of 2.5 due to the need of only two cells. Each cell is also above ground eliminating additional excavation costs.

-Ease of Maintenance: Since there are only two cells that collect the Monks Quarters waste, maintenance was given a score of 3. Additional calculations were necessary to determine how often the composting bins would need to be rotated.

-Aesthetic Appeal and Safety: The community composting units were given a score of 1.5 because they are above ground and more visible to Mainpat residents. In addition, odor could become an issue if the accumulation of solid and liquid waste became too high.

-Cultural Acceptance: The community composting units were given a score of 2.0 because they made use of the existing piping and toilets. However, Mainpat residents are not familiar with composting and it is likely a new concept for people using the monastery.

Option 2: Individual Composting Unit

-Initial Cost: The initial cost of the individual composting units was given a score of 1.5. This number was low due to the need of a total of 14 cells. The design of the cells also requires them to be underground, adding excavation costs.

-Ease of Maintenance: The individual composting unit achieved a score of 2.0 due to the amount of units that need to be maintained. There are more units to maintain than in the community composting unit.

-Aesthetic Appeal and Safety: The individual composting units got a score of 2.0 for aesthetic appeal and safety. This score was higher than the community due to the individual units being located underground. These underground units would not be seen and smell would not be a problem.

-Cultural Acceptance: The individual composting units achieved a 1.0 for cultural acceptance due to excavation and construction. The units would require a lot of excavation as well as the addition of new piping. It would also require several residents to share small toilets.

Based on the Secondary Decision Matrix in Table 4 the final design selected is a community composting unit. It received a score of 2.28 out of 3 and scored higher on nearly all criteria than the individual composting units. The next section of this report explains this final design in detail.

5.0 Final Design

The final design section is divided into the following three categories

- Relevant Calculations
- Final Design Schematic
- Cost of Implementing Final Design.

5.1 Relevant Calculations

The final design of the composting unit utilized the calculations located in Appendix B of this report. The calculations used to design the composting unit were:

- Mass of Liquids Evaporated.
- Liquid and Solid Mass Balance.
- Solids Decay rate.
- Leach Field Sizing.

The mass of liquid evaporated determined that only 5.25gallons/day of liquid would be evaporated out of 155gallons/day produced. This additional 149.75 gallons of liquid per day would require a leach field due to insufficient evaporation.

The liquids and solid mass balance determined that 3.7% of the mass would be solid and 96.3% would be liquid. This shows that there is sufficient liquid mass for the waste to flow from the monastery into the composting unit. The solid and liquid mass balance also determined how big the composting bin would need to be.

The solid decay rate calculation was used to determine how often the composting bins would need to be rotated. By modeling the decay of solid waste with a first order decay equation, it was determined that by day 15-20 the accumulation of solid waste would equal the degradation of solid waste. Therefore, as a conservative estimate, it was decided that every 30 days the composting bins would be rotated.

Finally, the leach field sizing calculation determined a leach field sized to be 31.6ft was required for the composting unit.

5.2 Final Design Schematic

After calculations determined the sizing of the community compost unit, AutoCAD sketches were created. Each aspect of the design is listed below.

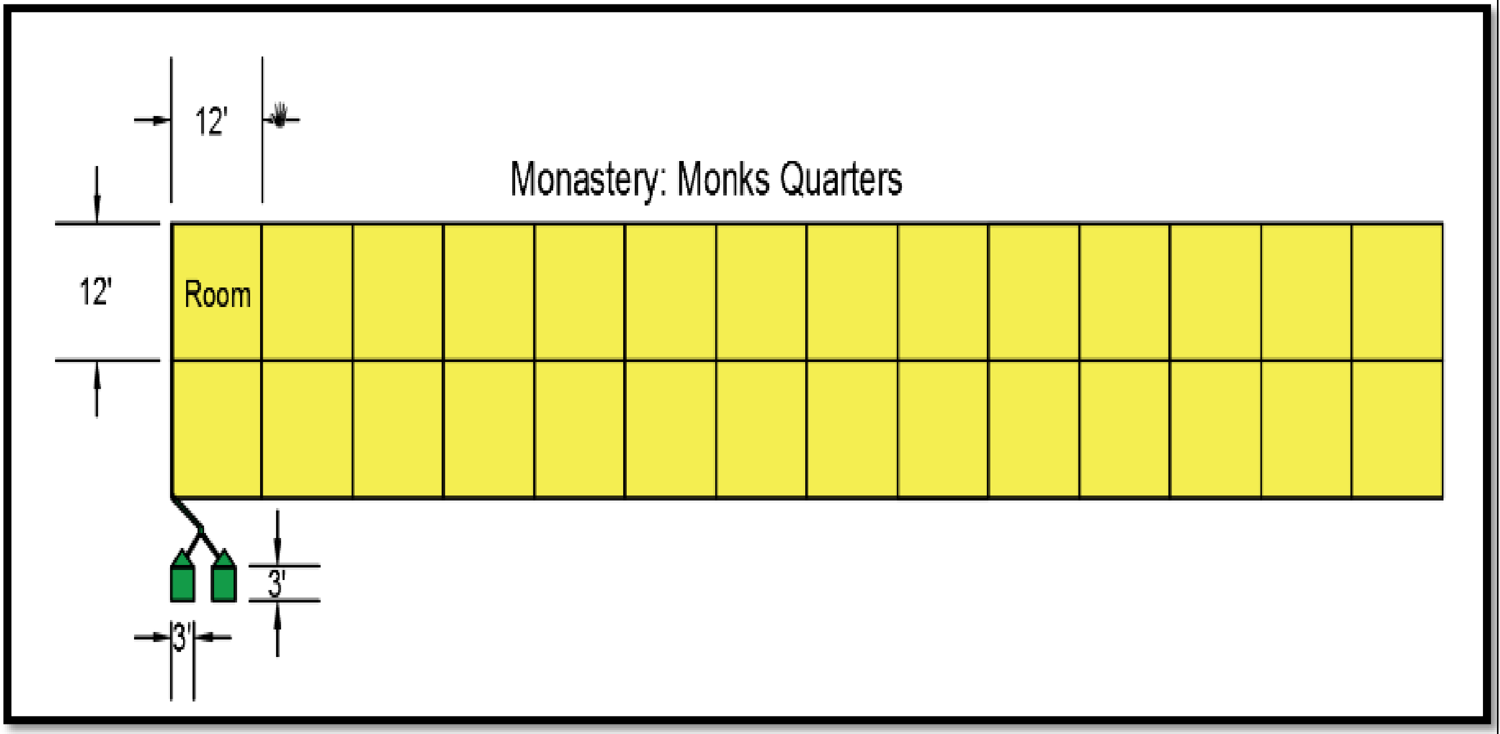

Figure 8: Scale Comparison of Final Design

Figure 8: Scale Comparison of Final Design shows the Monks Quarter in comparison to the composting bins. The Monks Quarter is composed of 28 12x12x12 foot rooms. Each room contains a toilet and flows to the composting unit via piping. The composting unit is 2 cells at 3x3x3 foot and is located at the cutoff pipe. The pipes were then connected and split to each of the cells of the composting unit.

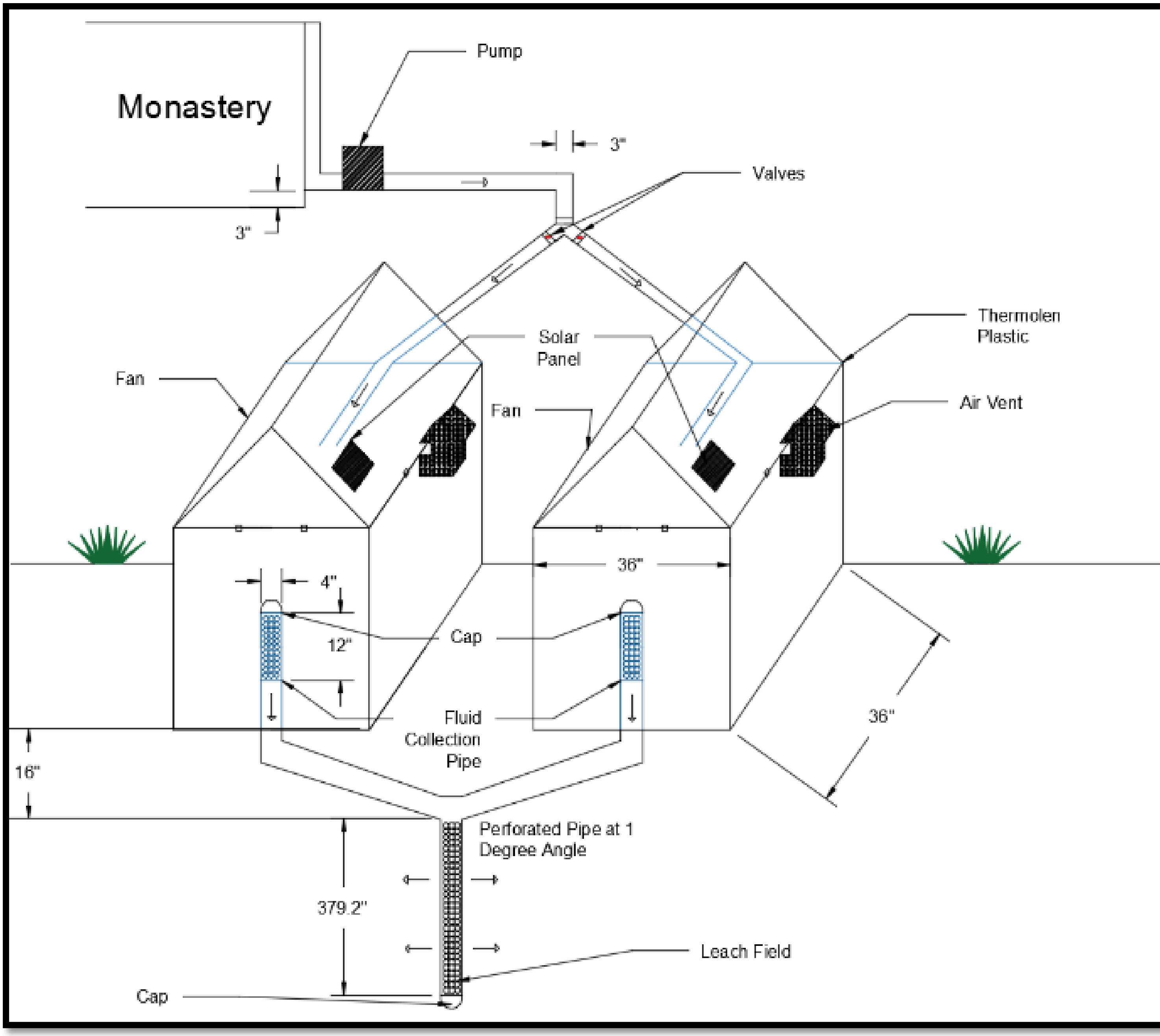

Figure 9: Composting Unit Detailed Design

Figure 9: Composting Unit Detailed Design shows the details of the composting unit. The wastewater flow comes from the Monks Quarters and flows into a macerator pump. The pump then pumps the waste to a 3 inch Wye pipe. At the both ends of the Wye pipe is a socket ball valve to shutoff flow when needed for maintenance and cleaning. The flow of the wastewater than goes into the composting cell.

The cells both have the inlet pipe coming perfectly centered on the top. This insures the waste will be evenly distributed inside the cell. Each 3x3x3 foot cell is designed to contain the solid waste for 30 days. After 30 days that cell is turned off and the other cell turned on.

When a cell is turned off that unit's compost waste will then be taken out from the removable top and put into a field. The compost at this point should be safe for humans but some safety such as gloves and area of field should be taken into consideration.

The cells are each fitted with a fan, vent, and solar panel. The 4inch fan will blow in air to increase the rate of decomposition. The air vent releases the accumulated gasses. The solar panel will feed the fan and will only run during sunlight hours.

The bottom of each cell contains a 1 foot of 4 inch perforated pipe. This pipe collects the fluid waste from the cells and flows 16 inches underground by 4 inch PVC to a leach field. The leach field is centered in between the cells and as calculated in Appendix B is 31.6 feet long. The leach field also has a downward slope of 1 percent for fluid flow.

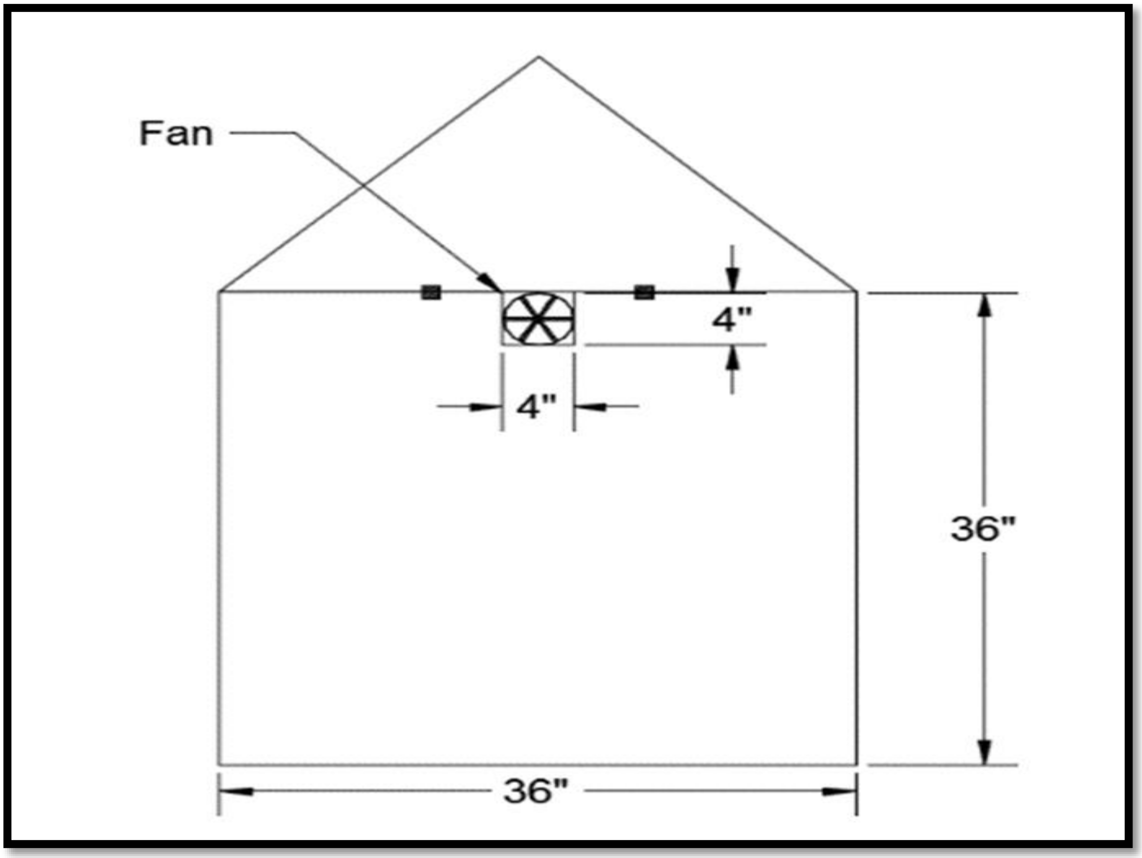

Figure 10: Design Left Side View

Figure 10: Design Left Side View shows the left side of a single cell. The drawing shows the 4 inch fan centered at the top of the composting cell. The drawing also shows the dimensions of the sides being 3x3 foot. The top of the cell also has latches that can be undone to remove the top for maintenance and cleaning. The top is angled so there will be no stagnant water from rain.

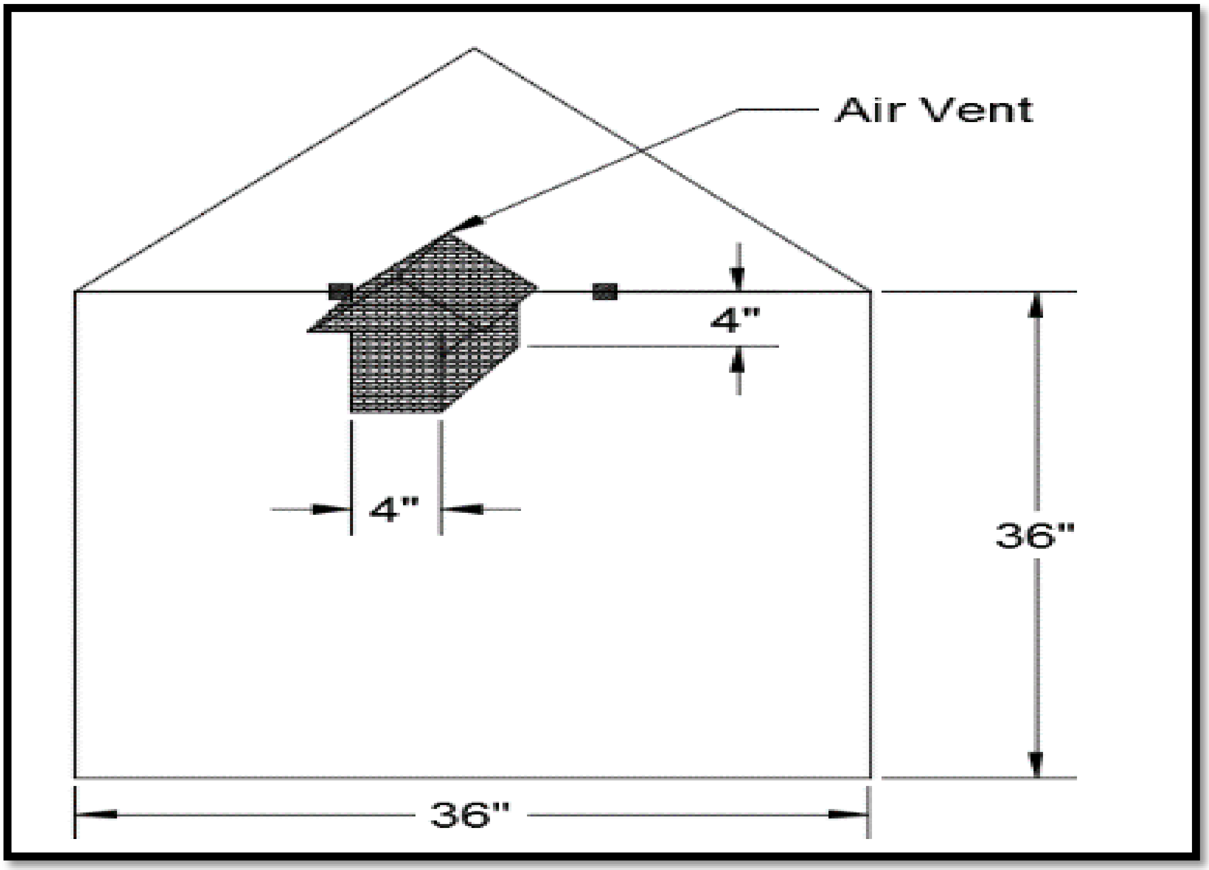

Figure 11: Design Right Side View

Figure 11: Design Right Side View shows the right side of a single cell. The drawing shows the 4 inch air vent centered at the top of the composting cell. The drawing also shows the dimensions of the sides being 3x3 foot. The top of the cell also has latches that can be undone to remove the top for maintenance and cleaning. The top is angled so there will be no stagnant water from rain.

5.3 Cost of Implementing Final Design

For the implementation of final design, the total cost came to be $3825.47. This cost includes the total parts cost and the estimated excavation costs. The part cost includes two fans with solar panel with a cost of $646.20 for the two units (6). Two units of the composting bins cost $399.98 (10). Two units of 4" straight pipe (10ft) cost $14.93 (15). Four units of 4" perforated pipe (10ft) cost $39.96 (2). Two air vents cost $41.82 (14). One unit of 3" wye pipe cost $6.25 (16). Four units of 3" straight pipe (10ft) cost $29.84 (1). Two 3" socket ball valves cost $95.08 (12). One unit of macerator pump cost $529.85 (4). Also, 3 units of 4" PVC cap cost $16.02 (9). Finally, two units of 4" PVC 45 elbow cost $5.54 (15). The total cost for composting unit $1,814.79. The estimated excavation costs for the leach line was $2,000.00. Making a total cost of $3,825.47.

Table 5: Compost Unit Cost

Part	Quantity	Price Per Unit ($)	Cost($)
Fan with solar panel	2	323.10	646.20
Composting Bin	2	199.99	399.98
4 in Straight Pipe (10ft)	2	7.46	14.93
4 in Perforated Pipe (10ft)	4	9.99	39.96
Vent	2	20.91	41.82
3in Wye Pipe	1	6.25	6.25
3in Straight Pipe (10ft)	4	7.46	29.84
3in Socket ball Valve	2	47.54	95.08
Macerator Pump	1	529.85	529.85
4in PVC Cap	3	5.34	16.02
4in PVC 45 Elbow	2	2.77	5.54
Total Parts Cost			1814.79
Estimated Excavation Costs			2000.00
Total Cost			**3825.47**

6.0 Recommendations

MAHB Inc. recommends the implementation of this final design to the monastery at Camp 3. Presently, there is no system in place to contain the wastewater effluent from the monastery. This could be a contributing factor to the outbreak of typhoid fever in Mainpat. By implementing this design the residents can turn their waste into a valuable resource. The leach field and compost are valuable for farming practices in the area and might even improve Mainpat's local economy.

The team also recommends that the Mainpat residents are educated regarding the use of the composting system. It is vital that they rotate cells every 30 days in order to enhance composting performance. All instructions should be printed in Tibetan (rather than English) so that the Mainpat residents understand what the system entails.

7.0 Budget and Scheduling

Table 6: Division of Labor for Engineering Services

Division of Labor for Engineering Services

Task	**Subtask**	J Hertzberg	G Becher	J Aljuaidi	H Mansouri
Task 1: Testing					
	1.1 Research				
	1.1.1 site-specific data	5	20	10	10
	1.1.2 equipment and GIS	0	0	0	12
	1.1.3 typhoid and testing methods	20	2	10	0
	1.2 Sampling Plan				
	1.2.1 cost of sampling	8	0	8	0
	1.2.2 QA/QC and sampling stats	20	2	10	0
	1.2.3 Protocol	34	5	10	2
Task 2: Wastewater					
	2.1 Research				
	2.1.1 site-specific data	0	12	0	8
	2.1.2 technical options	2	12	8	12
	2.2 Design				
	2.2.1 develop and screen criteria	7	30	19	29
	2.2.2 design and create drawings	25	15	22	20
	2.2.3 cost estimate to implement	0	10	0	5
Task 3: Project Management					
	3.1 Overview				
	3.1.1 Website	0	0	12	16
	3.1.2 Presentation	0	0	15	5
	3.1.3 Report	25	35	5	10
Total Hours		**146**	**143**	**129**	**129**

Table 7: Cost of Engineering Services

Cost of Engineering Services

Task	Subtask	Position	Rate	Hours	Total Cost
Task 1: Testing					
	1.1 Research				
	1.1.1site-specific data	Intern	40	45	1800
	1.1.2 equipment and GIS	Engineer	75	12	900
	1.1.3 typhoid and testing methods	Engineer	75	32	2400
	1.2 Sampling Plan				
	1.2.1 cost of sampling	Engineer	75	16	1200
	1.2.2 QA/QC and sampling stats	Engineer	75	32	2400
	1.2.3 Protocol	Engineer	75	51	3825
Task 2: Wastewater					
	2.1 Research				
	2.1.1 site-specific data	Intern	40	20	800
	2.1.2 technical options	Engineer	75	34	2550
	2.2 Design				
	2.2.1 develop and screen criteria	Engineer	75	85	6375
	2.2.2design and create drawings	Sr. Engineer	135	82	11070
	2.2.3 cost estimate to implement	Engineer	75	15	1125
Task 3: Project Management					
	3.1 Overview				
	3.1.1 Website	Intern	40	28	1120
	3.1.2 Presentation	Engineer	75	20	1500
	3.1.3 Report	Sr. Engineer	135	75	10125
				Total $	**47190**

Table 8: Estimated Division of Labor for Engineering Services

Task	Subtask	J Hertzberg	G Becher	J Aljuaidi	H Mansouri
	Division of Labor for Engineering Services (Estimated)				
Task 1: Testing					
	1.1 Research				
	1.1.1 site-specific data	10	30	0	0
	1.1.2 equipment and GIS	0	0	10	20
	1.1.3 typhoid and testing methods	25	0	25	0
	1.2 Sampling Plan				
	1.2.1 cost of sampling	10	10	5	10
	1.2.2 QA/QC and sampling stats	10	10	10	0
	1.2.3 Protocol	10	15	10	10
Task 2: Wastewater					
	2.1 Research				
	2.1.1 site specific data	0	30	10	10
	2.1.2 technical options	15	5	10	15
	2.2 Design				
	2.2.1 develop and screen criteria	15	5	15	15
	2.2.2 design and create drawings	15	10	15	40
	2.2.3 cost estimate to implement	10	10	20	5
Task 3: Project Management					
	3.1 Overview				
	3.1.1 Website	5	5	5	5
	3.1.2 Presentation	8	8	7	7
	3.1.3 Report	17	12	8	13
Total Hours		**150**	**150**	**150**	**150**

Table 9: Estimated Cost of Engineering Services

Cost of Engineering Services (Estimated)

Task	Subtask	Position	Rate	Hours	Total Cost
Task 1: Testing					
	1.1 Research				
	1.1.1 site-specific data	Intern	40	40	1600
	1.1.2 equipment and GIS	Engineer	75	30	2250
	1.1.3 typhoid and testing methods	Engineer	75	50	3750
	1.2 Sampling Plan				
	1.2.1 cost of sampling	Intern	40	35	1400
	1.2.2 QA/QC and sampling stats	Engineer	75	30	2250
	1.2.3 Protocol	Engineer	75	45	3375
Task 2: Wastewater					
	2.1 Research				
	2.1.1 site specific data	Intern	40	50	2000
	2.1.2 technical options	Engineer	75	45	3375
	2.2 Design				
	2.2.1 develop and screen criteria	Engineer	75	50	3750
	2.2.2 design and create drawings	Sr. Engineer	135	80	10800
	2.2.3 cost estimate to implement	Engineer	75	45	3375
Task 3:Project Management					
	3.1 Overview				
	3.1.1 Website	Intern	40	20	800
	3.1.2 Presentation	Engineer	75	30	2250
	3.1.3 Report	Sr. Engineer	135	50	6750
				Total $	**47725**

As Table 9 indicates, the estimated budget and the actual budget for this project differed by $535. The three positions for this project were: intern, engineer, and senior engineer. Each task was to be performed by one of these individuals (Their pay rates include overhead costs).

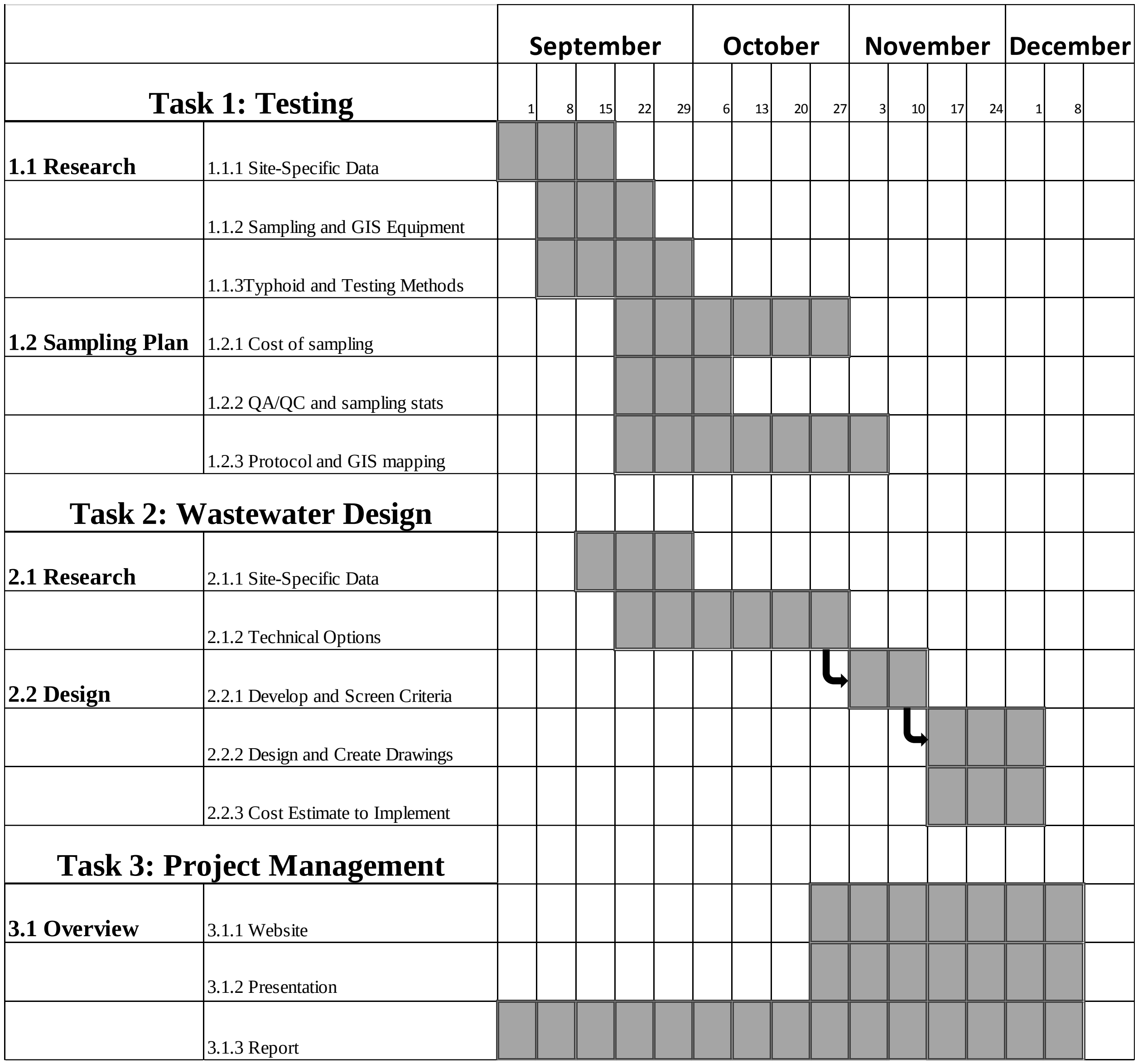

Figure 12: Timeline

As Figure 12 above indicates, the project tasks were completed from the beginning of September to the beginning of December. The sampling protocol tasks occurred during the first half of this project, whereas the wastewater design tasks occurred mostly during the latter half of the project. Overall, most tasks were performed on time, with some tasks taking longer due to unforeseen circumstances.

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Sampling Protocol

For Field Samplers at Mainpat, India

Prepared by:
MAHB Inc.
Northern Arizona University

Table of Contents

1.0 Introduction

This sampling protocol will be used for all field testers traveling to Mainpat, India in December 2014. Located in northeastern India, Mainpat is a Tibetan refugee camp with a population of approximately 900 people spread across seven camps. Each camp is served by a well, which is the source of water for all the inhabitants. Recently, an outbreak of typhoid fever has spread across the community of Mainpat. In order to determine where the typhoid originates from, several water quality parameters will be evaluated at each of Mainpat's seven camps. These water quality parameters will also give an indication of the overall health of Mainpat's water supply.

The field testers will follow this plan in order to ensure they gather the proper data and perform all field tests according to protocol. Because *no samples* will be brought back to the university, it is imperative that the samplers collect quality data and follow all procedures when sampling at Mainpat.

2.0 Water Quality Parameters to be Evaluated

The field samplers will be testing for five water quality parameters. These parameters are described, in detail, below.

Total Coliform Count: It is not possible to detect the presence of salmonella typhi (the bacteria causing typhoid fever) directly. Therefore, it is necessary to perform a "Total Coliform Count", a procedure that determines the presence of *indicator organisms.* These indicator organisms are not harmful but they are representative of the presence of harmful bacteria *salmonella typhi*. Because an outbreak of typhoid fever has recently occurred in Mainpat's refugee camps, it is critical that this test is utilized to determine the possible source of the *salmonella typhi* bacteria. The typical way to report total coliform is as "number of organisms per 100 mL" (US EPA Total Coliform).

Turbidity: Turbidity refers to the cloudiness of the water and can make water aesthetically unpleasing. There are, however, other benefits to testing for turbidity. Water with high turbidity cannot be disinfected and therefore poses a health issue to communities with turbid water. Furthermore, high turbidity can make it difficult to test for other water quality parameters. It is suggested that turbidity is the first parameter tested for this reason. There are two ways to report turbidity; as Nephelometric Turbidity Units (NTU) and Jackson Turbidity Units (JTU). The United States EPA uses NTU as its unit of measurement, however, 1 JTU ~ 1 NTU and so JTU is an appropriate unit of measurement for the purpose of this plan (US EPA Turbidity).

Nitrates: All water contains some level of nitrogen, however, nitrogen levels that are too high are dangerous. Nitrate-nitrogen, specifically, is harmful to people as it can cause diseases. The most notable disease caused by high nitrate levels is methemoglobinemia, more commonly called "blue-baby syndrome." In addition, high nitrate levels are indicative of contamination from sewage or fertilizers. Although nitrate levels are not related to typhoid fever, it is still an important secondary standard to test for at the camps (US EPA Nitrates).

Arsenic: Many waters contain natural arsenic from geologic processes spanning millions of years. Some arsenic is also produced from industrial activities, however this would not be a cause of arsenic in Mainpat's drinking water as the community is rural with no industries nearby. Arsenic is most commonly found in groundwater sources; because Mainpat's main source of water is groundwater it is important to test for arsenic at the refugee camps. Arsenic is a harmful contaminant and has both acute (short-term) and chronic (long-term) effects on the human body (US EPA Arsenic).

Lead: The most probable source of lead in Mainpat's drinking water is the distribution system that delivers water to the houses of Mainpat. If the pipes transporting Mainpat's water are composed of lead rather than PVC material, the probability of lead in the water supply increases significantly. Lead is a toxic contaminant that can cause brain damage to children and kidney failures for adults (US EPA Lead).

3.0 Equipment and Supplies

This section provides a comprehensive list of all equipment and supplies necessary for Mainpat field samplers. These materials include testing kits, personal protective equipment (PPE), and any other additional materials the samplers may need. The cost and quantities of these items will also be specified.

3.1 Testing Kits to be Used

The field samplers will be using five testing kits, one kit per water quality procedure. The testing kits correspond to the water quality parameters specified in Section 2.0 of this report. The five testing kits, along with their model number, number of tests per kit, and cost are provided in Table 1 below.

Table 1: Summary of Test Kits

Parameter	Testing Kit	Number of Tests per Kit	Cost Per kit
Total Coliform	LaMotte 4-3616	1	$14.50
Turbidity	LaMotte Model 7519-01	50	$69.15
Nitrates	LaMotte Model 3615-01	50	$84.20
Arsenic	Econo-Quick Model 481298	1	$189.00
Lead	First Alert	300	$12.99

The samplers will compare their results to both the United States EPA Standards and Bureau of Indian Standards. A summary of the standards for both the United States and India are provided in Table 2 below. The detection limits of the kits are also provided.

Table 2: United States EPA Standards vs. India Standards and Detection Limits of Kits

	United States	India	Detection Limit
Total Coliform	<5% samples TC +	<5% samples TC +	1 CFU/100mL
Turbidity	1 NTU	1 NTU*	5 JTU
Nitrates	10 ppm	10 ppm	0.2 ppm
Arsenic	10 ppb	10 ppb*	0.3 ppb
Lead	15 ppb	10 ppb	15 ppb

The detection limits are sufficiently low enough to compare to the standards of both countries, with a few exceptions. Turbidity, for example, can only be detected to 5 JTU (5 NTU) but the standard for turbidity in both countries is 1 NTU. In addition, the standard for lead is stricter in India than in the United States. The detection limit for the lead kit detects to levels as low as 15 ppb so can only be compared to US standards.

In general, anything above the United States Standards for any of the five parameters shall be considered unacceptable. Ultimately, though, the field samplers should use their engineering judgment in evaluating the water quality data and determine what is and what is not acceptable.

*For India's turbidity standard, if no alternate water source is available 5 NTU is acceptable (Bureau of India Standards, Drinking Water –Specification).
*For India's Arsenic standard, if no alternate water source is available 50 ppb is acceptable (Bureau of India Standards, Drinking Water –Specification).

3.1.1 Total Coliform Test Kit

The following materials should all be in the Total Coliform LaMotte Model 4-3616 testing kit. *Prior to any sampling or testing*, ensure that all these materials are present. A picture of the kit is also provided below in Figure 3.1.

- 5 glass tubes, marked at 10 mL, each containing a Coliform Test Tablet.
- Coliform Test Tablet contains: nutrients, gelling substance, and pH indicator.
- Sterile water sampling bag.
- Dechlorinating tablet.

Figure 3.1: LaMotte Model 4-3616 for Total Coliform

3.1.2 Turbidity Testing Kit

The following materials should all be in the Turbidity LaMotte Model 7519-01 testing kit. *Prior to any sampling or testing*, ensure that all these materials are present. A picture of the kit is also provided below in Figure 3.2.

- Standard Turbidity Reagent (60 mL)
- 2 turbidity columns
- 1 brush
- 1 test tube
- 1 pipet, 0.5 mL, plastic, with cap included
- 1 plastic stirring rod

Figure 3.2: LaMotte Model 7519-01 for Turbidity

3.1.3 Nitrates Testing Kit

The following materials should all be in the Nitrates LaMotte Model 3615-01 testing kit. *Prior to any sampling or testing*, ensure that all these materials are present. A picture of the kit is also provided below in Figure 3.3.

- 2 120 mL vials of Mixed Acid Reagent.
- 10 g of Nitrate Reducing Reagent.
- 1 Dispenser Cap
- 1 Plastic Spoon
- 2 test tubes (5 & 10 mL), each with 1 cap
- Water Sample Bottle
- 0.5 mL plastic Pipet
- Low Range Comparator
- Nitrate-Nitrogen Low Range Comparator Bar

Figure 3.3: LaMotte Model 3615-01 for Nitrates

3.1.4 Arsenic Testing Kit

The following materials should all be in the Arsenic Econo-Quick Model 481298 testing kit. *Prior to any sampling or testing*, ensure that all these materials are present. A picture of the kit is also provided below in Figure 3.4.

- Reaction bottles
- White caps with turret
- Test strips
- Arsenic Color Chart
- Three spoons (each color coded for different measurements)
- Three Reagents (labeled as First, Second, and Third Reagent)

Figure 3.4: Econo-Quick Model 481298 for Arsenic

3.1.5 Lead Testing Kit

The following materials should all be in the First Alert Drinking Water testing kit. *Prior to any sampling or testing*, ensure that all these materials are present. A picture of the kit is also provided below in Figure 3.5. It is important to note that this testing kit performs additional water quality tests, but the samplers will only test for lead using this kit.

- Test vial
- Dropper pipette
- Two test strips
- Desiccant (to be discarded)

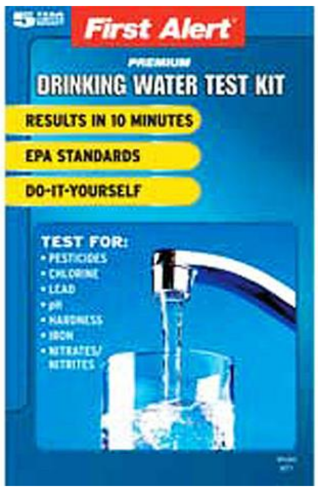


Figure 3.5: First Alert Drinking Water Test Kit

3.2 Additional Materials Required

The field samplers will need some additional water sampling supplies that are not provided by the five testing kits above. These items include:

- Water sampling bottles
- Alcohol wipes
- Labels for sampling
- pH strips

The field samplers will also need Personal Protective Equipment (PPE) when sampling at Mainpat. The *Health and Safety Plan* provides more information about all the safety procedures and safety equipment necessary for the field samplers at Mainpat. The PPE required for *all* samplers is:

- Coveralls
- Latex Gloves
- Safety glasses or chemical splash goggles
- Long sleeve shirts
- Hair ties (hair should not go below shoulders)
- Long pants

The quantity of PPE required is listed in Section 3.4 of this protocol.

3.3 Number of Samples Required

A statistical analysis was performed to determine the number of samples required at each camp for the data to be statistically significant. By assuming the sample data are normally distributed, a formula along with a z-chart can be utilized. The equation used to determine the number of samples is as follows:

$$N = \frac{[z^2 \times P \times (1-P)]}{c^2}$$ (Pearson Education Inc.)

Where:

N is the number of samples.

z is from chart (Table 4) based on desired confidence level.

p is probability of performing a procedure inaccurately.

c is confidence interval (margin of error).

The z-chart based off a normal distribution (See Figure 9.1 in References) provides values of z at different confidence intervals. Table 4 below shows values of z at varying confidence level.

Table 3: Z values at different confidence levels

Z	Confidence level
1.645	90%
1.96	95%
2.58	99%

In order to ensure that the sampling procedure is economically feasible and can be done in a reasonable amount of time, a 90% confidence level was chosen for the sampling statistics. Therefore, the z value is 1.645. The "p" value is the probability of performing the testing procedure incorrectly. For this protocol, a value of p=0.02 was chosen. This assumes that one out of fifty samples collected is done so using a procedure incorrectly. The "c" value represents the margin of error and is often equal to 5%. This means that all data recorded will have a ± 5% margin of error. By substituting these three values into the equation above, the total number of samples required for each test at camp one was computed.

The analysis determined that 21 tests* were necessary in camp one for the data to be statistically significant. This number of tests allows for a confidence interval of 90% and a margin of error of + 5%. By extrapolating this number of tests from camp one, the number of tests required at the other camps can be determined. Table 5 below shows the number of tests required for each camp for statistically significant results.

Table 4: Number of Household Tests required for TC and Turbidity

Camp No.	1	2	3	4	5	6	7	**Total**
Number of Tests	21	12	6	11	4	4	7	**65**

*It is important to note that these 21 tests are only for the **total coliform** and **turbidity** tests. Turbidity and Total Coliform will be tested at all three locations in each camp (well, house before filter, and house after filter). Turbidity, Lead, and Total Coliform will be tested at the home before filter. All five parameters will be evaluated at the well. (Nitrates and Arsenic are not necessary to test at households).

The tests for nitrates, arsenic, and lead do not require as many tests because they will *not* be tested at as many locations. Table 6 below shows the number of tests required for statistical significance for *all* tests at each camp. The data in Table 6 was used to determine the number of testing kits required. This, in turn, determined the cost of testing which is detailed in the following section.

Table 5: Minimum Number of Tests Required for all Camps

	Total Coliform	Turbidity	Nitrates	Arsenic	Lead
Camp 1	21	21	7	7	6
Camp 2	12	12	4	4	4
Camp 3	6	6	2	2	2
Camp 4	11	11	4	4	3
Camp 5	4	4	2	2	1
Camp 6	4	4	2	2	2
Camp 7	7	7	3	3	2
Total	**65**	**65**	**24**	**24**	**20**

3.4 Cost of Sampling

The following tables show the cost of testing kits and the cost of PPE.

Table 6: Cost of Testing Kits

Test	No. of Tests	Cost per kit	Number of kits	Total cost of test
TC	70	$ 14.50	70	$ 1,015.00
Turbidity	70	$ 69.15	2	$ 138.30
Lead	25	$ 12.99	25	$ 324.75
Arsenic	30	$ 189.00	1	$ 189.00
Nitrates	30	$ 84.20	1	$ 84.20

The total cost of the testing kits is **$1,751.25**. This takes into account that the samplers will create four duplicates per water quality test as well one blank. (See QA/QC).

Note: The Arsenic Testing Kit contains enough materials for 300 tests. Although only 48 total tests are required, the samplers may perform additional arsenic tests for a better sample size.

In addition to testing kits, PPE for the field samplers is required. The cost for all PPE is detailed in Table 8 below. The references at the end of this protocol are the source of all pricing information for these materials.

Table 7: Cost of PPE and Additional Materials

Item	Unit Cost	No. of Items	Total Cost
Coveralls	$ 13.20	4	$ 52.80
Box of 100 Latex Gloves	$ 8.90	5	$ 44.50
Safety Goggles	$ 5.49	4	$ 21.96
1000 Sampling Labels	$ 55.00	1	$ 55.00
Case of 300 Sample Bottles	$ 187.00	1	$ 187.00
Alcohol Wipes (40 count)	$ 4.59	3	$ 13.77
pH strips (200 count)	$ 9.48	1	$ 9.48

The cost for PPE and additional sampling materials is **$384.51**

<u>Grand Total: $2,135.76</u>

3.5 Location and naming scheme for samples

The water samples will be taken at one of three locations in each camp. These locations are: at the well, at the household (before the filter), and at the household (after the filter). Samples will be recorded based on what water quality procedure is employed, which camp the sampling occurs at, and where at the camp the sample was taken. The naming scheme for the samples will be as follows:

- Roman numeral indicating at which camp the sample was taken (I – VII).
- The house number where the sample was taken.

Note: The samplers will create a numbering scheme for the houses at each camp. By numbering the houses and recording these assigned numbers the samplers know exactly which house they performed the water quality test.

- Where in the camp the procedure was performed.

  BF: Before Filter in Home

  AF: After Filter in Home

  W: Well

- The type of water quality test performed.

  Total Coliform: TC

  NTU: Turbidity

  NO_3: Nitrates

  Pb: Lead

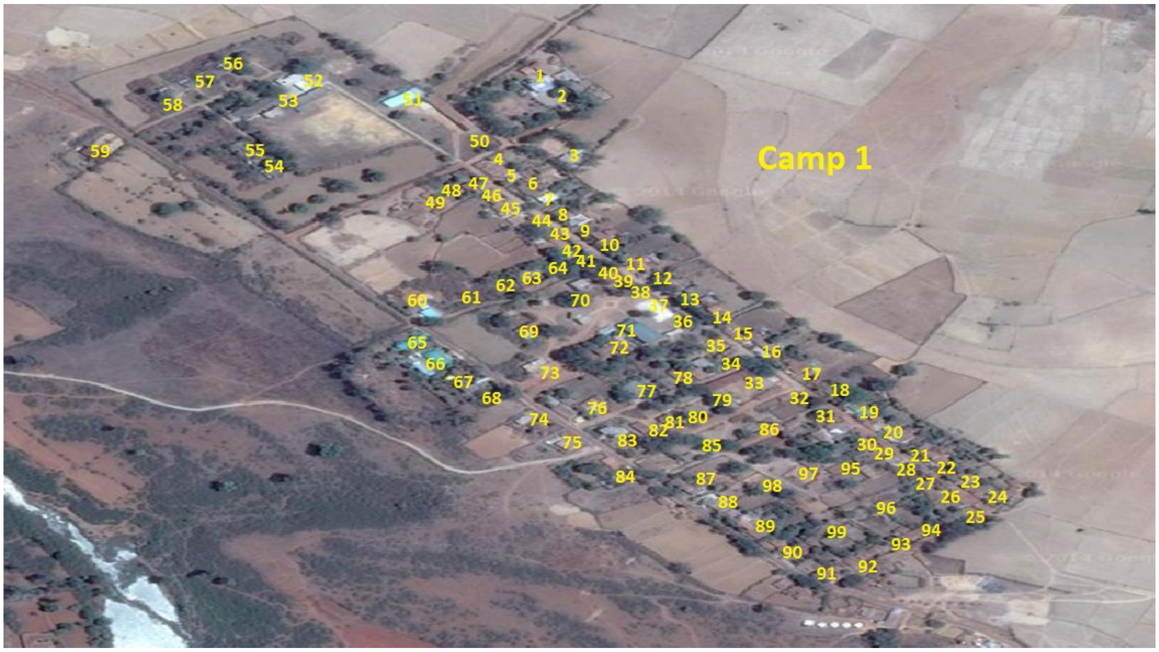
  As: Arsenic

- Label all duplicate samples as (Sample ID – 2).

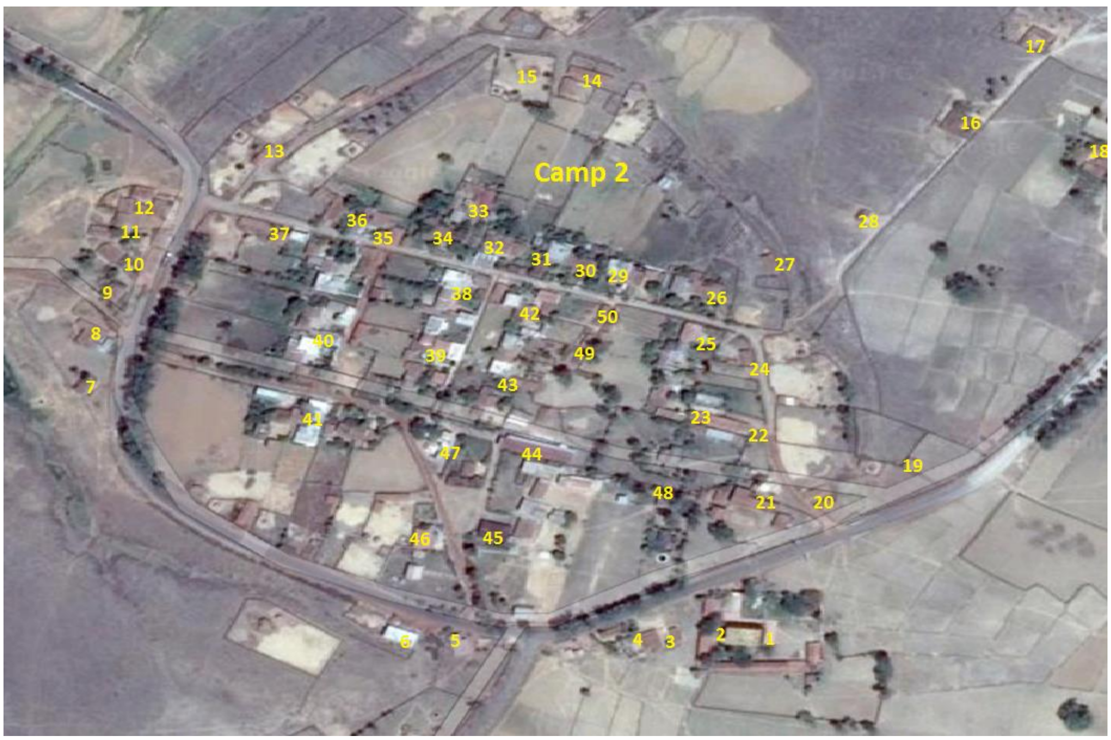
Example ID: III-NTU-5-AF represents a turbidity test in camp 3 at house # 5 *after* running through the household filter. If a duplicate test is taken, its Sample ID would be III-NTU-5-AF-2.

The houses in Mainpat's seven camps were numbered so that samplers could easily identify where exactly the samples were taken. Using Google Earth the images below were created to provide guidance to the field samplers. In addition, the field samplers will use GPS to mark specific house locations. Therefore, when the samplers come back to NAU they will be able to identify where exactly each household test was performed.

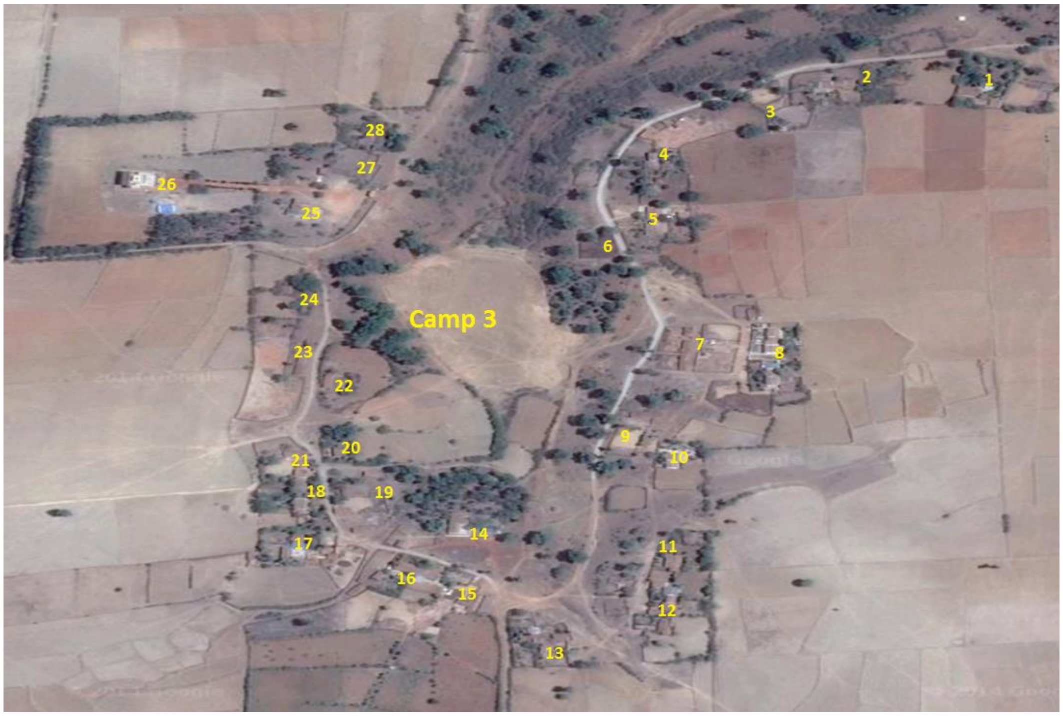
Housing Numbers and Locations for Camp 1.



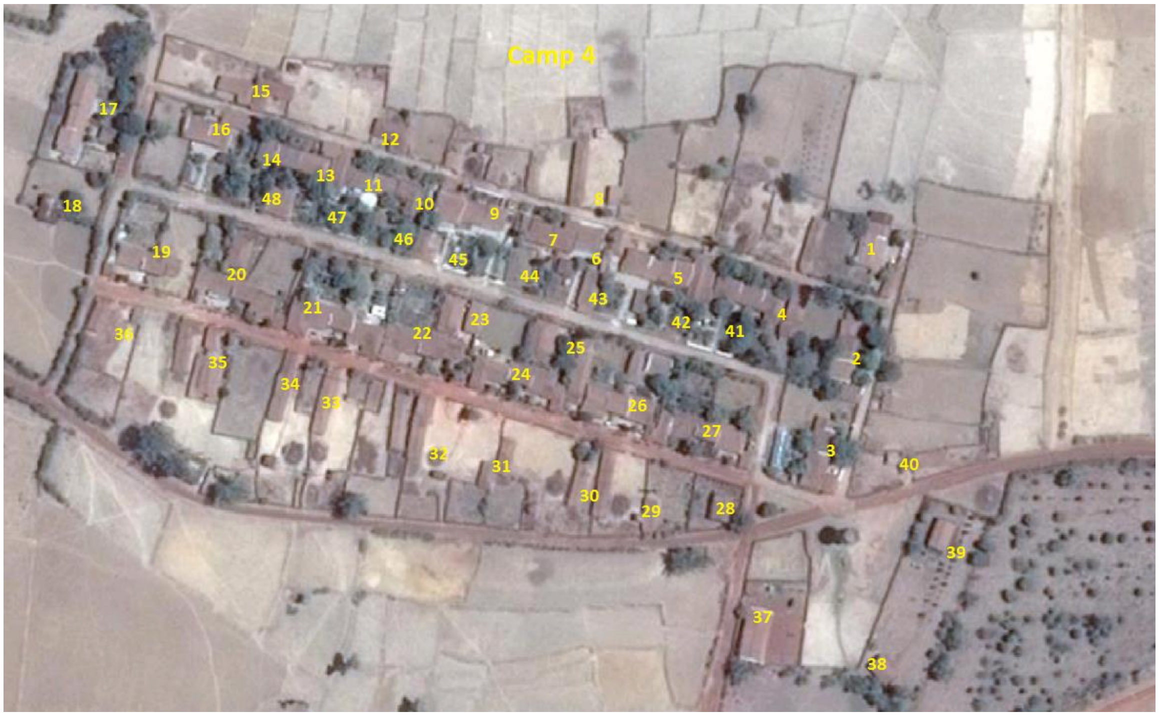
Housing Numbers and Locations for Camp 2.



Housing Numbers and Locations for Camp 3.

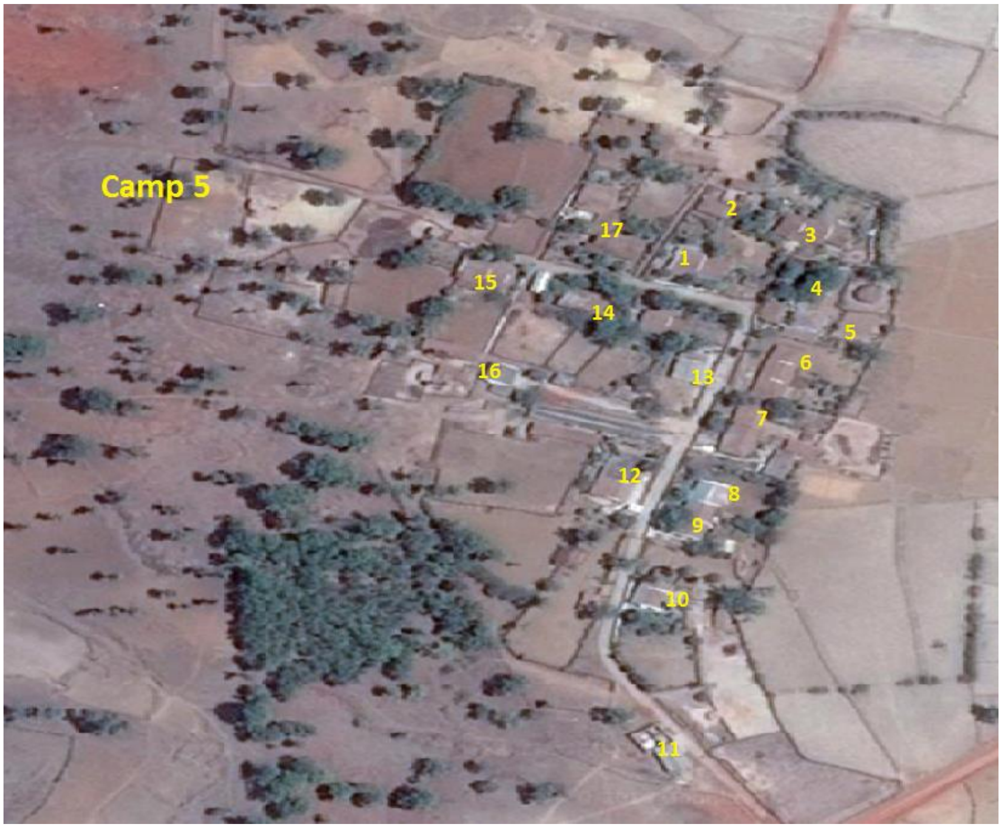


Housing Numbers and Locations for Camp 4.



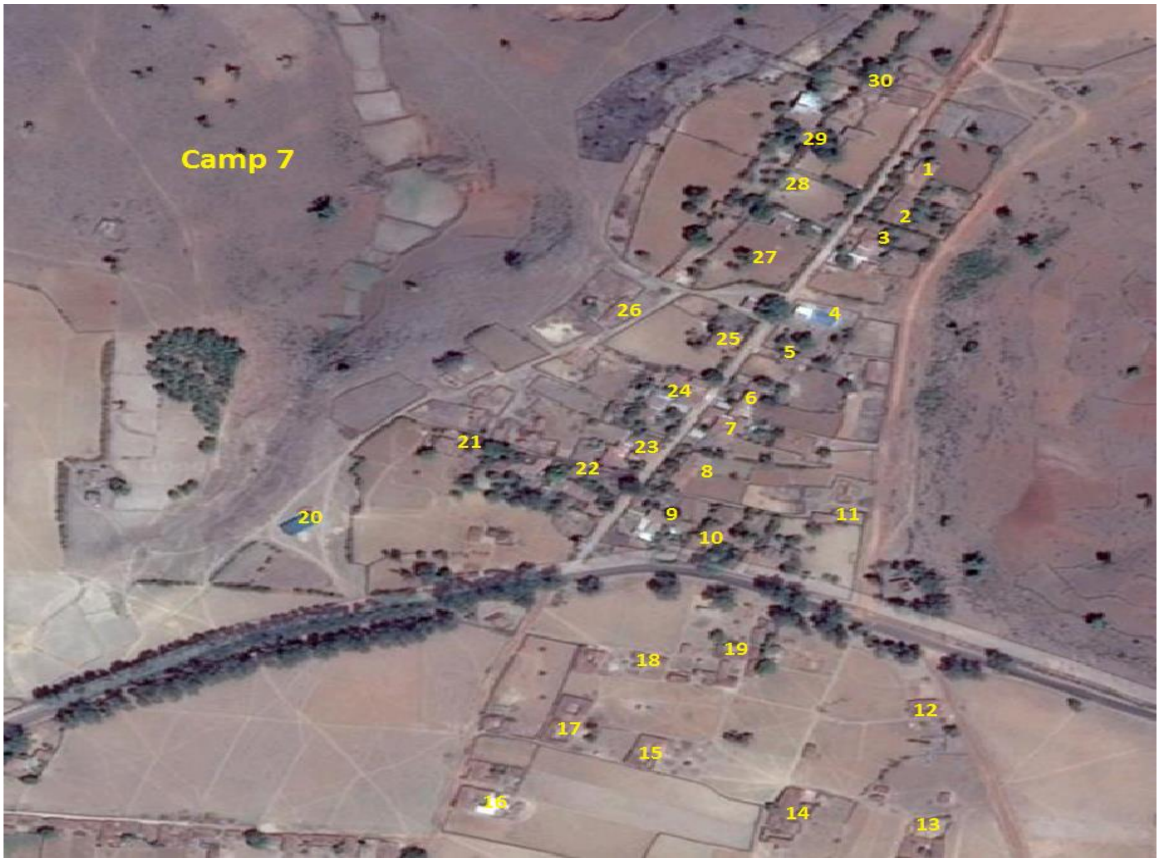
Housing Numbers and Locations for Camp 5.

.



Housing Numbers and Locations for Camp 6.

Housing Numbers and Locations for Camp 7.



4.0 Water Quality Procedures for Field Samplers

The field samplers at Mainpat are required to follow these water quality procedures to ensure accurate results. All procedures listed below are for sampling *at the well,* with special notes indicating changes for sampling at the household.

4.1 Total Coliform Testing Procedure

The testing kit used for this procedure is the *LaMotte Total Coliform Test Kit for Drinking Water* (See: Section 3.1.1) This test method is a “Presence/Absence” method meaning it will not provide a quantitative count for total coliforms, but rather, it will indicate whether there is a presence or absence of coliforms. The detection limit for this testing kit is 1 organism/100 mL, meaning that *any* indicator organisms constitute a positive test result.

1) Using an alcohol pad, wipe the entire water outlet area of the faucet/hose.

2) Allow water to run for 2 to 3 minutes.

3) Reduce the water flow to a rate that will fill the *Water Sampling Bag* slowly without splashing. Tear off the top of the bag at the scored line and pull the tabs outward to open the bag. Do not touch the bag opening or inner surface.

4) Fill the bag to the 4 oz. fill line. Pull the wire ends to close and whirl the bag for three complete revolutions. Shake the bag to dissolve the tablet.

5) Remove all 5 tubes from the display package and remove the caps.

NOTE: *Do not remove the tablets from tubes.*

CAUTION: *Do not touch inner surface of the caps and tubes or handle the tablet.*

6) Unwhirl the bag and pull the tabs outward to open the bag. Fold one tape wire inward to form a spout. Carefully fill **all 5 tubes** to the 10 mL line with the water sample. Replace the caps tightly. **Do not mix or shake tubes.**

7) Stand the carton upright and place all 5 tubes into the display package. All tubes should now be standing vertically with the tablet at the bottom of the tube. The tablet should lie flat on the bottom of each tube.

8) Store the tubes at room temperature, out of direct sunlight, for 44-48 hours. The air temperature should be fairly constant and between 70 and 85 degrees F.

NOTE: Do not disturb, handle or shake the tubes during the designated incubation time period. If these storage conditions are not followed precisely, the results of the test may vary and may not be valid.

Interpreting Test Results

<u>Positive Test</u>

Sample tubes that exhibit the following characteristics are indicative of a positive test result.

- Indicator turns yellow*
- Many gas bubbles evident within gelling substance
- Gel rises to surface of sample.
- Substrate below gel is cloudy.

*If the pH is low enough (under 6.8) some samples can turn yellow prematurely. It is important to note that **both** the yellow color **and** gas bubbles must be present in order to establish a positive test result. For this reason, pH strips are on the packing list so they can be utilized for this test.

<u>Negative Test</u>

Sample tubes that exhibit the following characteristics are indicative of a negative test result.

- Indicator remains red or turns yellow with few gas bubbles.
- Gelling substance remains on bottom of tube.
- Substrate above gelling substance is clear.

Note: When testing the water at the household the water quality procedure remains the same, however, it is only necessary to run the water for 20 seconds (Step 2).

When testing the water *after filter*, the above procedure remains the same with the exception of steps 1 and 2. The procedure for testing the water *after filter* is as follows:

1. Soak a cotton ball or gauze with household alcohol and wipe the entire nozzle of the filter clean.

2. Allow water from filter to run from for 20 seconds.

Repeat steps 3-8.

4.2 Turbidity Testing Procedure

The test kit used for this procedure is the *LaMotte Turbidity Kit* (See: Section 3.1.2) A table is provided below to determine the approximate level of turbidity in JTU. The detection limit for this testing kit is 5 JTU.

1) Turn on faucet/hose (or nozzle of filter) and let it run for 20 seconds.

2) Fill one turbidity column to the 50 ml line with the water sample.

NOTE: If the black dot on the bottom of the tube is not visible when looking down through the column of liquid, pour out a sufficient amount of the test sample so that the tube is filled to the 25 mL line.

3) Fill the second turbidity column with an amount of turbidity-free water that is equal to the amount of sample being measured. Distilled water is preferred, however, clear tap water may be used instead. This column is used as the control for the first turbidity column.

4) Place the two columns side by side and note the difference in clarity. If the black dot is equally clear in both tubes, the turbidity is zero. If the black dot in the sample column is less clear, proceed to Step 5.

5) Shake the Standard Turbidity Reagent vigorously. Add 0.5 mL to the "clear water" tube. Use the stirring rod to stir contents of both tubes to equally distribute turbid particles. Check for amount of turbidity by looking down through the solution at the black dot. If the turbidity of the sample water is greater than that of the "clear water", continue to add Standard Turbidity Reagent in 0.5 mL increments to the "clear water" tube, mixing after each addition until the turbidity equals that of the sample. Record total amount of Standard Turbidity Reagent added.

6) Use the table below to determine the turbidity of the sample water based on the number of measured additions of Standard Turbidity Reagent. Record the results.

TURBITITY TEST RESULTS

Number of Measured Additions	Amount in mL	50 mL Graduation	25 mL Graduation
1	0.5	5 JTU	10 JTU
2	1.0	10 JTU	20 JTU
3	1.5	15 JTU	30 JTU
4	2.0	20 JTU	40 JTU
5	2.5	25 JTU	50 JTU
6	3.0	30 JTU	60 JTU
7	3.5	35 JTU	70 JTU
8	4.0	40 JTU	80 JTU
9	4.5	45 JTU	90 JTU
10	5.0	50 JTU	100 JTU
15	7.5	75 JTU	150 JTU
20	10.0	100 JTU	200 JTU

4.3 Nitrates Testing Procedure

The test kit used for this procedure is the *LaMotte Nitrate Nitrogen Kit* (See: Section 3.1.3). It utilizes a *Low Range Comparator* and *Low Range Comparator Bar* to determine the color of a prepared sample. This color corresponds to a nitrogen concentration, which can then be converted into a nitrate concentration using a simple calculation. The detection limit for this testing kit is 0.2 ppm NO_3.

1) Turn on the faucet/hose and allow to run for 20 seconds. Fill the water-sampling bottle with sample water.

2) Use the 0.5 mL pipet to add 0.5 mL of the water sample to a test tube.

3) Add Distilled Water to the lower line (5 mL).

4) Dilute to second line with the *Mixed Acid Reagent*. Cap and mix.

5) Wait 2 minutes. Use the 0.1 g spoon to add one level measure (avoid any excess) of *Nitrate Reducing Reagent*.

6) The mixing procedure is extremely important. Cap tube. Invert tube slowly and completely 30 times in 1 minute to ensure complete mixing.

7) Wait 10 minutes.

8) Insert test tube into *Low Range Comparator* with *Nitrate Nitrogen Low*

Range Comparator Bar. Fill the other test tube to the 10 mL line with *untreated* sample water.* Place in *Low Range Comparator*. Match sample color to a color standard. Multiply the reading by 10. Record as ppm Nitrate-Nitrogen.

NOTE: To convert to nitrate, multiply by 4.4. Record results as ppm Nitrate.

* See the figure below and read the procedure for "Test Results" for instructions on where to place each test tube as well as how to use the Comparator Bar.

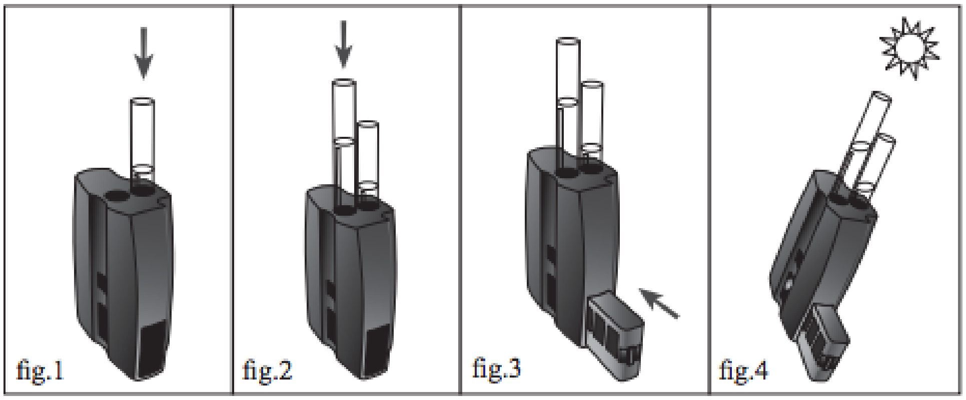
Interpreting Test Results

The results of this test are interpreted from the use of the Low Range Comparator and Low Range Comparator Bar. Two test tubes must be placed in the Low Range Comparator. One test tube will be untreated sample water filled to the 10 mL mark. It is inserted into the rear hole on top of the Low Range Comparator (see Figure 1).

The second test tube is the sample the procedure was performed on. Remove the cap and insert this tube in the front hole of the top of the Low Range Comparator (see Figure 2).

Slide the Low Range Comparator Bar into the Low Range Comparator (see Figure 3). Position the comparator so that light shines down through the test tubes (see Figure 4).

Match the color of the reaction to the color standards. Read the result from the Low Range Comparator Bar and record results appropriately.



4.4 Arsenic Testing Procedure

The testing kit used for this procedure is the *Econo-Quick* Arsenic Testing Kit (See: Section 3.1.4). It utilizes a color chart to compare to water samples to semi-quantitatively determine the concentration of arsenic in the sample. The detection limit for this testing kit is 0.3 ppb.

1) Turn on the faucet and allow to run for 20 seconds. Fill a sampling bottle and use a thermometer to verify the temperature of the sample. It is not necessary to record this temperature but for best results the water temperature should be between 25 and 28 degrees Celsius. Dispose of the water sample properly.

2) Turn the faucet down to a slow trickle then take the Reaction Bottle and fill it to the upper marked line (50 mL).

3) Add 1 level pink spoon of First Reagent to the Reaction Bottle. Cap securely with the red cap and shake vigorously, with bottle upright, for **15 seconds.**

4) Uncap the Reaction Bottle and add 1 level red spoon of the Second Reagent. Recap securely with the red cap and shake vigorously, with bottle upright, for 15 seconds. Allow the sample to sit for **2 minutes** in order to minimize H_2S interference.

5) Uncap the Reaction Bottle and add 1 level white spoon of Third Reagent. Cap securely with red cap and shake vigorously with bottle upright for **5 seconds.**

6) Immediately uncap and recap securely using the white turret cap. The turret cap MUST be dry as the Arsenic test strips will not provide a reading if they are wet.

7) Remove one Arsenic test strip from its bottle (immediately recap the test strip bottle). Insert the test strip into the turret.

a) Position the strip so that the test pad and red line are facing the back of the white cap

b) Insert the strip into the turret until the red line is even with the top of the turret, and now close (flip down) the turret. This will hold the test strip in place.

c) Allow the reaction to occur in an undisturbed, well-ventilated area. (NOTE: the test strip must be inserted and oriented correctly, and to the correct depth, in order for the results to be accurate).

8) **Wait 10 minutes.**

9) **After the 10 minute wait (no longer than 12 minutes),** pull up the turret and carefully remove the test strip **(do not let it fall into the bottle liquid).** Use the Arsenic Test Kit Color Chart to match the test strip pad color **within the next 30 seconds** (colors oxidize when exposed to light). For best matching accuracy position the reacted test pad behind the punched holes in the color chart. View the center of the test strip pad through the hole to confirm the color match and arsenic level. Record your results.

4.5 Lead Testing Procedure

The test kit used for this procedure is the *First Alert Kit.* This kit contains tests for more than just lead. However, only lead will be tested for the purpose of this sampling plan. The detection limit for this testing kit is 15 ppb.

1) Open the **Lead / Pesticide** packet and take out all contents.

2) Turn on faucet and allow water to run for 20 seconds. Fill a water sample bottle with some amount of water (50-300 mL).

3) Place exactly TWO dropper-fuls of water sample into test vial. To pick up sample, tightly squeeze the bulb at the end of the dropper and place the open end into water sample. Release the bulb to pick up sample, then squeeze again to expel sample into vial.

4) Swirl vial gently for several seconds. Place a flat surface.

5) Place both test strips into the test vial, with arrows pointing DOWN.

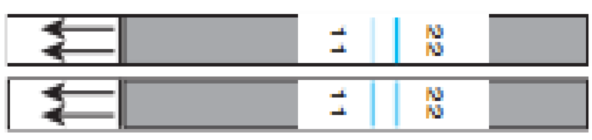
6) **Wait 10 minutes.** Do not disturb strips or vial during this time. Blue lines will appear on the strips.

7) Take the strips out of the vial and read results.

Interpreting Test Results

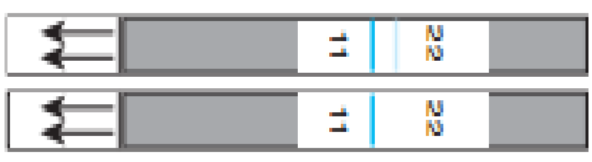
<u>Positive Test</u>

The top line of the strip (next to number 2) is darker than the bottom line of the strip (next to number 1), or lines are equally dark. The picture below shows the two circumstances representing a positive test.



<u>Negative Test</u>

The bottom line of the strip (next to number 1) is darker than the top line of the strip (next to number 2). If you only see one line next to number 1 and **no line** next to number 2 the test is negative. The picture below shows the two circumstances representing a negative test

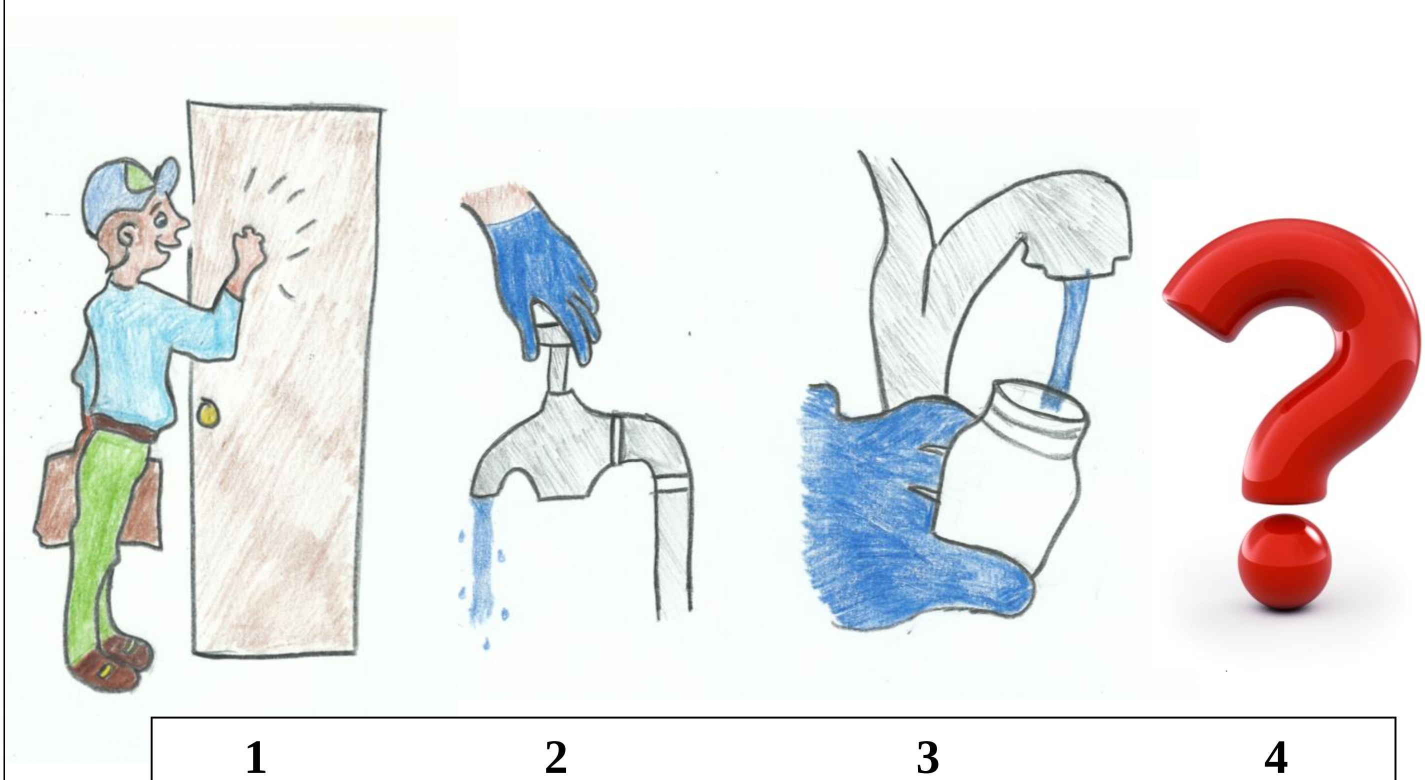


5.0 Working with Mainpat Residents

Working with people from a different culture can sometimes be a difficult process. It is important that the residents of Mainpat feel comfortable with sampling in their homes. For this reason, an “Authorization Form” and Infographic have been created for the residents of Mainpat. The authorization form grants permission to the field samplers to enter the homes of Mainpat residents and the infographic explains, using illustrations, what exactly the samplers will be doing at their homes. Because the refugees at Mainpat do not speak English, a Tibetan translator will be present and assist the samplers in conveying important information to Mainpat residents.

5.1 Infographic for Mainpat residents

Although a Tibetan translator will be present at Mainpat, it is helpful to create an information sheet of illustrations for Mainpat residents. This way, the residents can understand what exactly the field testers will be doing at the household. An infographic is provided below. It explains what the samplers will be doing at the homes of Mainpat residents: Notifying the residents, turning on their faucet, filling sampling bottles, and then making sure all the residents’ questions are answered.



1 2 3 4

5.2 Mainpat Resident Authorization Form

The sampling protocol requires field workers to enter the homes of the residents of Mainpat. Because of this, an authorization form must be signed by both parties to give consent to the field samplers to enter the homes of Mainpat residents. A sample authorization form is given below:

I, ____, give permission to

(Name of Resident)

____ to perform water quality tests at both my kitchen

(Name of sampler)

sink and my container of filtered water. I understand that it is important I do not interfere with the field samplers while they are testing.

Resident Signature: ____ Date: ______________

Sampler Signature: ____ Date: ______________

6.0 Data Recording Sheet for Field Samplers

Because no samples will be taken back to the university, it is imperative that the samplers record their results for *all* water quality tests at *all* camps. A “Data Recording Sheet” has been provided for field samplers to fill out while at Mainpat.

Sample ID	Date	Time	Test					If Pb or TC P/A?	If NTU, NO_3, or As record value (ppm)
			TC	NTU	NO_3	As	Pb		

As stated previously, the field samplers will have GPS in order to identify which houses correspond to which numbers. Therefore, the Sample ID from the data recording sheet indicates all pertinent sampling information and answers questions such as: At which camp was the test taken? At which home was the test taken? What water quality procedure was used?

7.0 Health and Safety Plan

The health and safety of the field samplers at Mainpat are of utmost importance. The field samplers will be handing water samples that may contain harmful contaminants. In addition, the samplers will be sampling at the homes of Mainpat residents so it is crucial that both the sampler and resident are safe. This plan outlines the necessary procedures and personal protective equipment (PPE) necessary to ensure that all samplers are practicing in a safe, secure manner.

Safety Procedures Prior to Mainpat

Before any sampling can begin it is necessary that all field samplers have passed their "Field Sampling" examination. By passing this test, the sampler has demonstrated sufficient knowledge of sampling protocol and safety procedures. The sampler should be aware of all testing kits they are using and how to properly store them for international airline travel. A checklist should be prepared of all equipment that will be taken. In the event that an item is lost or stolen, the sampler will know exactly what is missing and its quantity. In addition, the field samplers must fill out an NAU "Risk Form" prior to traveling to Mainpat, India. They must also familiarize themselves with the Environmental Health and Safety policies located on NAU's website.

Safety Procedures at Mainpat

Each testing kit comes with a Material Data Safety Sheet (MSDS) that lists and explains all the chemical reagents in the kit. It is important that the sampler familiarizes his or herself with these chemicals and understands how to properly use each one. The PPE listed in the next section must be worn at all times when sampling at the house or the well. In addition, the PPE is to be worn during the analysis of the water samples. It is crucial that the sampler knows how to carry out all five sampling procedures. If for whatever reason the sampler cannot recall the procedure, consult the sampling protocol immediately before moving forward.

Personal Protective Equipment (PPE)

As stated in Section 3.2 of this protocol, all samplers must wear/use the following when sampling or analyzing samples:

- Coveralls
- Latex Gloves
- Safety glasses or chemical splash goggles
- Long sleeve shirts
- Hair ties (hair should not go below shoulders)
- Long pants

Storage of Samples

Different procedures require different amounts of storage time. Some samples, for example, may require up to 48 hours of storage time. It is imperative that the samples remain undisturbed from both the environment and people during this time. All caps on the samples must be securely tightened to prevent any exposure to the outside environment. In addition, the area where the samples are stored should be sufficiently secure, remote, and away from Mainpat residents or wildlife in the area. Always use the data-recording sheet at the time the samples are analyzed. Per Lar, the head field sampler, chain-of-custody forms are not required for this trip.

Disposal of Samples and Other Sampling Materials

Certain items from the water quality testing kits should never be reused. The total coliform testing kit and lead testing kit, for example, are one-time use kits and must be disposed of after each use, including in between duplicates. The testing kits for nitrates, arsenic, and turbidity are appropriate for multiple tests, however, different sampling bottles *must* be used for each sample. Always dispose of all materials from the kits appropriately when testing is complete. Because there are no hazardous chemicals in these kits, they can be disposed of as municipal solid waste, per India's regulations. It is up to the field samplers if they would like to bring trash bags for the trip.

Safety of Mainpat Residents

Before any field samplers can enter the home of a Mainpat resident, the resident must sign an "Authorization Form" This form gives permission to field samplers to enter the homes and perform water quality tests. Mainpat resident will also be given an infographic that shows, with illustrations, what exactly the field samplers will be doing in their homes. This inforgraphic can be seen in the sampling work plan.

Contact Information

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8.0 Quality Assurance/Quality Control Plan

In order to collect usable data, the field samplers traveling to Mainpat must follow a QA/QC plan. This plan will outline how to obtain accurate and precise results when testing at the seven Mainpat camps.

According to the California Department of Water Resources, a QA/QC for field sampling requires the following components:

1. Objectives of the studies are developed before any activities begin.
2. Study design is statistically sound (sampling sites are representative of the environment, number of samples have appropriate statistical power, etc.)
3. Proper sampling, equipment and analytical procedures are used.
4. Field crew staff is properly trained.
5. QC samples such as blanks and replicates are incorporated in sampling plans.
6. Sample custody procedures are in place.
7. Corrective actions are applied when QC measures identify errors, or defects at any point in the data acquisition process

This QA/QC plan will address these components and identify ways that the Sampling Plan and/or Health and Safety Plan meet these requirements.

1. Objectives of the studies are developed before any activities begin.

The primary goal of this sampling plan is to determine the origin of the *salmonella typhi* bacteria utilizing the Total Coliform Count. The overall water quality of the Mainpat refugee camps is also of importance. This is why secondary water quality tests (turbidity, nitrates, arsenic, and lead) are also included. All field samplers should be aware of these overarching objectives prior to any field-testing activities.

2. Study design is statistically sound (sampling sites are representative of the environment, number of samples have appropriate power, etc.).

For accurate and precise results the correct number of samples must be taken at each of the seven Mainpat sites. If the study design is not statistically sound the data collected by samplers is nearly useless as it is not representative of the Mainpat community. Therefore, it is crucial that a large enough sample size is used and samples are taken in all seven of Mainpat's camps. Section 3.3 of the Sampling Protocol describes the statistical methods used in greater detail.

3. Proper sampling, equipment and analytical procedures are used.

To provide the upmost accurate sampling data, analysis procedures are based on manufacturer specifications. These procedures are all described in Section 4.0 of the Sampling Protocol. In addition, the Health and Safety Plan in Section 7.0 details all PPE required and ensures that field samplers are familiar with the techniques to be utilized.

4. Field crew staff is properly trained.

The field samplers must pass a "Field Sampling" examination prior to traveling to Mainpat. Completion of this test demonstrates sufficient knowledge of field sampling activities. In addition, the field samplers are engineering students who have had prior experience with laboratory work.

5. QC samples such as blanks and replicates are incorporated in sampling plans.

Prior to any testing, the field samplers will run a blank for each water quality test to ensure the testing kits are calibrated correctly. The source of this water shall be the same source as the samplers' drinking water (i.e. water bottles). The samples will be labeled as "QC blanks." In addition, the samplers will create duplicate samples for the first two to five water quality tests they perform for each of the five parameters.

6. Sample custody procedures are in place.

Lar will be in charge of *all* data recording sheets. The sheet will include the location of the test, the date/time of sampling, and indicate the test results. After the data sheet is returned to the university it will be entered into a computer based data entry program, such as Microsoft Excel. Once the data is compiled in one place, the field samplers can begin analyzing it and determine which water samples are acceptable.

7. Corrective actions are applied when QC measures identify errors, or defects at any point in the data acquisition process.

The field samplers shall identify any human errors or product defect throughout the testing procedure (i.e. blanks). If there are human errors such as mislabeling, or sample exposure to outside contamination, the sample shall not be included in data analysis. If any errors or defects occur during field activities, it is up the sampler to use sound engineering judgment when determining solutions.

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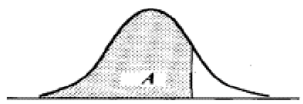
Entry is $t(A;\ \nu)$ where $P\{t(\nu) \leq t(A;\ \nu)\} = A$



	A						
ν	.60	.70	.80	.85	.90	.95	.975
1	0.325	0.727	1.376	1.963	3.078	6.314	12.706
2	0.289	0.617	1.061	1.386	1.886	2.920	4.303
3	0.277	0.584	0.978	1.250	1.638	2.353	3.182
4	0.271	0.569	0.941	1.190	1.533	2.132	2.776
5	0.267	0.559	0.920	1.156	1.476	2.015	2.571
6	0.265	0.553	0.906	1.134	1.440	1.943	2.447
7	0.263	0.549	0.896	1.119	1.415	1.895	2.365
8	0.262	0.546	0.889	1.108	1.397	1.860	2.306
9	0.261	0.543	0.883	1.100	1.383	1.833	2.262
10	0.260	0.542	0.879	1.093	1.372	1.812	2.228
11	0.260	0.540	0.876	1.088	1.363	1.796	2.201
12	0.259	0.539	0.873	1.083	1.356	1.782	2.179
13	0.259	0.537	0.870	1.079	1.350	1.771	2.160
14	0.258	0.537	0.868	1.076	1.345	1.761	2.145
15	0.258	0.536	0.866	1.074	1.341	1.753	2.131
16	0.258	0.535	0.865	1.071	1.337	1.746	2.120
17	0.257	0.534	0.863	1.069	1.333	1.740	2.110
18	0.257	0.534	0.862	1.067	1.330	1.734	2.101
19	0.257	0.533	0.861	1.066	1.328	1.729	2.093
20	0.257	0.533	0.860	1.064	1.325	1.725	2.086
21	0.257	0.532	0.859	1.063	1.323	1.721	2.080
22	0.256	0.532	0.858	1.061	1.321	1.717	2.074
23	0.256	0.532	0.858	1.060	1.319	1.714	2.069
24	0.256	0.531	0.857	1.059	1.318	1.711	2.064
25	0.256	0.531	0.856	1.058	1.316	1.708	2.060
26	0.256	0.531	0.856	1.058	1.315	1.706	2.056
27	0.256	0.531	0.855	1.057	1.314	1.703	2.052
28	0.256	0.530	0.855	1.056	1.313	1.701	2.048
29	0.256	0.530	0.854	1.055	1.311	1.699	2.045
30	0.256	0.530	0.854	1.055	1.310	1.697	2.042
40	0.255	0.529	0.851	1.050	1.303	1.684	2.021
60	0.254	0.527	0.848	1.045	1.296	1.671	2.000
120	0.254	0.526	0.845	1.041	1.289	1.658	1.980
∞	0.253	0.524	0.842	1.036	1.282	1.645	1.960

Figure 9.1 Normal Distribution Data used for Z-chart

Appendix B: Compost Calculations

Mass of Liquids Evaporated

Assumptions:

Q = 300 cfm (fan/blower)
Vent opening = 4" diameter
Length of Tank = 4 ft
Width of Tank = 3 ft
Temperature = 8 degrees C
$\nu_{air} = 1.50 \times 10^{-4}$ ft²/s
$D_{H20,air} = 0.282$ cm²/s at standard conditions

Correction for Temperature for Diffusivity

$$D_{H20,air} \text{ @ } 281 \text{ K} = (0.282 \text{ cm}^2/\text{s})\left(\frac{281}{298}\right)^{3/2}$$

$$D_{H20,air} = 0.258 \text{ cm}^2/\text{s} = 2.78 \times 10^{-4} \text{ ft}^2/\text{s}$$

Calculations:

Q = 300 cfm = 5 cfs

$$v = \frac{5 \text{ ft}^3/\text{s}}{\pi \left(\frac{2"}{12"}\right)^2}$$

v = 57.2 ft/s

$$Re = \frac{vL}{\nu} = \frac{(57.2 \text{ ft/s})(4\text{ft})}{1.5 \times 10^{-4} \text{ ft}^2/\text{s}} = \mathbf{1525333}$$

$$Sc = \frac{\nu}{D_{AB}} = \frac{1.5 \times 10^{-4} \text{ ft}^2/\text{s}}{2.78 \times 10^{-4} \text{ ft}^2/\text{s}} = \mathbf{0.54}$$

$$Sh = 0.664(200000)^{1/2}(0.54)^{1/3} + 0.0365(0.54)^{1/3}[(1525333)^{4/5} - (200000)^{4/5}]$$

Sh = **2353.2**

$$Sh = \frac{kL}{D_{AB}} = 2353.2 = \frac{k(4 \text{ ft})}{2.78 \times 10^{-4} \text{ ft}^2/\text{s}}$$

$$\mathbf{k = 0.1635 \ \frac{ft}{s}}$$

$$N_A = k(c_{as} - c_{ao})$$

$$c = \frac{\left(\frac{8.1\ \text{mmHg}}{760\ \text{mmHg}}\right)}{\left(\frac{0.0821\ \text{atm}*\text{L}}{\text{mol}*\text{K}}\right)(281\text{K})\left(\frac{1\text{m}^3}{1000\ \text{L}}\right)}$$

$c = \left(\frac{0.462\ mol}{\text{m}^3}\right)\left(\frac{18\ g}{gmol}\right)\left(\frac{1m}{3.28\ ft}\right)^3\left(\frac{1\ lb}{453.6\ g}\right)$ = **5.2 * 10^{-4} lb/ft^3**

N_A = (0.1635 ft/s)(5.2 * 10^{-4} lb/ft^3)

N_A = 8.5 * 10^{-5} lb/ft^2*s

W = N_A* A = 8.5 * 10^{-5} lb/ft^2*s (12 ft^2)(86400s/day) = 88.1 lb/day = 10.5 gal/day

Because the liquids evaporate only half the day, the mass flux is **5.25 gal/day.**

W = 5.25 gal/day

Liquid and Solids Mass Balance

Assumptions:
100 people.
Solid Waste is 75% Liquid. (2 lbs waste/person/day)
0.5 gal/flush
Flushing twice a day.
1 lb. feces/person/day @ 2 times a day.
Urinating 0.125 gallons/person/day @ 3 times a day

Liquid Mass Produced Daily

$$100\ people\ \left[\frac{0.375\ gallons\ liquid}{person*day}+\frac{1\ gallon\ flushing}{person*day}+\frac{0.18\ gallons\ liquid}{person*day}\right]*\frac{8.34\ lbs}{1\ gallon\ liquid} = \mathbf{1293\ lbs}$$

Solid Mass Produced Daily

$$100\ people\ \left[\frac{2\ lbs\ solid\ waste}{person*day}*0.25\ solids\ ratio\right] = \mathbf{50\ lbs}$$

Therefore, for every 50 lbs of solid waste produced, 1293 lbs of liquids are produced. The overall percentage of solids and liquids are:

$$\frac{50\ \text{lbs solids}}{1393\ \text{lbs total}} = 3.7\%\ \text{solids.}$$

100%-3.7% = 96.3% liquids

Overall liquid/solids mass balance:
3.7% solids
96.3% liquids

Solids Decay Rates

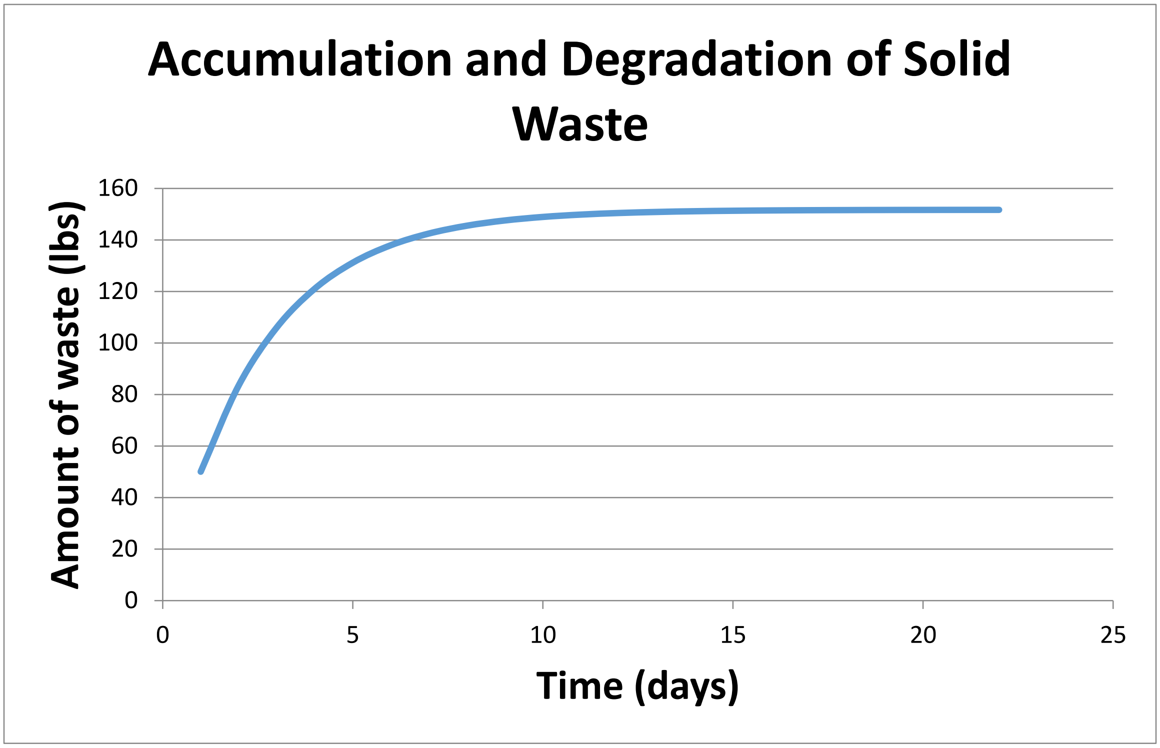
Waste at Beginning of Each Day

Day	Waste (lbs)
1	50
2	83.5
3	106.0
4	121.0
5	131.1
6	137.9
7	142.4
8	145.5
9	147.5
10	148.9
11	149.8
12	150.4
13	150.8
14	151.1
15	151.3
16	151.4
17	151.5
18	151.5
19	151.6
20	151.6
21	151.6
22	151.6
23	151.6
24	151.7
25	151.7
26	151.7
27	151.7
28	151.7
29	151.7
30	151.7

Waste at End of Each Day

Day	Waste Remaining (lbs)
1	33.5
2	56.0
3	71.0
4	81.1
5	87.9
6	92.4
7	95.5
8	97.5
9	98.9
10	99.8
11	100.4
12	100.8
13	101.1
14	101.3
15	101.4
16	101.5
17	101.5
18	101.6
19	101.6
20	101.6
21	101.6
22	101.6
23	101.7
24	101.7
25	101.7
26	101.7
27	101.7
28	101.7
29	101.7
30	101.7

Follows a first order decay equation (k = -0.4/day)



Leach Field Sizing

Assumptions:

Calculated Daily Output=155gallons/day

Percolation rate= 2.5 gallons/ft^2

Safety Factor=5ft

Area per Flow=2.33ft

Calculations:

Wall Area=$\frac{155 gallons/day}{2.5 gallons/ft^2}$=62$ft^2$

Lineal Feet of Trench=$\frac{62ft^2}{2.33\ ft}$=26.62ft

Revised Total=5ft+26.61ft=**31.61ft**