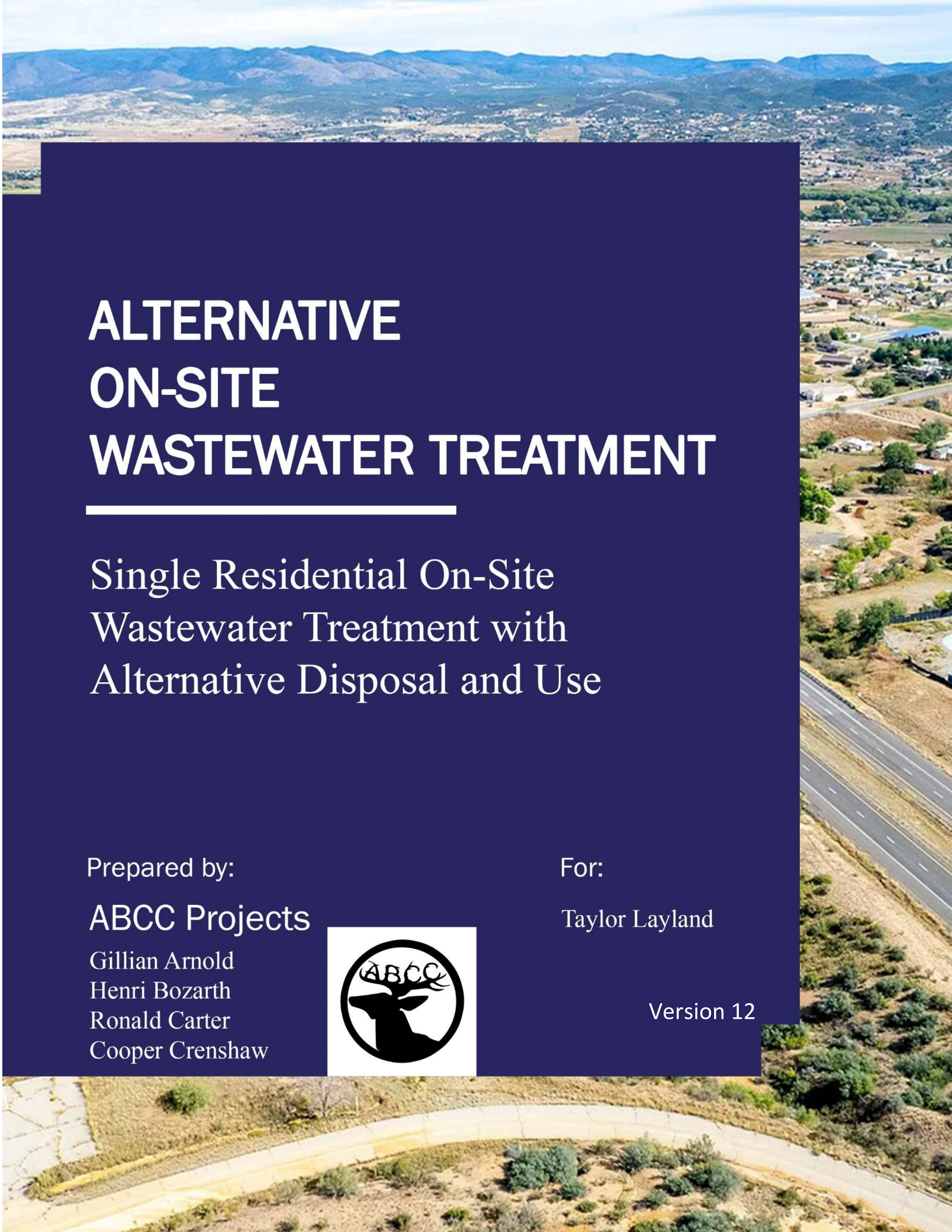

ALTERNATIVE ON-SITE WASTEWATER TREATMENT

Single Residential On-Site Wastewater Treatment with Alternative Disposal and Use

Prepared by:

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For:

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Version 12

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Equations

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Abbreviations

Arizona Administrative Code: AAC
Arizona Department of Environmental Quality: ADEQ
Biological Oxygen Demand for 5 Days: BOD_5
Chemical Biological Oxygen Demand for 5 Days: $CBOD_5$
Colony Forming Units: cfu
Escherichia Coli: E. Coli
Intermittent Sand Filter: ISF
Liter: L
Milligram: mg
Milliliter: mL
Mini Wastewater Treatment Plant: Mini WWTP
Personal Protective Equipment: PPE
Power of Hydrogen: pH
Total Suspended Solids: TSS
Wastewater Treatment Plant: WWTP

Acknowledgement

Persons of particular importance to the completion of this project include many students and employees of Northern Arizona University.

Special thanks, foremost, to Dr. Jefferey Leonard Heiderscheidt Ph.D. for guiding the creation and progress of this engineering project, whose input was invaluable at many stages throughout the entire design section of the project.

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Thanks to Daniel Langsmith for assisting with Civil 3D and working with the contour data.

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1.0 Project Introduction

The installation of an on-site wastewater treatment plant is a typical item for most residences residing too far from a municipal wastewater treatment plant. Such systems allow for waste removal and treatment from a household, while remaining a simple device with only yearly or less maintenance, making it easy for homeowners to use.

However, most of these systems discharge water into the ground, making it unobtainable until infiltration lets it reach a local aquifer or hits an aquitard layer. This water could be used for other uses should it be treated to reasonable quality, instead of simply ebbing away. With many states in the southwest US (United States) suffering from droughts and lowering water sources, methods to reduce loss of water and reduce use of potable water are needed.

This design plan goes into the design of such systems. Instead of letting the wastewater infiltrate and become inaccessible, where it is no longer useful for many years, the wastewater can be treated and then reused back on the site of its production. This water ends up infiltrating regardless, whether through ground application or by coming back into the waste system, but by adding a reuse step, the total water need for a site is reduced.

1.1 Project Background

This project is being performed by ABCC Projects for Taylor Layland, who is acting as the communicator for the clients who own the site. ABCC Projects has been contracted to design an on-site wastewater treatment facility for the site, designing a system to take care of a single-family residence in Dewey-Humboldt, Arizona.

This system will be installed on a 5-acre lot, currently undeveloped and consisting of mostly of highland desert sand and rock, desert shrubs, and juniper trees. An ephemeral drainage gulley runs along the north end of the lot but is not directly a part of the property. The nearby lots are currently developed in a similar fashion to the end goal of this property, with large lot sizes consisting of residences constructed on them. The nearby lots have their own on-site wastewater systems installed.

The on-site wastewater system is to be designed to handle the needs of a single-family home, designed by a prefab company, Coventry Log-Homes, specifically the Lakeside Model, which includes two bedrooms, two full bathrooms, a laundry closet, and a full kitchen with dishwasher [3].

1.2 Project Purpose

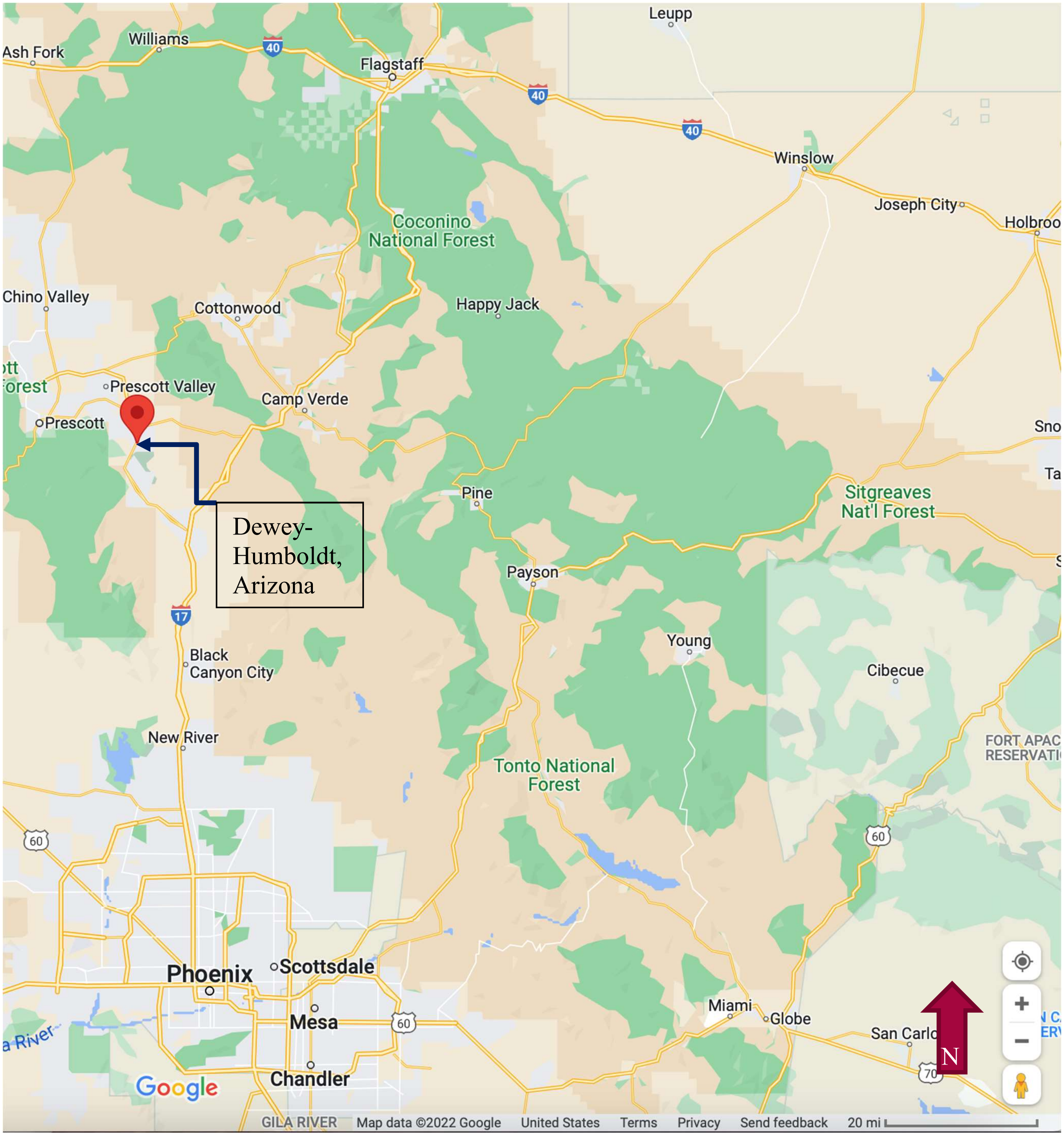
This project is being performed to complete two major goals.

Objection 1 is to create a wastewater-handling system for the future tenants on the site. This allows the tenants to live in the chosen area where no such municipal systems exist and achieves the environmental goals of the Arizona Department of Environmental Quality to limit damage to the local environment from wastewater discharges.

Objective 2 is to produce safe-to-use, treated water produced from wastewater on site. This allows the tenants to perform irrigation of plants around the future residence with treated wastewater from the wastewater-handling system, which overall reduces the amount of potable water consumed on the site.

1.3 Project Location

The lot of land is at 11800 Prescott Dells Ranch Road, Dewey-Humboldt, Arizona 86327. Figure 1-1 shows Dewey-Humboldt in relation to Flagstaff and Phoenix.



1-1. Site Location regarding Flagstaff and Phoenix [2]

Figure 1-2 shows the site location within Dewey-Humboldt and the general boundary of the 5-acre site to be built on. A specific map showing the boundary with more accuracy, as well as other nearby parcels on land, can be found in Appendix A.

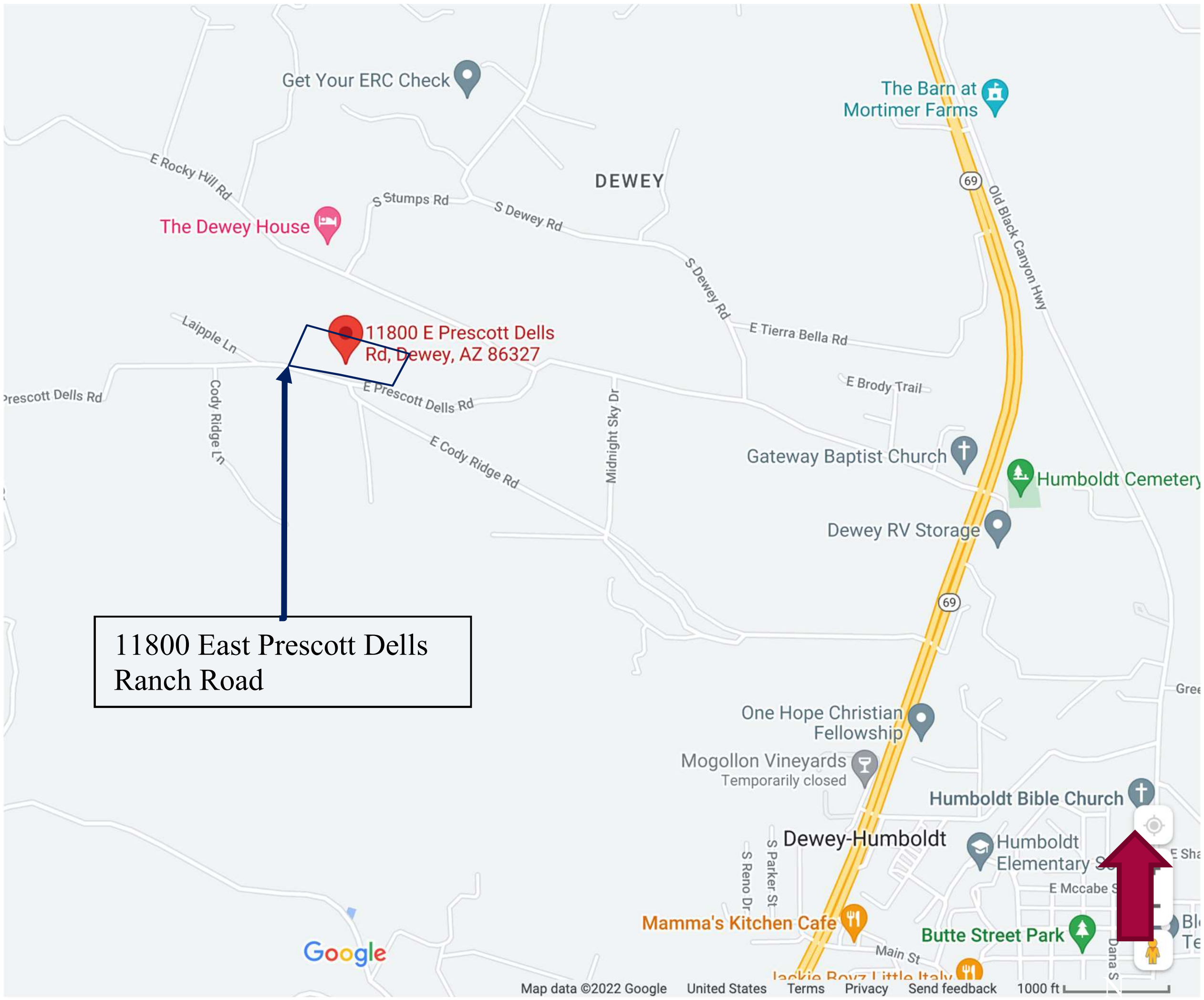


Figure 1-2. Site Location with regards to Dewey-Humboldt [2]

1.4 Constraints and Limitations

Constraints encountered during the project will mostly stem from costs. With a large lot size and the nature of this system not requiring utility hookups, the only major constraint will be cost.

The client has set a rough early estimate of $35,000 for this system that is to be designed around. A simple septic system would achieve the first goal of creating a wastewater-handling system, but it would not achieve the second goal of creating treated water usable for irrigation. In order to achieve a treatment quality allowed by the AAC and ADEQ, more expensive systems must be found. The cost set up by the client could limit these systems in alternatives research.

Limitations of this project include the inability to gain site access. Designs will be limited to numbers and data gathered from online sources, which may not truly represent the site as much as a true site investigation would.

Additionally, another team is working to prepare the site for the prefab house installation, which includes foundational grading and drainage grading. This grading could limit the areas where the system may be installed, namely the location of the treatment tank with regards to the nearest driveway.

2.0 City and State Regulation Research

Research focused on understanding codes related to the design of on-site wastewater treatment systems. While many alternatives are available, research into county allowances was performed first to ensure such systems are allowed.

Code research began with county info, researching the Yavapai County Codes. It was found that the county simply points users to use the Arizona Administrative Code (AAC) for designing on-site wastewater systems, thus all codes related to designs were sourced from this [3]. More specifically, nearly all controlling codes are found in AAC Title 18 Environmental Quality, Chapter 9 Department of Environmental Quality – Water Pollution Control (hereafter 18 AAC 9).

18 AAC 9, Article 3: Aquifer Protection Permits-General Permits and Part E: Type 4 General Permits was found to contain all permits, and standard design rules for systems, as well as allowed systems and designs. All systems fall under the designation of a Type 4 General Permit, with some exceptions involved in the attempt to reuse the water.

Standards involving Objective 2 for water reuse were found in 18 AAC 9, Article 7: Use of Reclaimed Water and Part B: Reclaimed Water. Defined within are the use of recycled water on sites, permitting requirements and design principles. The water produced by the on-site wastewater system will not be suitable for potable use, and thus must be treated so it can be used for irrigation reuse. In order to achieve this, the reclaimed water must meet Class A+ or A, in which case it can be used for residential irrigation, so long as signage exists to warn a person to not drink the water. This restricts the owners from watering crops where the water encounters fruiting bodies, thus root vegetables and leafy crops cannot be watered this way.

According to the AAC Title 18, Chapter 9, Article 1: Aquifer Protection Permits – General Provisions, specifically section R18-9-B204, Class A+ and A water must have:

- Undergone Secondary Treatment
- Undergone Filtration
- Meet the requirements of Table 2-1

Table 2-1. 18 AAC 9 Requirements for Reclaimed Class A+ and A Water

Comparison of Treatment		
County Requirements		
BOD_5	30	mg/L (30 day)
or	45	mg/L (week)
$CBOD_5$	25	mg/L (30 day)
or	40	mg/L (week)
TSS	30	mg/L (30 day)
or	45	mg/L (week)
pH	6-9	
Removal Efficiency	85%	BOD_5, $CBOD_5$, TSS
Nitrogen	<10	mg/L (5-month rolling geometric mean)
Fecal Coliforms		
Daily Tests*	<200	cfu/100mL
Daily E. Coli**	<126	cfu/100mL
Single Max*	< 800	cfu/100mL
Single Max E. Coli**	< 504	cfu/100mL

*Daily Tests (4 of 7 in week)
**Single Sample Maximum

If the chosen treatment scenarios cannot meet standards for Class A+ and A water, the option to use gray water still exists. For systems that separate gray water, provisions are found in 18 AAC 9, Article 7 Part D: Gray Water. It allows residential users to use up to 400 gallons per day of gray water and can be used for garden and landscape watering; however, it cannot be a surface application method and must be a watering method akin to drip irrigation. Watering of food plants is still limited to those that do not have the edible product in contact with the grey water, which disallows watering of root vegetables like potatoes, but not shrubs and trees that fruit.

In order to fulfill the requirements for grey water, the following must be satisfied:

- Cannot contain runoff from hazardous chemicals, such as cleaning car parts, greasy/oily rags, or disposing of waste solutions
- Water cannot contain any fecal contaminants, thus fecal soiled garments and diapers cannot feed into the gray water
- Must remain separate from any potable or black water systems, other than including overflow into a septic system

Leech field specifications are found in 18 AAC 9, Article 3 Part E: Type 4 General Permits, as well as the other dispersal methods for discharging wastewater into the ground and/or environment.

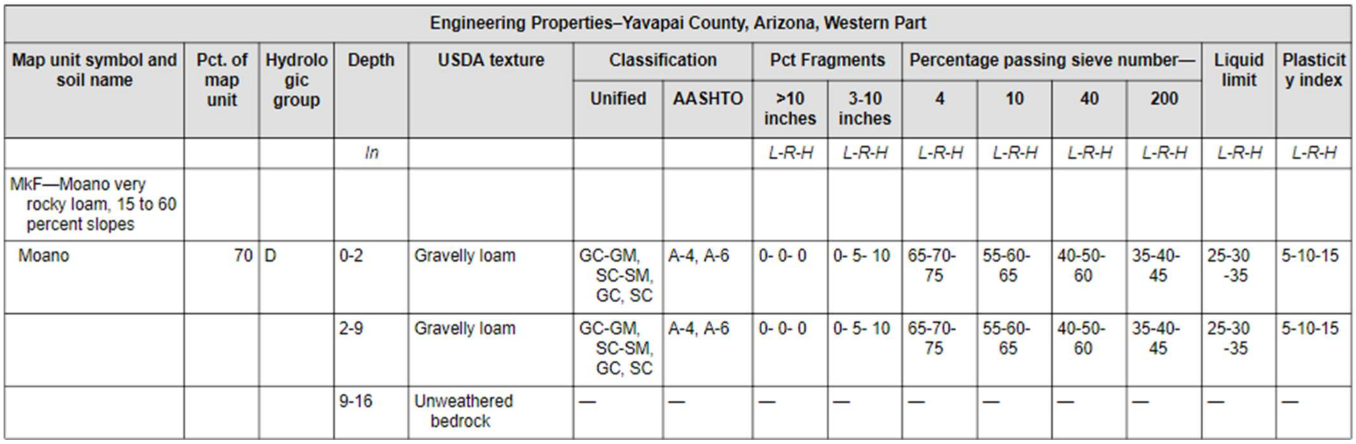
3.0 Site Investigation

The client did not grant site access to perform a site investigation. As a result, many assumptions were made, and online sources were used to retrieve applicable information.

3.1 Geotechnical Data

Due to the clients not granting site access, data was gathered from the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Web Soil Survey [4]. This provided data used with the AAC to design the leach field. The following table represents the findings of the NRCS report.

Table 3-1. USDA Soil Report for Site



Engineering Properties–Yavapai County, Arizona, Western Part

Map unit symbol and soil name	Pct. of map unit	Hydrologic group	Depth	USDA texture	Classification		Pct Fragments		Percentage passing sieve number—				Liquid limit	Plasticity index
					Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
			In				*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*
MkF—Moano very rocky loam, 15 to 60 percent slopes														
Moano	70	D	0-2	Gravelly loam	GC-GM, SC-SM, GC, SC	A-4, A-6	0- 0- 0	0- 5- 10	65-70-75	55-60-65	40-50-60	35-40-45	25-30-35	5-10-15
			2-9	Gravelly loam	GC-GM, SC-SM, GC, SC	A-4, A-6	0- 0- 0	0- 5- 10	65-70-75	55-60-65	40-50-60	35-40-45	25-30-35	5-10-15
			9-16	Unweathered bedrock	—	—	—	—	—	—	—	—	—	—

This data is representative of the entire western section of Yavapai County and does not contain additional information pertinent to the site alone.

It should be noted that under 18 AAC 9, use of such sources does not constitute a proper site investigation, as outlined in R18-9-A310. Site Investigation for Type 4 On-site Wastewater Treatment Facilities. Such use of online sources is insufficient to properly determine the soil infiltration rate for the site's specific areas. While soil changes across distances such as 10 yards may not be significant, a specific choice of site for a leech field can be made on bad judgement without a proper soil sampling data set, especially if there are unforeseen soil qualities that are not found in the resolution scale of the Web Soil Survey. Such oversite can lead to a system failure of the leach field.

For this project analysis, online data was used to move forward. However, should the project become a real construction design in the future, a proper site investigation must be performed.

3.2 Surveying

With the inability to access the site for a proper survey of the land, data acquisition from existing sources was pursued.

After this, an attempt was made to use the Yavapai County Geographical Information Systems (GIS) Contour Request application to find contour data [5]. Initially, this was thought to be another dead end as the program requires users to pay a fee to receive the contour data, a fee that for this site was $100. However, Ellie Dellard from the Yavapai County GIS office noticed the request as originating from college students and provided the data free of charge. It should be noted that a real project would need to pay this fee or find contour data elsewhere.

These contours represent the surrounding plots of land and the main site with 2ft contours.

The data was provided as DWG files, which were imported into AutoCAD to create a simple topographic map. General locations of the development site and nearby roads were added. Figure 3-1 is an example of this map.

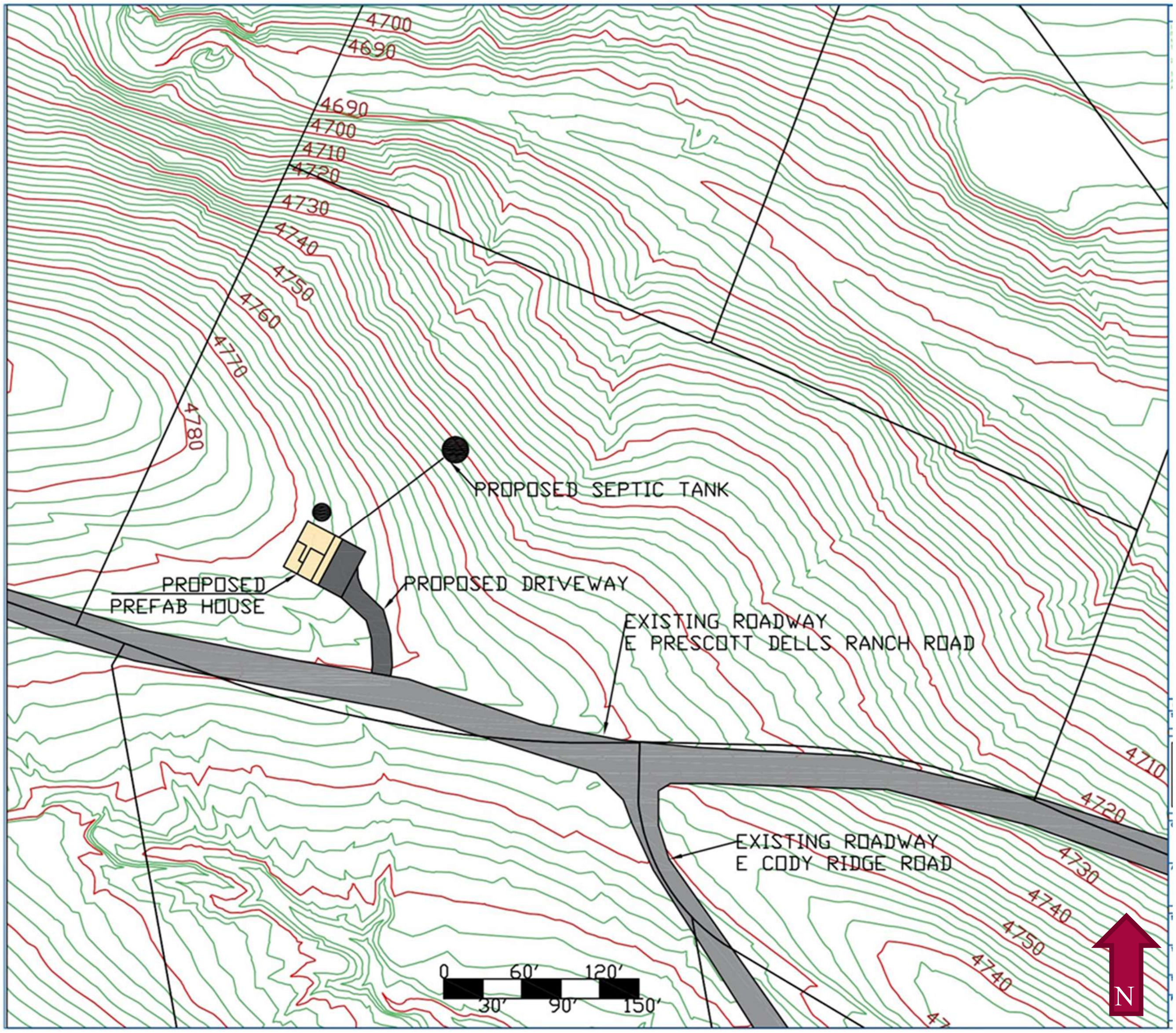


Figure 3-1. Site Topography with Proposed Site Development

3.3 Design Flow Determination

Using an image of the prefab log home on the company's website (Figure 3-2), a count of fixtures was done to begin the flow math for a basic septic tank. While the flow values found by using the septic tank section of the AAC are focused on that system, the AAC notes that all alternative systems are to use the same flow values outlined for a septic tank.

An additional assumption was made that a dishwasher would be included in the fixture count, which cannot be seen in the image below, but all other fixtures are clearly represented on it. The dishwasher addition was asked for inclusion by the client.

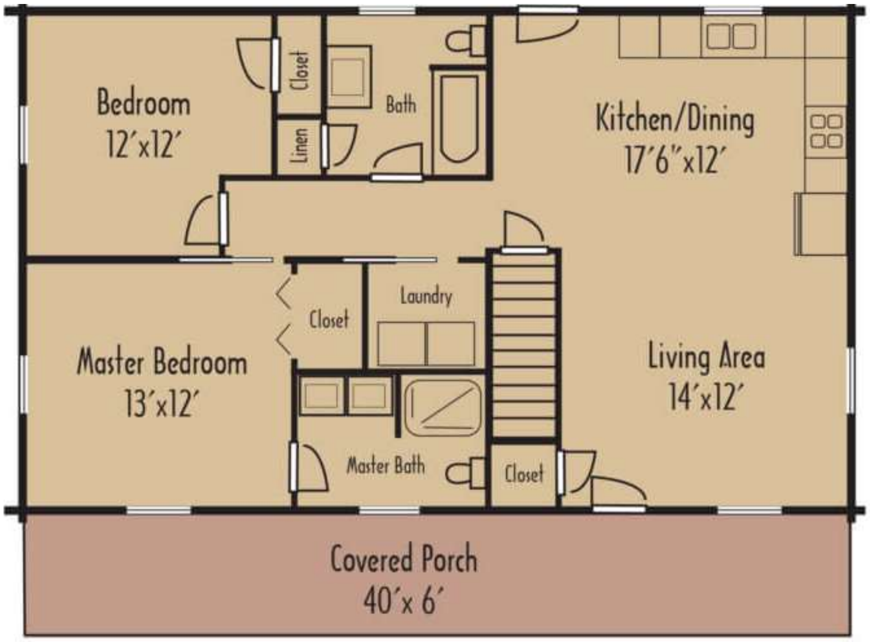


Figure 3-2. Coventry Log Homes-Lakeside Model Floorplan [1]

Using 18 AAC 9, a fixture count was performed, which resulted in a design wastewater flow rate as shown in Table 3-2.

Table 3-2. Design Flow Calculation

Design Flow		
Bedrooms	2	
Fixture Count		Multiplier
Bathtubs	2	2
Toilets	2	1
Clothes Washer	1	2
Sink w/ Dishwasher	1	2
Total Fixtures	10	
14 or less?	Yes	
Design Volume	1000	gal
Design Flow	350	gal/day

The final design flow that any researched alternatives must attain will be 350 gallons per day, and the septic tank, if used, must be at least 1000 gallons, as required by 18 AAC 9 for the fixture count found in Table 3-2.

4.0 Design Alternatives

Technology options research was focused on finding alternatives for the on-site wastewater treatment unit's design. It was found that Yavapai County and ADEQ had a list of approved, permit-capable systems that helped narrow down research [4].

Research then focused on systems that could reduce the contaminant content of the wastewater, using three different approaches:

- Design for a basic septic system with no reuse of water to uphold AAC and complete Objective 1 only
- Design a system such that black and gray water never mix, thus following AAC guidelines while achieving both Objectives
- Design a system capable of high treatment levels to Class A or A+ Reclaimed water standards to satisfy both Objectives

4.1 Initial Alternatives Selection

With the above approaches, the list provided by Yavapai County was sifted through to produce useful design options that warranted further exploration into their treatment levels and applicability to the project.

Some options, such as composting toilets and sewage vaults, were deemed non-viable due to the inapplicability of the system with attempting to reuse water on site. Others are simply leach field options, such as the gravel-less trench system, and it was decided that a standard trench leach field would be used to simplify discharge steps and focus on treatment options. Larger options, like the evapotranspiration field and constructed wetlands, were removed based on feasibility with site and land requirements. Lastly, many optional filter methods existed, like peat and textile filters, but were also removed due to higher requirement of the owners to care for the filters.

With non-viable options removed, a series of systems were chosen for analysis, based on judgement considering system size and ease of use for the clients.

As a baseline, a standard septic system (Figure 4-1) was designed, as it accomplishes Objective 1. It is a useful baseline to have and shows the client the absolute lowest cost required should they decide their water reuse needs change. Further, this system also requires design since it remains a required component for most of the more advanced treatment systems.

Figure 4-1. Septic Tank Process Diagram

The second system includes a simple filter to be used for a separated gray water line (Figure 4-2). Gray water cannot contain any water coming from toilets or kitchen sinks, and includes water from showers, sinks, and laundry machines. As 18 AAC 9 has several codes already outlining such a system and use of gray water, it was an easy choice for an alternative. The filter design is a basic sand filter and requires about as much maintenance as the septic tank does, which can help the client ensure both systems receive maintenance instead of requiring two different maintenance cycles. This system is additional to the basic septic system, as 18 AAC 9 requires that any gray water system be only additional, and that if the gray water system ever has a fault that the septic tank accept all household wastewater through safeties in the gray water filter.

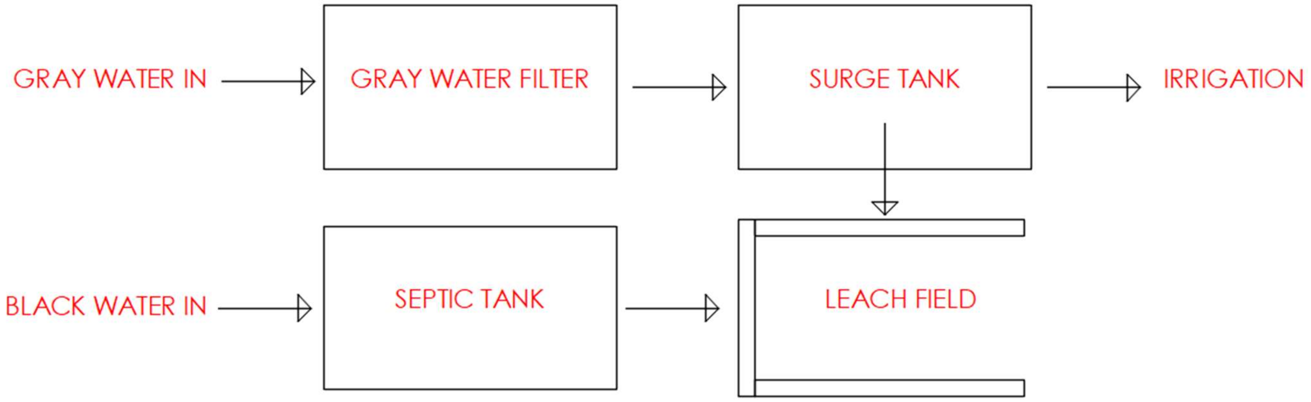


Figure 4-2. Gray Water Process Diagram

The third system is the use of an intermittent sand filter located after the septic tank, but unlike the gray water sand filter, it does not require the separation of black and gray water. Once again, this system is an add-on to the septic system, but due to the biological and physical treating power of larger sand filters, it was deemed an alternative capable of reaching the treatment goals. However, it is noted that additional treatment steps, such as chlorination, may be needed, and will require further analysis.

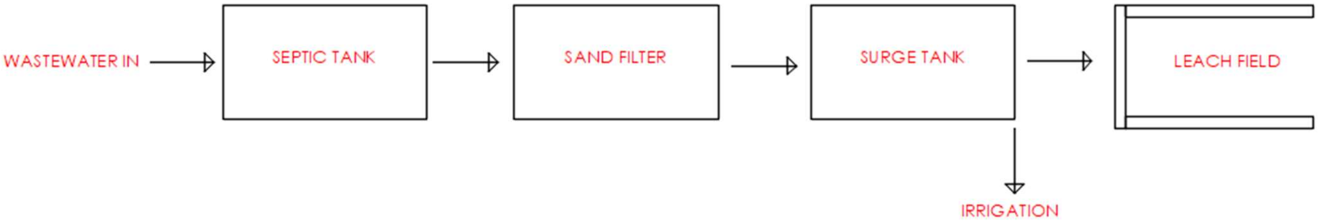


Figure 4-3. Sand Filter Process Diagram

The final system will be called a Mini Wastewater Treatment Plant (Mini WWTP) going further, as many names exist for this system depending on design specifics (Figure 4-4). It does not need a septic system to function and instead replaces it. This system achieves the treatment goals of Objective 2, much like a large-scale WWTP serving a city or community. However, it is noted that the cost of such a system is often higher.

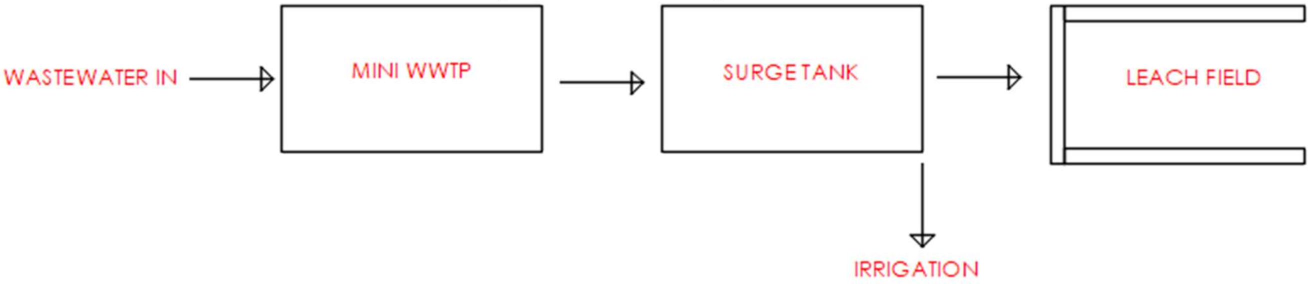


Figure 4-4. Anerobic Wastewater treatment Process Diagram

Finally, a standard trench leach field was deemed a necessary option for discharge of wastewater for any system designed. It is mostly unaffected by any of the systems discussed above as per AAC regulation, and acts as a discharge for all systems, either for treated wastewater or overflow discharge.

4.2 Standard Septic Tank

4.2.1 System Process

A conventional septic system has specific design requirements in order to meet treatment standards. There are a few public safety concerns associated with the outflow of septic fluids into residential property. The design requirements are outlined in Title 18 AAC 9 and were created by ADEQ.

A conventional septic system in its most basic form is a system designed to treat organic solids anaerobically and release liquid waste into the ground while retaining larger solid waste. This involves a septic tank including a baffle wall to increase the hydraulic retention time within the tank. After this there is a leach field designed to convey the stream out of the tank in a systematic and thoughtful way to spread out the outflow into as high of a surface area as allowable by economic and geographic constraints.

The end goal of this system is to create a way to dispose of waste for those too far from a municipality's gravity sewer system, where they cannot hook up to the sewer main. A septic system is a very effective and tried method that has been used for decades, and as mentioned above, is a requirement for many of the more advanced treatment designs.

4.2.2 System Design

For the conventional septic system design, the main parameters to design around are 18 AAC 9, Article 3. Aquifer Protection Permits. This regulation outlines the main parameters when designing a conventional septic system in Arizona.

The major parameters considered are as follows: the inlet compartment of any septic tank must be within 67-75% of the total capacity of the tank, the tank designed turns out to be around 68%, so within range. The next design criteria involve the liquid depth and the total capacity of the tank; the total capacity of the tank depends on the number of fixtures in the dwelling, this turns out to be a 1000-gallon tank necessary for this dwelling.

According to the document, a tank of 1000-gallons must be at least 8 feet in length and the width must be 33-50% of the length. There also needs to be an opening in each of the two chambers that are accessible from the ground level; these openings must be at least 20 inches in diameter. If a compartment exceeds 12 feet in length, there must be another opening provided over the baffle wall. The tank's depth must support 42 inches maximum liquid level depth, with at least 9 inches of open space above the liquid level.

The cover of the tank must be at least 2 inches from the top of the inlet fitting. There are various geotechnical and mechanical parameters with load support, this has not yet been considered in the design process of the tank, however something to consider for the final design; all these parameters can be found in title 18.

Figures 4-5 and 4-6 show the side view and top view of the septic tank.

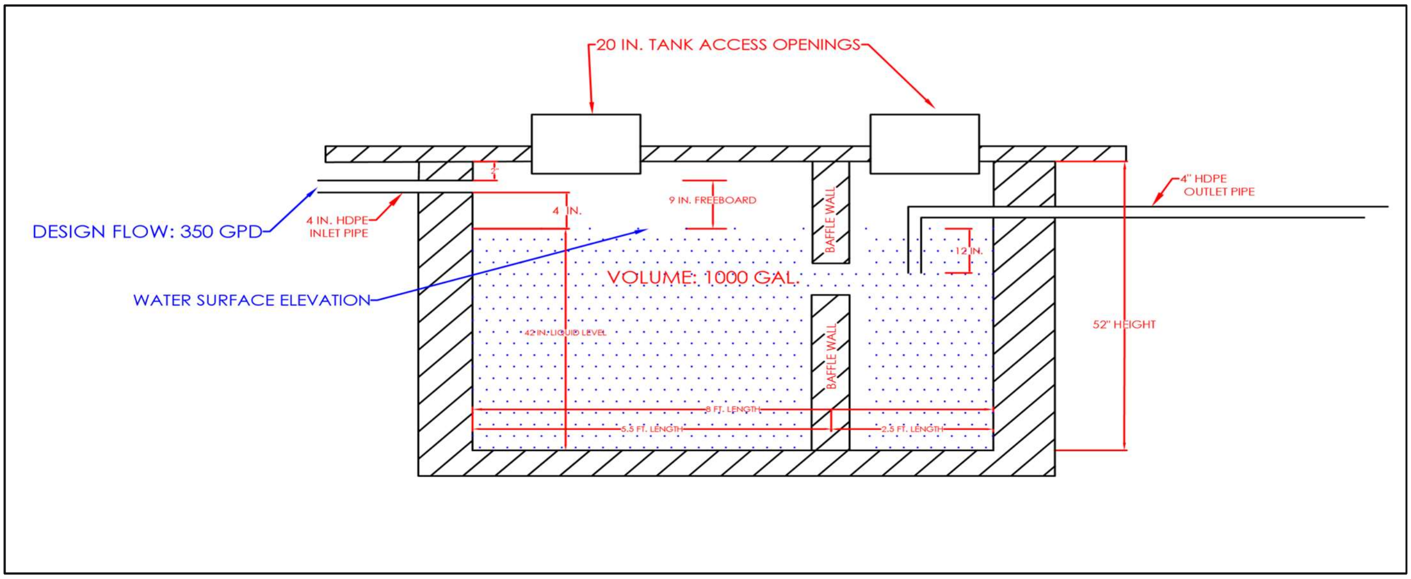


Figure 4-5. Septic Tank Cross-Section

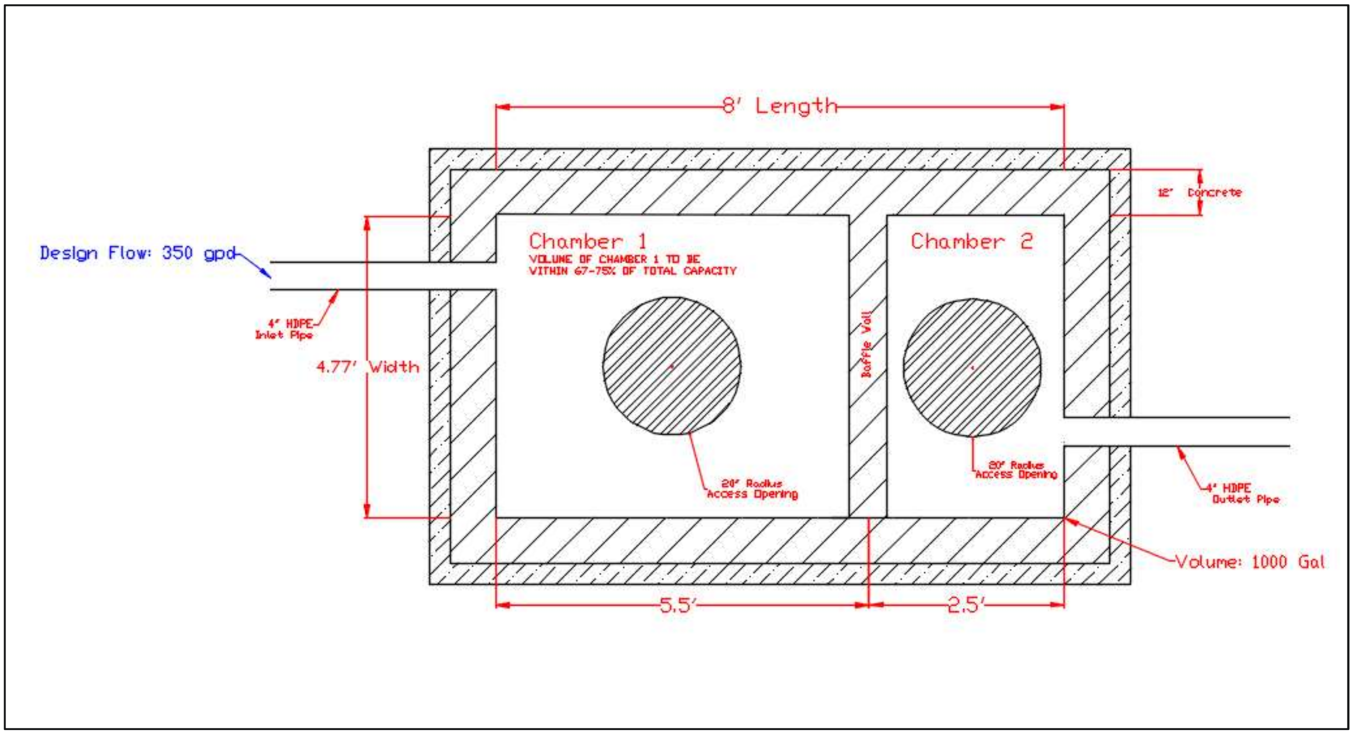


Figure 4-6. Septic Tank Top View

4.2.3 Maintenance

A conventional septic system will need regular inspection at least every three years by a septic system professional. Septic systems are pumped typically every three to five years, while alternative systems will need more frequent.

There are many ways to prevent the need for premature maintenance. This includes not flushing harmful things down with the waste such as wipes, condoms, pharmaceuticals, etc. It also includes limiting use of extreme dumping down into the septic tank, as large amounts of nutrient-poor water tend to flush out the septic tank and reduce its treatment quality, requiring the need for supplements.

4.3 Gray Water Filtration

4.3.1 System Process

18 AAC 9 does not list requirements to treat gray water before use on site. However, due to safety concerns and the possible harm untreated gray water could have on vegetation, pumps, and tanks, a sand filter will be installed to treat the gray water. This is deemed necessary as many items such as soap suds, greases, mild chemicals, etc. could end up in this water stream, and should not be reapplied to ground vegetation or handled by humans.

This system runs in parallel to a normal septic tank. 18 AAC 9 requires that the septic tank be designed to handle the full load of the wastewater stream if the gray water filter has a fault. An overflow within the sand filter tank itself exists to push this water to the septic tank should it ever overfill or fail. This design includes an attached surge tank, as it is important to operation of the sand filter.

Greywater is defined by the AAC as residential, used water that does not meet household hobby chemicals, fecal contamination including diaper washing, and oils and car residues. Wastewater lines with the house will thus need to be designed with this gray and black water segregation in mind. In short, the kitchen sink, toilets, and the dishwasher will need to be routed to the black water line leading to the septic system, while the remaining showers, bathroom sinks, and laundry wastewater can go into the gray water system.

These segregated gray water lines will combine into a flow leading to the gray water filter and surge tank. The filter includes two main treatment steps: a biofilter trap followed by sand filtration. This sand filter is sometimes called a Biosand Filter, and it is a recommended design by the Centers for Disease Control and Prevention (CDC) [7].

4.3.2 System Design

Water collected from the residence will flow first into the biofilter trap. This water coming from the gray water pipes falls directly into large baskets full of wood chips or 100% wood mulch. This layer is held within baskets above the sand filter that allows the water to easily flow out the bottom and into the standing water layer. This wood chip filter traps most hairs, greases, and other biological materials that can clog the fine sand layer below.

The wood chips sit atop a metal framework that allows the boxes to be pulled and shifted for maintenance, such as completely removing the biofilter boxes from the system through the access port. The framework will also have enough space for a pump truck to be able to access the sand for maintenance.

A large fine sand layer fills 2.75ft of the filter, chosen based on similar systems [6]. It represents most of the water treatment being done, except for the wood chip filter doing some of the initial work. This sand layer both entraps larger particles and soap scums, as well as producing a layer of microorganisms to treat for any pathogenic contaminants, as well as process a few of the biological materials. The entire sand layer remains submerged in water due to the discharge pipe water level control, as suggested by the CDC.

The sand tank's length and width dimensions are based on the incoming flow rate and the infiltration rate of the chosen sand in the sand layer. It was found that about 75% of household water can be separated into gray water [5]. This was applied to the initial design flow volume required by the AAC, creating a flow value of 262.5 gallons per day.

Using a fine sand as denoted by United States Department of Agriculture (USDA) standards of 0.6-1.18mm in particle diameter, an infiltration rate of 0.94 inches per hour was used [9]. This calculated with the design flow showed that the sand filter required a minimum surface area of 18.67ft^2.

This fine sand layer is prevented from draining into the drainage pipe by two layers: a layer of geotextile fabric followed by a gravel layer. The geotextile fabric should keep the sand from washing down into the gravel layer without affecting the infiltration rate of the entire system. The gravel layer is 0.75ft thick and includes the drainage pipe in that depth. This allows the treated water to easily flow into the drainage pipe.

The drainage pipe, which is a perforated pipe that collects water from the bottom, flows up and out the discharge control bend. This drains into the surge tank, which will hold the water until it is pumped out for irrigation purposes or overflows to the leach field drain. A pump controls both movements, and a valve can be switched to change the direction of the pump flow between the irrigation lines and the leach field.

In accordance with 18 AAC 9, the gray water filter must have an overflow that leads to the septic tank so untreated gray water doesn't back up and cause residential damage. This is done in case of a clog or fault of the gray water filter. In addition, an overflow must lead to the leach field for the treated effluent of the gray water that ends up in the surge tank. The AAC requires treated gray water sit for no longer than 24hrs, thus it will also be pumped from the surge tank out and directly to the leach field, so as not to disturb the septic tank.

Figure 4-7 is a cross section of this system, and Figure 4-8 shows a top view.

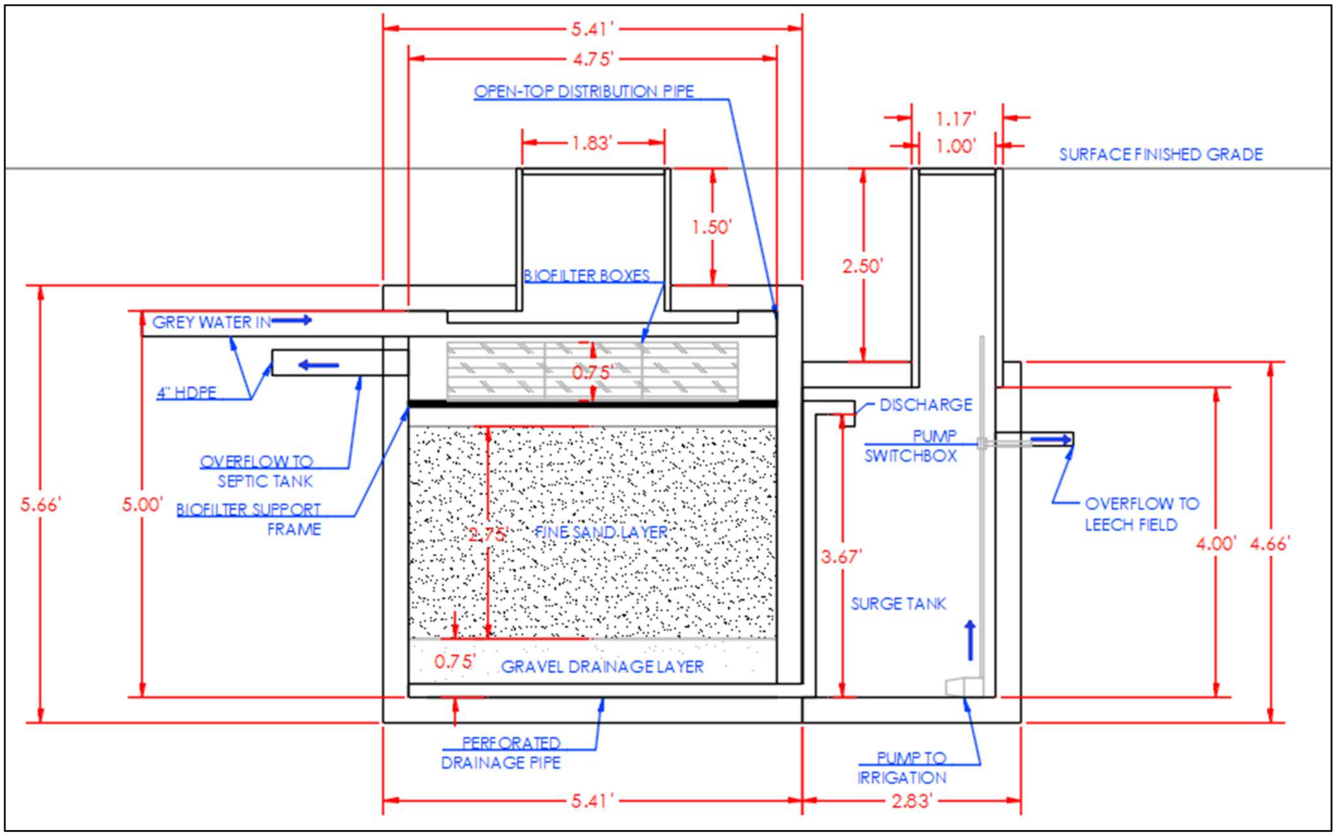


Figure 4-7. Gray Water Filter Cross Section

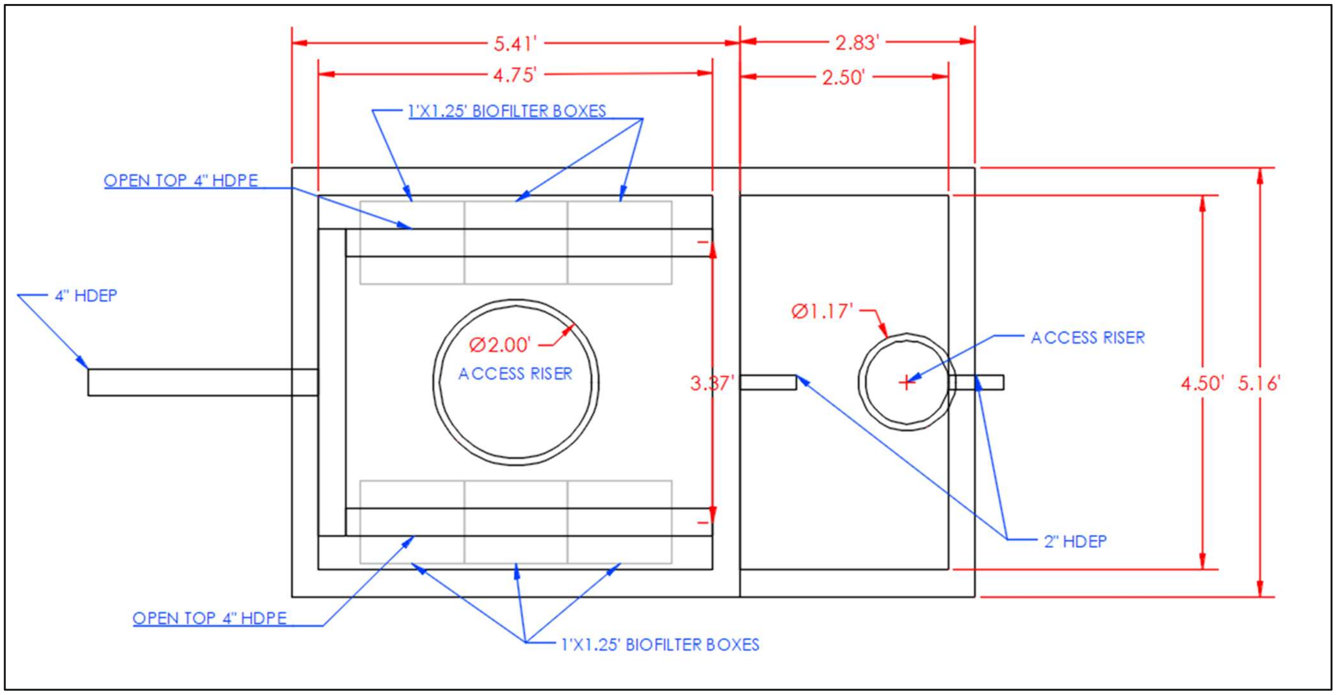


Figure 4-8. Gray Water Filter Top View

4.3.3 Maintenance

Maintenance of this system can be aligned with septic tank inspections, occurring once a year at minimum. Once a year, the biofilter traps need to be cleaned out and replaced with new material [10]. The removed material can be composted or thrown away at the client’s wishes, but handling must include PPE to reduce direct contact with materials.

The boxes holding the material can then easily be refilled with material and slid back into place.

The sand filter will require more heavy-duty maintenance. The sand must be pumped from the tank every 3-5 years to retain the treatment quality of the sand filter as no backwash system is being designed. With this, new sand must be put into the tank. This should be done by a professional and can be done in tandem with the need to pump the septic tank as well.

Additionally, checking the surge tank for sand buildup is necessary. Some sand may make it through the geotextile fabric and gravel layers, ending up discharging from the discharge pipe. It is recommended that at the same time a professional is pumping the sand filter itself, they should also pump the surge tank to keep it clean. This only needs to be done if the surge tank has a considerable level of sand in it.

Finally, the pump will require maintenance. It should be checked to ensure it remains functional and be replaced when not functional. This includes the valve that drains into the leach field when necessary. This must be done to ensure the greywater does not become stagnant and always drains into the leech field once every 24 hours as per 18 AAC 9.

4.4 Sand Filter Filtration

4.4.1 System Process

Intermittent sand filters (ISFs) are used with on-site septic systems to produce a higher quality effluent for direct discharge, leech field discharge, or storage for reuse. An ISF relies on a dosing pipe system to distribute a load of pretreated wastewater from a septic tank into a sand filter bed made up of several layers. The largest layer is a fine material like sand, but other fines, such as anthracite, can also be used. In addition to this layer a small fabric layer and rock layer are positioned above the sand, to aid in filtration through the media. Below the filter media there is a layer of pea gravel with another layer of rocks below. The rocks sit above the perforated PVC pipe that works as the underdrain for the filtered effluent.

The performance of the ISF system is dependent on the following factors, pretreatment quality, media size, media depth, hydraulic loading rate, organic loading rate, and the dosing. Each of these parameters lead to the typical effluent levels of 5 mg/L of BOD and TSS. An ISF can also nitrify 80% of the ammonia applied to the filter. Fecal coliforms are another area where the ISF excels, producing effluent with a reduction of approximately 99% compared to the influent.

4.4.2 System Design

The proposed intermittent sand filter's design is guided by the EPA and will be used with a conventional septic system. The design of the conventional system is shown in Section 4.2 above. The design flow leaving the conventional system is 350 gal/day as required by the inflow rate the septic tank will output into the sand filter. To design the filter bed size, the flow rate and hydraulic loading rate are required. The minimum area required is the quotient of the flow rate and hydraulic loading rate. The hydraulic loading rate is given by the EPA manual in a range, while the design flow has been determined through fixture count. The design of the filter bed should use fine sand between 0.25- and 0.75-mm grains. The standard depth of the filter bed is 24-inches, with other layers of media at smaller depths. Figure 4-9 shows the layer depths for each media.

This filter bed will be sized to be 15-ft by 15-ft, giving an area of approximately 225 square feet. Figure 4-9 shows this sizing. The hydraulic loading rate for this filter will be 2-gal/ft^2/day according to the EPA manual. The organic loading for this system will be a calculated rate between 0.0005- and 0.002-lb/ft^2/day. This filter bed is also designed to handle a range of dosage from the septic tank, at minimum half of the daily flow out of the system will need to reach the ISF with a maximum of 1.5 times the daily flow reaching the ISF. The filter will also be dosed between 12 and 48 times per day using a timed pump located in an intermediate holding tank designed to hold the maximum flow to the filter.

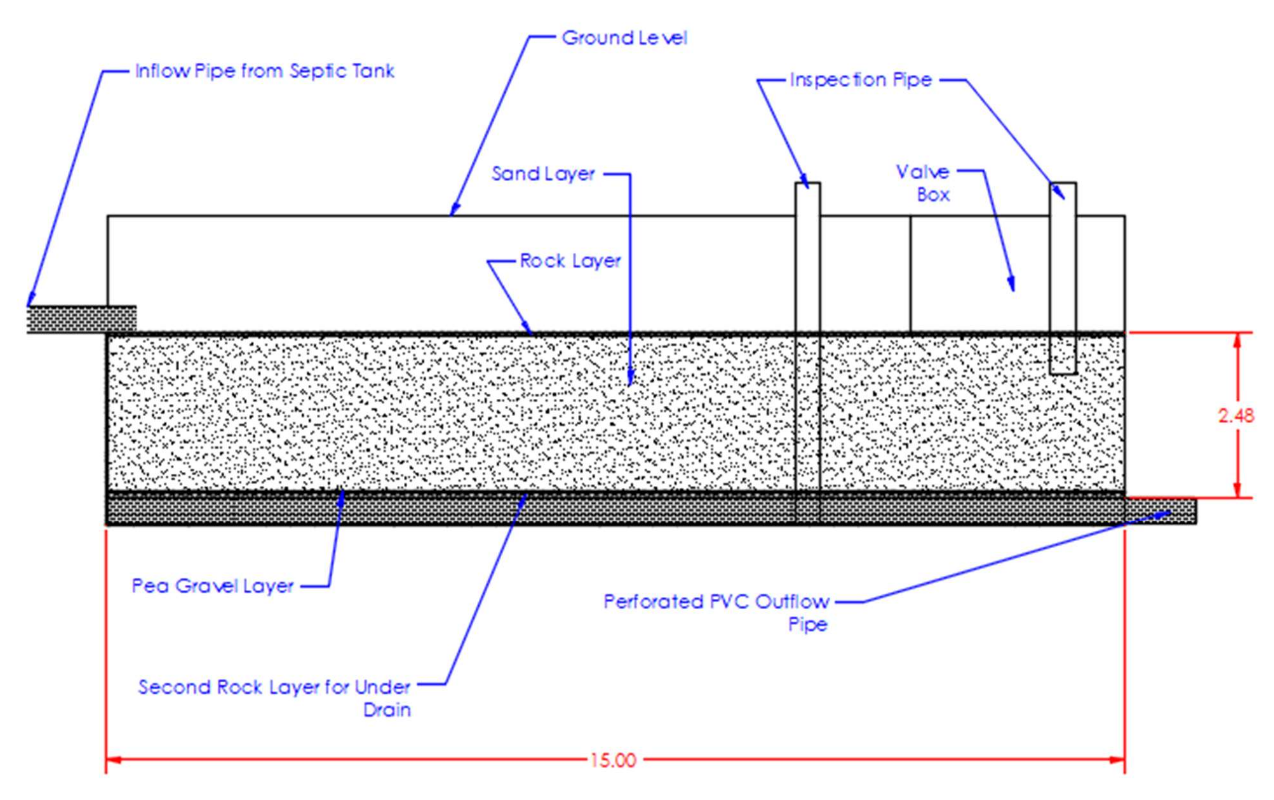


Figure 4-9. Sand Filter System Cross Section

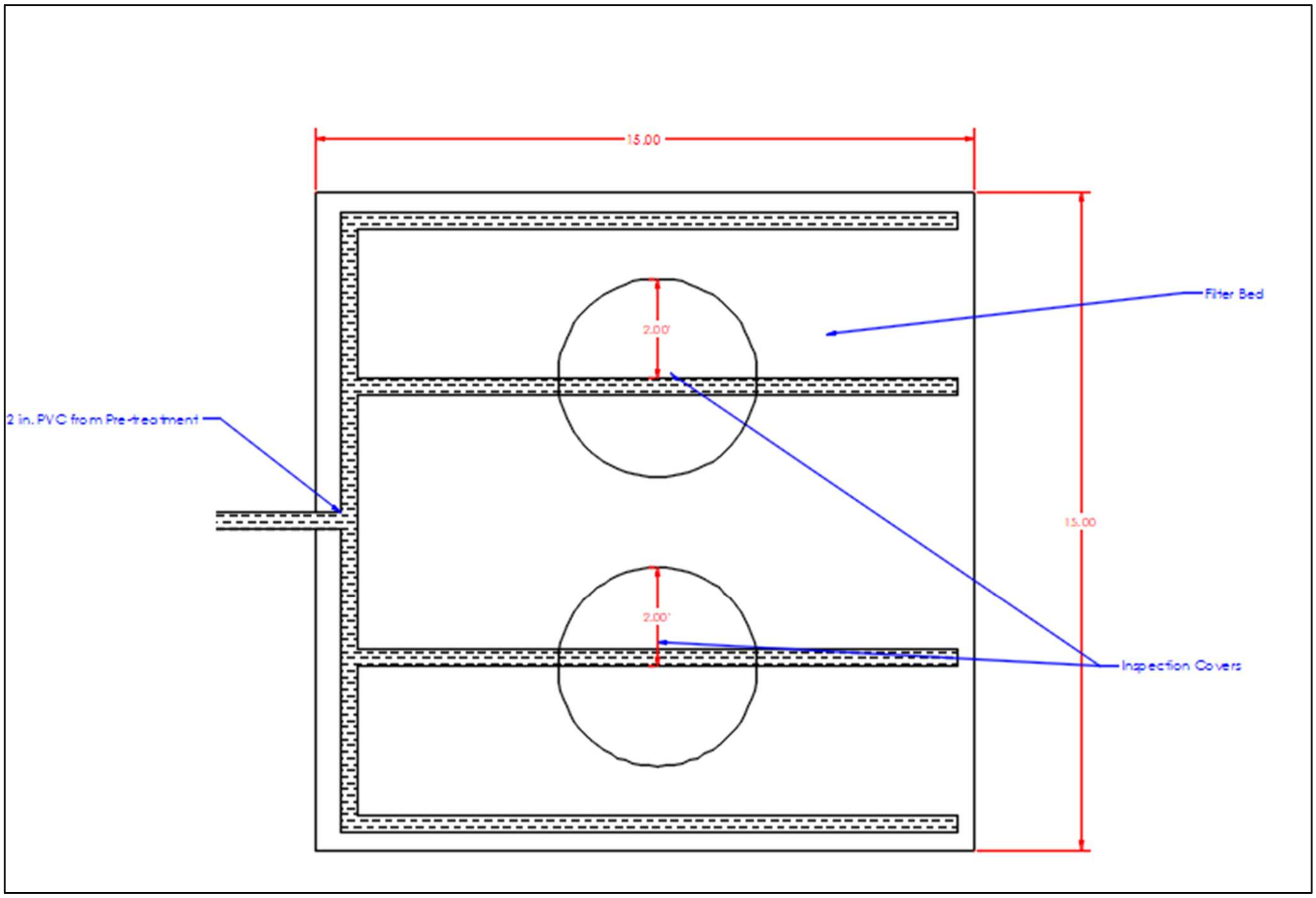


Figure 4-10. Sand Filter System Top View

4.4.3 Maintenance

The system will be designed within an insulated maintenance vault to protect from excessive heat and freezing temperatures. Operation and maintenance are minimal for an ISF, consisting of the following maintenance and inspection operations. Within the insulated vault, there are inspection covers to check the filter bed and underdrain for clogging. The recommended maintenance for the sand filter includes raking the sand media as needed, with replacement of the media every 3-5 years. Inspection of the filter bed and dosing system should be completed every 3-6 months. In addition, the system should be flushed annually.

4.5 Anerobic Wastewater Treatment System

4.5.1 System Process

Unlike the systems outlined above, this system does not require a septic tank, and instead does the entire treatment process alone, with a surge tank to collect the treated water.

This aerobic treatment process takes place in a concrete tank that contains three different chambers in series [11]. The first is the pretreatment or trash chamber. In this chamber, solid materials settle out of suspension of the water, much like a septic tank's first chamber. This prevents the heavier solids from damaging the later stages of treatment.

After the pretreatment chamber, the water is moved into the aeration chamber. Here oxygen is pushed into the water from a diffused air system [10]. Diffused-system, low-pressure blowers force air though small pipes to the bottom of the chamber, adding oxygen to the chamber that helps support the aerobic microorganism growth and obtain the biological load required to treat the water [11]. The microorganisms found in this chamber will digest most nutrients still found in the wastewater, including important items like nitrogen and ammonia.

After the aeration chamber, the wastewater goes into the clarifier chamber. In the clarifier, some solids settle out, and the remaining water flows up toward a disinfection step. Disinfection happens though an ultraviolet (UV) light hitting the wastewater just above the outlet pipe of the system. This process destroys the cells of most remaining organisms by damaging the cellular process within, such as DNA replication, preventing them from growth and multiplication. After disinfection is complete the water is discharged to use for irrigation. With a septic field as an alternative outlet if a failure or excess water was to happen.

Figure 4-11 shows a cross section of this system, and Figure 4-12 shows a top view.

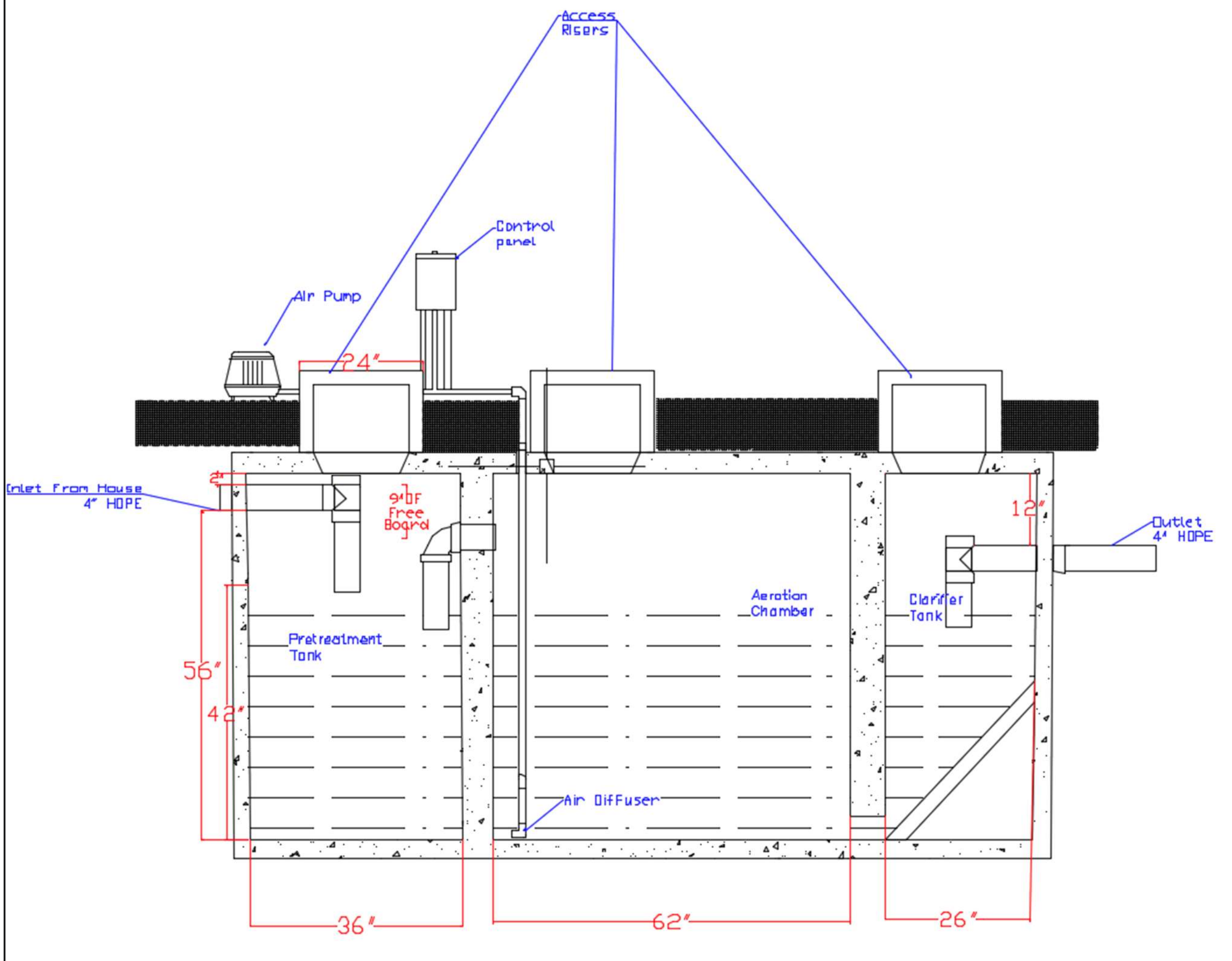


Figure 4-11: Aerobic Wastewater Treatment System Cross Section

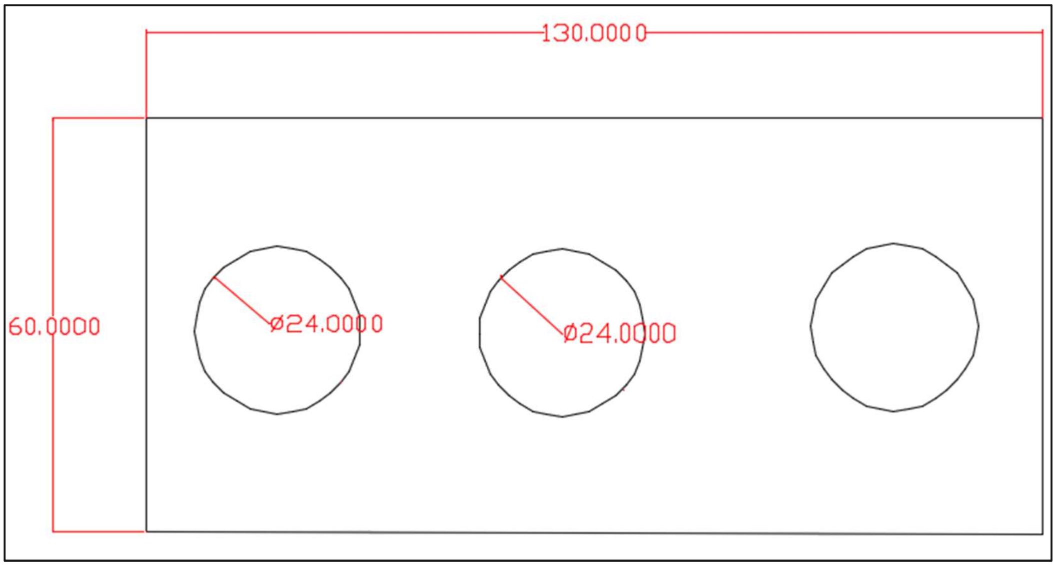


Figure 4-12: Aerobic Wastewater Treatment System Top View

4.5.2 System Design

For the Aerobic treatment system, the Delta Treatment system LLC ENVIRO-AIRE precast concreate tank was used as our model [14]. The tank has a length of 10 ft by 5 ft with three 24-inch manholes to access each tank. In front of the first manhole an air diffuser pump is found and after the first manhole is the control panel. The effluent has a 12 mg/L BOD and 16 mg/L TSS [14].

4.5.3 Maintenance

Maintenance for an aerobic septic system is much more labor intensive than a traditional septic system. For this system, the pretreatment and aerobic chambers will have to have the solid waste pumped out by a septic pumping company once a year. Maintenance is also required to upkeep the diffusion system and the UV disinfection system. To upkeep the air diffusion system the owner must check for inadequate air pressure and clogged diffuser. If problems are found, they must either replace the system's aerator or clean the diffuser. To maintain the UV disinfection system the owners of the system need to check that power is always working to power the UV unit and that the light lamp is changed when the lamp burns out.

5.0 Final Design Recommendations

With the above alternatives thoroughly explored, they were put through a decision matrix to decide upon a final recommendation.

5.1 Design Decision Matrix

The decision matrix includes five major criteria for the final design: Cost of Installation, Cost of Maintenance, Maintenance Requirements, Treatment Quality, and Ease of Use.

Cost of Installation is a major upfront that the client would likely wish to keep as low as possible. With the constraint of a $35,000 budget, the system must do its best to remain below this amount. For the intents of this analysis, only the cost of the physical system itself has been examined, as installation cost will likely be similar enough across systems to not warrant an in-depth analysis for this project. This is given a weight of 2.

Cost of Maintenance is a more long-term effect the client will feel with using the system. The more it costs to run the system, the less likely the client will be happy in the long term. Analysis here is focused on materials and required items it will cost to keep the system running and does not include major items such as a randomly malfunctioning part unless said part malfunctions when expected to need replacement (EX: a pump rated to run for 5 years will be looked at, a randomly broken one will not). This is given a weight of 3.

Maintenance Requirements focuses on the physical work needed to be performed by either hired professionals or the clients themselves to keep the system running. Replacement of filter materials is an example of this, as well as required pumping. This is given a weight of 3.

Treatment Quality focuses exclusively on the output water of the system, and how it may be able to complete Objective 2. Higher quality water will rate higher, but simple achievement of the required goals will still rate higher than non-attainment of this objective. This is given a weight of 5.

Ease of Use is focused on client interaction with the system and requires work the client may have to put in daily to ensure the system runs properly. The less the client needs to concern themselves with the system, the higher it is rated. This is given a weight of 2.

Using the above guidelines, a series of pros and cons were made to examine each of the systems. The breakdown of these can be found in the table below. These pros and cons were compared to a scoring system rated from 0-10. Most scores ranged from 1-10, however, as a score of 0 represents a complete failure of the objective. This was mainly saved for the septic tank, to represent that it has no treatment for the desired irrigation water.

The Standard Septic system was designed mainly as a basis for the other systems, but due to its simplicity and ease of use for the client, it was possible it could become a major alternative. At a typical cost of $4,500, the installation cost is low, and maintenance cost is low due to the fact it only really needs to be pumped every few years, a cost of about $400. This was given a cost of installation score of 10 and a cost of maintenance score of 10, as it was the cheapest of the options. Maintenance cost is low due to the few maintenance steps needed, as this system only needs to be pumped every 3 years and gives it a score of 10. Finally, the client need only concern themselves with the system whenever it needs pumping or inspections, giving it also a score of 10. However, the alternative fails the major Objective of providing irrigation-level treated water, and thus a score of 0.

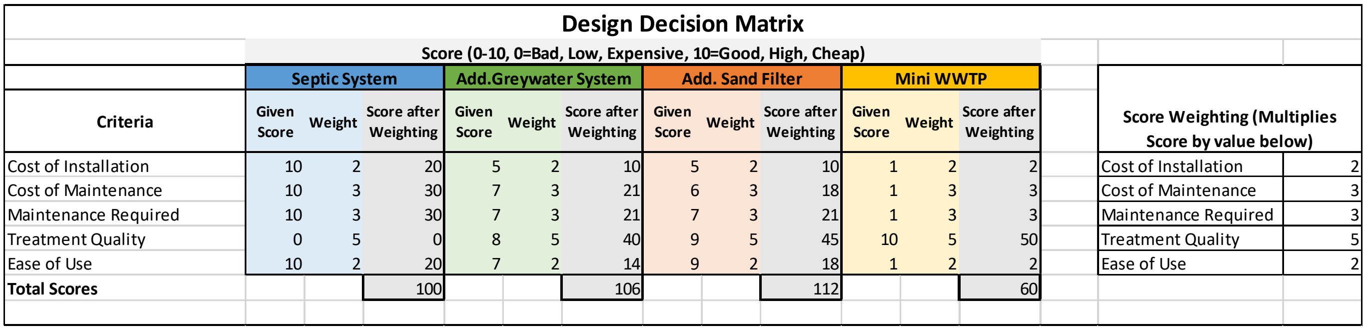
The Gray Water system uses the septic tank to function, meaning that since the standard cost of a Gray Water system is $3,500, this brings the total to $9,000. A rating weight was created between the cost extremes of the Septic Tank and Anerobic wastewater treatment system based on the system's price, which resulted in a score of 6. Additionally, the system provides useful water to the client, but does require more maintenance due to the biofilter boxes. It must also be pumped like the septic tank around the same timing, meaning its total cost sits around $9,000 for installation and $800 every few years for pumping, a rating that has kept the systems cost of maintenance and maintenance required scores closer to the Septic Tank scores of 7 for each. The client must also be willing to clean out the biofilter boxes, and while this is cheap, it is an extra step in maintenance for the client, giving it a slightly lower rating in Ease of Use of 7 as well. This system also requires all of the house pipes to be segregated into black and gray water, which is an additional upfront cost not currently calculated, but was decided to reduce the Cost of Installation score to 5 instead of 6 as listed above. It provides a reasonable treatment quality for the water, achieving the requirements for Gray Water. However, since it does not capture all of the possible water like that lost in the black water system, it was scored lower than the sand filter's treatment effluent, a score 8.

The Sand Filter system sits after the septic tank, again making it a tacked-on cost. However, the installation of a full Septic with sand filter system usually costs around $1,800, giving it a Cost of Installation score of 5 like the Gray Water system. It requires similar maintenance to the Gray Water system, requiring pumping every few years, but in larger volumes, which was decided to make the Cost of Maintenance score one lower than the Gray Water system at 6. However, due to it being easier to use and requiring less maintenance by the client, it got a higher score of 9 in Ease of Use. It also has a reasonably high treatment quality, 5mg/L of BOD and TSS, which was able to attain the reclaimed water standards, but not as high for all measures as the Aerobic wastewater treatment system, giving it a score of 9.

The Mini WWTP treatment system is the most expensive and most daunting to care for by the clients. Its installation cost is high, $18,000 since this system includes UV disinfection, giving it a cost of installation score of 1. To add to that, client interaction with the system is high, as they must monitor the flow rates, treatment levels, oxygen levels, and overall keep a close eye on the system to maintain treatment, meaning that Ease of Use is a score of 1. Replacement parts for items such as UV systems are also very high, and it still needs to have the first chamber pumped every few years like the other systems. This in tandem with the fact that any professionals who attempt to repair the system will require a higher level of knowledge to properly make repairs or maintenance it will decrease both the Maintenance required and Cost of Maintenance scores to 1. It does receive top marks, however, for achieving some of the highest treatment levels for the effluent, bringing nearly all criteria down below Reclaimed A or A+ water, being given the only score of 10 for treatment quality.

The scores explained above have been compiled into the decision matrix in Table 5-1. The scores were compared to the listed score weights, and finally added together for final scores. As can be seen, the distribution favored the middle ground options. The aerobic wastewater treatment plant was the lowest scoring option since it was so expensive and maintenance intensive. The Septic Tank was reasonably close to the two middle-ground options; however, its complete failure of the treatment objective ensured it was never truly an option for Objective 2. The middle options of the Gray Water and Sand Filter were close in scores, but due to ease of use and treatment quality, the chosen system became the Sand Filter.

Table 5-1. Design Decision Matrix



Design Decision Matrix

	Score (0-10, 0=Bad, Low, Expensive, 10=Good, High, Cheap)											
	Septic System			**Add.Greywater System**			**Add. Sand Filter**			**Mini WWTP**		
Criteria	**Given Score**	**Weight**	**Score after Weighting**	**Given Score**	**Weight**	**Score after Weighting**	**Given Score**	**Weight**	**Score after Weighting**	**Given Score**	**Weight**	**Score after Weighting**
Cost of Installation	10	2	20	5	2	10	5	2	10	1	2	2
Cost of Maintenance	10	3	30	7	3	21	6	3	18	1	3	3
Maintenance Required	10	3	30	7	3	21	7	3	21	1	3	3
Treatment Quality	0	5	0	8	5	40	9	5	45	10	5	50
Ease of Use	10	2	20	7	2	14	9	2	18	1	2	2
Total Scores			100			106			112			60

Score Weighting (Multiplies Score by value below)	
Cost of Installation	2
Cost of Maintenance	3
Maintenance Required	3
Treatment Quality	5
Ease of Use	2

5.2 Final Design Recommendation

Based on the results of the design matrix above, the design moving forward will be of a Sand Filter in series with a Standard Septic tank. This will accomplish both Objectives while remaining the easiest system to use for the desired treatment levels.

5.2.1 System Overview

This system contains 4 major components, which will all be explained in more detail in the following sections. These components are the septic tank, the sand filter, the surge tank, and the leach field. The following diagram will help outline this process.

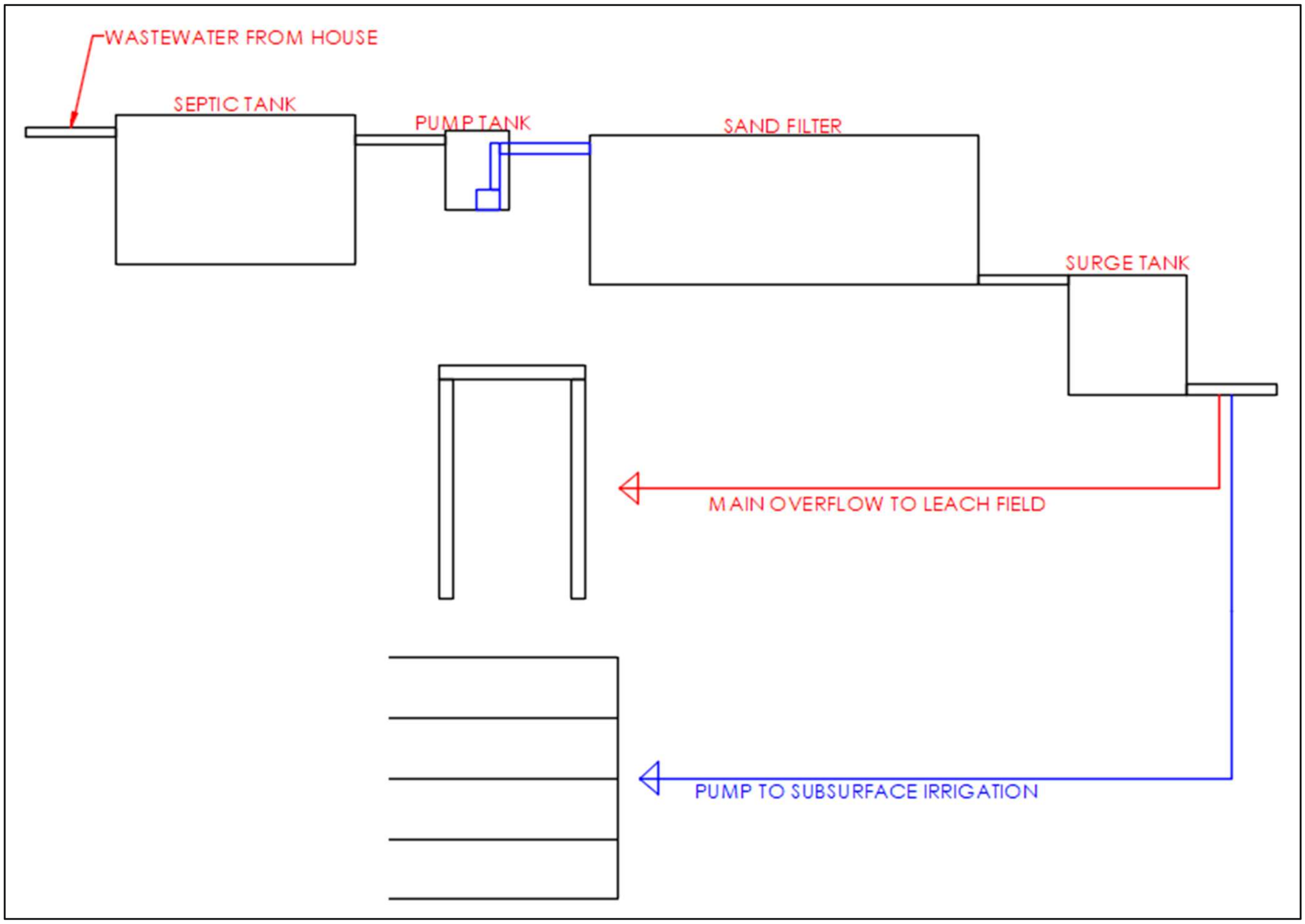


Figure 5-1. Sand Filter Full System Diagram

Water flows from the residence to the septic tank, where it is initially treated, and solids are left behind. This water overflows the outlet pipe and into a pump tank, which will control the water input into the sand filter. The pump tank pressurizes the water to flow into the distribution system located within the sand filter. Water then infiltrates through the sand filter and out through the drainage system on the bottom of the sand layer. This treated water is collected by the surge tank, where it will either be discharged into a subsurface irrigation water line by the pump or drain into the leach field via gravity.

5.2.2 Septic Tank

The septic tank is the first step in treating this wastewater for reuse and for disposal. At its most basic form a septic tank is essentially a catch-all for all wastewater which drains from a dwelling unit; in the case of this design project – a single family home. The tank will be buried close to the house for the least amount of energy loss throughout the system. The tank will be underground and watertight to prevent any sort of leaching into the soil. The tank's main purpose is to be able to collect wastewater from the dwelling to store and start to settle some of the solids.

A septic tank is no new technology when it comes to the field of environmental engineering, and at its core it is very simple. The tank has one baffle wall in the inside creating two chambers within the tank. This is to diffuse the flow from the house to the inside of the tank. When the flow is fed into the tank the increase in energy could potentially cause turbidity within the volume of the tank, stirring the solids around. The baffle wall also prevents any scum that has risen to the top or solids that have settles from escaping the tank into further parts of the system, potentially requiring additional maintenance to be done on the system.

Regular maintenance is required for a septic tank because of the fats, oils, and greases that rise to the top of the liquid level, hence the two access ports from the ground level for each of the two chambers. This maintenance is detailed in the O & M manual but should be completed every 3-5 years, which includes pumping out all the scum that forms at the top and solids that have settled. If this pumping and regular attention is not performed to a tank, then that will undoubtably decrease the life of the tank.

Although maintenance is inevitable, excessive maintenance can be avoided in a variety of ways. This includes avoiding flushing dangerous items like wipes, condoms, medications, etc. down the toilet with the garbage. As excessive amounts of nutrient-poor water tend to flush out the septic tank and lower its treatment quality, necessitating the need for supplements, it also entails restricting the usage of extreme dumping down into the septic tank.

Many septic tanks come off the shelf but for the purpose of this project a septic tank was designed and drafted. The main parameters to design around are detailed in AZDEQ Title 18 [16.]. The tank is designed to be 1000 gallons, the only thing that affects the required volume of the tank is the number of fixtures. When regarding volume, the following are the main factors considered: the intake compartment must not exceed 67 to 75 percent of the tank's total capacity; nevertheless, the compartment as desired holds a capacity of around 68 percent, which is within the acceptable range, while staying cost effective.

18 AAC 9 specifies that a 1000-gallon tank must have a minimum length of 8 feet and a width that is between 33-50% of the length. Additionally, each of the two chambers that are reachable from the ground level must have an aperture with a minimum diameter of 20 inches. A second opening over the baffle wall must be provided if a compartment is longer than 12 feet. With at least 9 inches of open space above the liquid level, the tank's liquid depth must accommodate a maximum liquid level depth of 42 inches.

At least 2 inches must separate the tank's cover from the top of the inlet fitting. There are several geotechnical and mechanical factors with load support; these have not yet been considered in the tank's design process, but they should be done by other parties. You can find all these parameters in Title 18 of AAC.

These main regulations and design standards are what drove the final design found in this report. The other consideration when designing the tank was monetary restrictions applied by the clients.

5.2.3 Sand Filter

The chosen alternative for secondary treatment to bring this domestic wastewater up to AZDEQ and Yavapai County standards for irrigation reuse is an intermittent sand filter. Once again, while an "off the shelf" option is available, to fit the client's needs better ABCC has designed and drafted an ISF.

To design the ISF the EPA manual was followed. The chosen design consists of a top layer of rocks, the filter media made up of sand, a layer of pea gravel, and a final layer of rock over the underdrain. The proposed filter is a pressure dosed system and will require an intermediate pump tank between the initial septic tank and the ISF to release the proper flow throughout the dosing schedule. This pump tank will be cylindrical and have a capacity of 525 gallons as the ISF is designed to handle 1.5 times the daily flow out of the septic tank. The dimensions of the tank are 60" in diameter and 48" in height; And will contain a submersible pump able to accommodate the ISF dosing system's needs.

The ISF will be dosed every 2 hours for 12 doses per day. The approximate volume per dose is 30 gallons delivered to the ISF through perforated 2" PVC with 98 orifices over the filter bed. The table below shows the dosing design values.

Table 5-2. Dosing design and calculation

Dosing		
Design Flow	350	gal/day
Dosing Tank Volume FOS	1.5	flow/day
Dosing Tank Volume	525	gal
Doses/day	12	doses/day
Volume/Dose	29.2	gal/dose
Orifices	97.2	Orifices

The filter has been designed according to three parameters, the hydraulic loading rate, the design flow, and the organic loading rate. The hydraulic loading rate is a chosen value in a range provided by the EPA in the manual, the design flow was also provided from the fixture count as discussed earlier. The base area required for the ISF is based on the design flow divided by the hydraulic loading rate, but this filter area needed to be adjusted for the organic loading rate. An assumed typical organic load from a 2-compartment septic tank was taken as 158 mg/L BOD. This was converted into lb/day using the flow rate, and finally the organic loading rate was determined by dividing the organic load by the area. The organic loading rate was too high for the base area determined earlier and was iterated until the loading rate was within the proper range. The values for the filter design can be found in the table below.

Table 5-3. ISF Design Parameters

ISF Design		
Ideal Design Flow	350	gal/day
Hydraulic loading rate	2	gal/ft^2/day
Surface area of Filter Bed	225	ft^2
Height of bed	2.48	ft
Width of Bed	15	ft
Length of Bed	15	ft
Typical Effluent BOD5	158	mg/l
Typical Effluent BOD5	0.00132	lb./gal
Organic Load	0.46160	lb. BOD$_5$/day
Organic Loading Rate	0.00205	lb. BOD$_5$/ft^2/day

The treated water is then collected in the underdrain and flows into the final surge tank. This water is treated to a standard that allows for reuse as irrigation. The treatment values can be found in Table 5-4 below.

Table 5-4. Sand Filter Comparison of Treatment Levels to 18 AAC 9

Comparison of Treatment					
	County Requirements		**Sand Filter**		Attain?
BOD_5	30	mg/L (30 day)	3	mg/L (30 day)	Yes
or	45	mg/L (week)		mg/L (week)	
$CBOD_5$	25	mg/L (30 day)	2.17	mg/L (30 day)	Yes
or	40	mg/L (week)		mg/L (week)	
TSS	30	mg/L (30 day)	16.2	mg/L (30 day)	Yes
or	45	mg/L (week)		mg/L (week)	
pH	6-9				
Removal Efficiency	85%	BOD5, CBOD5, TSS	93%	BOD_5, $CBOD_5$, TSS	Yes
Nitrogen	<10	mg/L (5-month rolling geoetric mean)	5.9	mg/L (5-month rolling geometric mean)	Yes
Fecal Coliforms					
Daily Tests	200	cfu/100mL	72.8	cfu/100mL	Yes
Daily E. Coli	126	cfu/100mL		cfu/100mL	
Single Max	800	cfu/100mL		cfu/100mL	
Single Max E. Coli	504	cfu/100mL		cfu/100mL	

5.2.4 Surge Tank

The surge tank captures the treated effluent from the sand filter and stores it for use as irrigation water. This is done through a simple inlet that flows into the tank near the top.

The tank itself is a simple, off-the-shelf 350-gallon water tank [13]. This tank is 46" in diameter by 50" tall and cylindrical, and it includes joints for 2" pipe connections, one at the top and one at the bottom. It also has a 16" hatch on top, which will be modified to 2' to keep consistency across the entire system for access ports. This surge tank can be seen in Figure 5-2.

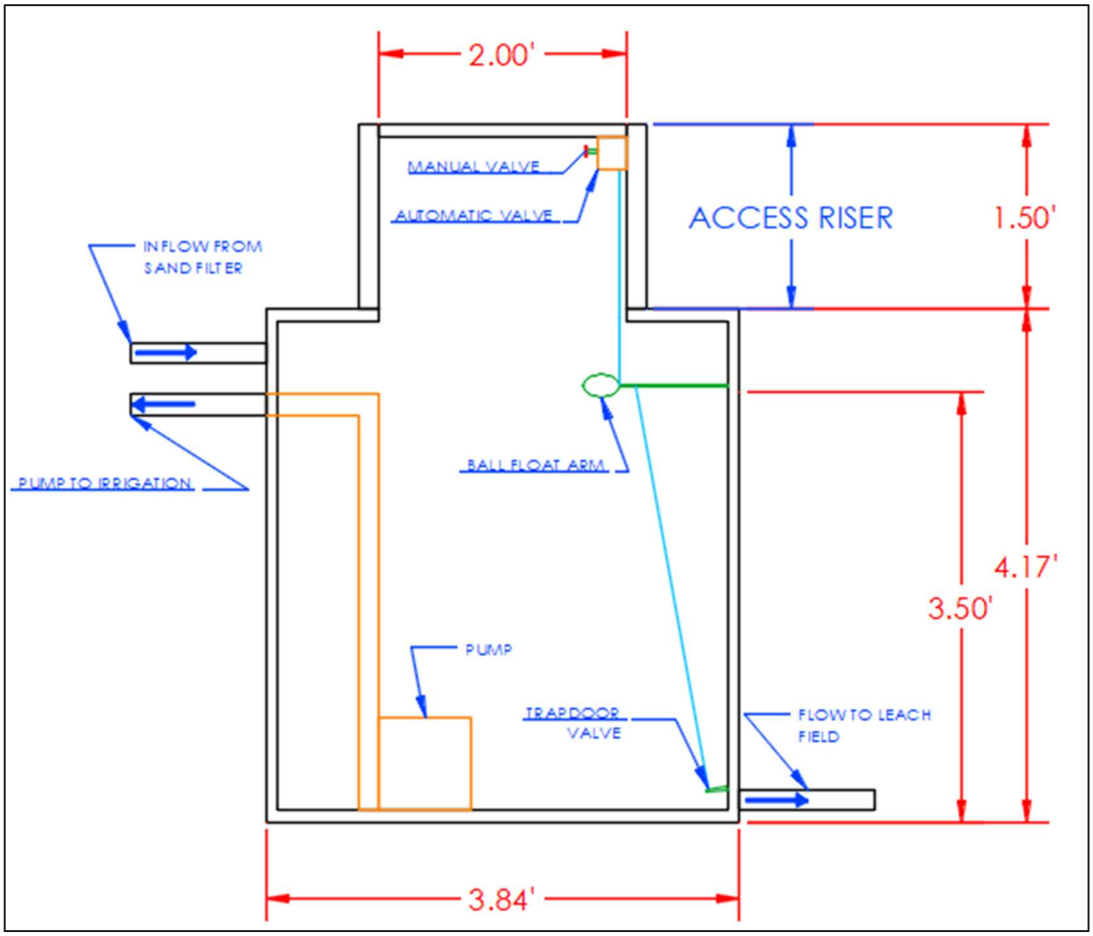


Figure 5-2. Surge Tank

The tank must have several control devices installed. The main outflow of the tank will be controlled by a simple trapdoor valve, which is lifted to allow flow to exit the tank and released back down to stop flow to the leach field. This acts very similarly to the trapdoor valve within a toilet, but instead it doesn't float until the tank is completely full and closes as soon as it is allowed to.

This trapdoor valve is connected to a chain that attaches to a float arm near the top of the tank. This float arm is located 42" above the bottom of the tank to provide the 300-gallon volume. When the water rises to raise this float to its perpendicular position at 42", the trapdoor valve is lifted and allows the excess flow to drain out, thus keeping the tank from overflowing or backflowing into the sand filter.

This float arm is also attached to another chain that goes up near the access hatch. It is attached to a small motor, which the pump controller has access to automatically use. At certain points or after certain actions, the controller will instruct this motor to pull the float arm up, and thus the trapdoor valve will open. This process is done to ensure the tank never has water sit long enough to become septic since no disinfection stage is being used.

The following equation and table outline the process to calculate the time for the tank to drain. It was made using the integrated function below, and assuming a cylindrical tank and cylindrical orifice/outlet [14].

Equation 5-1. Drainage Time Equation [16]

$$t = \frac{A}{aC} * \left(\sqrt{H1} - \sqrt{H0}\right) * \sqrt{\frac{2}{g}}$$

Where t equals the time to drain
A is the area of the tank
a is the area of the outlet pipe
C is the coefficient of discharge for the orifice
H is the height of the water
g is gravity

Table 5-5. Surge Tank Drain Calculations [16]

Tank Draining		
Tank Diameter	46	in
Float Height	42	in
Area of Tank	1662	In^3
Max Volume	302	gallons
Inflow	350	gal/day
Outlet Diameter	2	in
Outlet Area	3.141	In^2
Outlet Discharge Coefficient	0.8	
Gravity	32	ft/s^2
Time to Discharge	309	seconds
	5.15	minutes

It takes 5.15 minutes for the full 300 gallons of the water tank to drain through its 2” outlet to the leach field. Thus, the pump controller will have the chain be lifted for 6 minutes to fully drain the tank before releasing it to its original position.

This automatic draining will occur at two specific instances. The first is directly after an irrigation event. The pump controller will allow the system to deliver a specified amount of water based on the user’s input. This may be manually done, or it may be automatic having been given an irrigation area. Whichever is used, the remaining water not used for irrigation will drain to the leach field via this automatic draining.

The second instance for automatic draining will occur once every 24 hours unless an irrigation drain has been performed that day already. In following similar codes for gray water that say to never let the water sit for more than 24 hours, this system will ensure the water does not become septic. Every day at a user specified hour, the system will perform the same automatic draining if required due to lack of irrigation drain. It is suggested this is done around noon, so that water sources such as afternoon laundry and night showers can be collected for use by the system.

If the system detects that an automatic 24-hour drain needs to occur, it will assume that the flows need to be controlled to not overpower the leach field. Thus, over the course of this hour, it will open for 1.5 minutes every 15 minutes over that hour to reduce the immediate water load to the leach field. The irrigation draining will not need to do this as the amount of water should be highly reduced from irrigation and thus not a major issue.

This system is not a “Smart” system, meaning it will not know how full the tank is at any point and thus how much water can be delivered before the irrigation is performed. Once water is reduced to a water level of 5”, the pump will shut off, as this will protect the submersible pump from damage of running with no water around it. If this is not enough water that the pump controller intends to output, it should be programmed to notify the user of the difference in delivered vs requested water. It is then on the user to supplement the remaining water with normal potable water for the plants via surface application as needed. An automatic draining will then be performed with the submersible pump fully turned off.

5.2.5 Leach Field

The leach field has been designed using the same AAC standards as is required for a standard septic tank. In doing so, the field will act both as the standard discharge for the sand filter/septic system and as overflow for whenever the treated water is not used, and the surge tank empties.

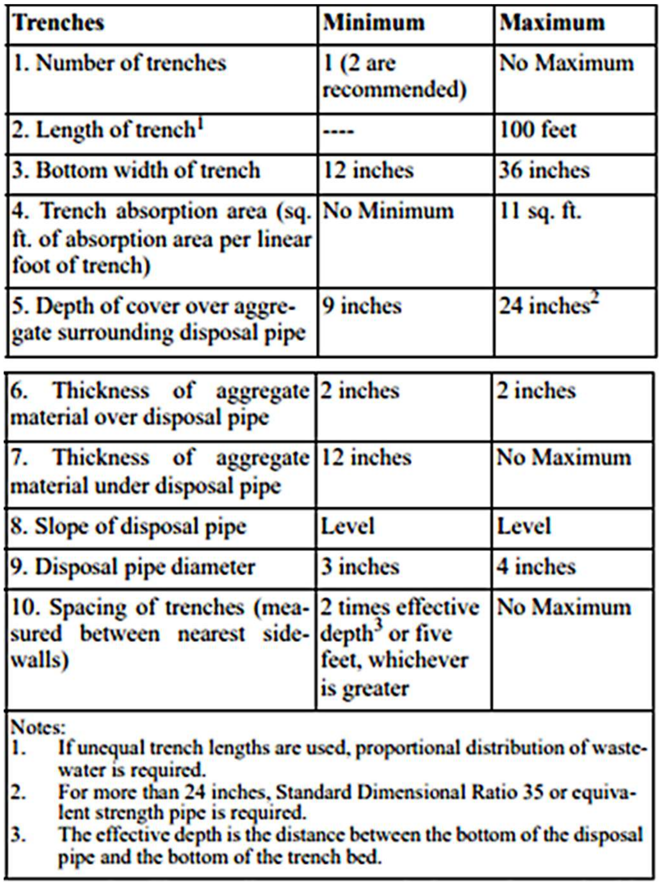
A fixture count and required Soil Absorption Rate was found under 18 AAC 9. Calculations for such can be found below, ultimately giving out a required flow rate and size of the leach field.

Table 5-6. Leach Field Sizing

Soil Adsorption Rate		
Gravelly sandy clay loam		
SAR		
Trench, Chamber, Pit	0.2	gal/day/Ft^2
Bed	0.13	gal/day/Ft^2
Design Area Size		
Design Flow	350	gal/day
Design Area (Trench)	1750	Ft^2
Design Area (Bed)	2692.3	Ft^2
Square Side Length (Trench)	41.8	ft
Square Side Length (Bed)	51.9	ft

In accordance with 18 AAC 9, the following table sums up nearly all requirements that the leach field must attain.

Table 5-7. Trench Design Table from 18 AAC 9



Trenches	Minimum	Maximum
1. Number of trenches	1 (2 are recommended)	No Maximum
2. Length of trench[1]	----	100 feet
3. Bottom width of trench	12 inches	36 inches
4. Trench absorption area (sq. ft. of absorption area per linear foot of trench)	No Minimum	11 sq. ft.
5. Depth of cover over aggregate surrounding disposal pipe	9 inches	24 inches[2]
6. Thickness of aggregate material over disposal pipe	2 inches	2 inches
7. Thickness of aggregate material under disposal pipe	12 inches	No Maximum
8. Slope of disposal pipe	Level	Level
9. Disposal pipe diameter	3 inches	4 inches
10. Spacing of trenches (measured between nearest sidewalls)	2 times effective depth[3] or five feet, whichever is greater	No Maximum

Notes:
1. If unequal trench lengths are used, proportional distribution of wastewater is required.
2. For more than 24 inches, Standard Dimensional Ratio 35 or equivalent strength pipe is required.
3. The effective depth is the distance between the bottom of the disposal pipe and the bottom of the trench bed.

The leach field was calculated to have a required absorption area of 583.3 ft^2, which was found by multiplying the design flow by the 0.6 Trench Soil Absorption Rate of Table 5-3. This is spread out over the surface area of the aggregate surrounding each of the distribution pipes.

Two pipes distribute the water load. Each pipe is 40ft long, with 2.5ft of aggregate below it, and a bottom width of 34ft, making 8ft^2 per 1 foot of pipe length in absorption area. This totals 688 ft^2 of adsorption area when including a 1.5ft edge around each of the ends of the distribution pipes. 5 ft of space exists between the edge of each aggregate section. The following table outlines the minimum requirements and the final chosen design amounts,

Table 5-8. Leach Field Design Parameters

Leach Field Design Parameters		
Feet Between pipes	5.0	ft
Number of Distributor Pipes	2.0	
Adsorption Area per foot	8.0	Ft^2
Aggregate Under Thickness	2.5	ft
Bottom Width	3.0	ft
Design Area	583.3	Ft^2
Total Pipe Length	72.9	ft
Pipe Length	36.5	ft
Chosen Length	40.0	ft
Endcaps Area (All 10)	48.0	Ft^2
Area per trench	320.0	Ft^2
Total Area, No Endcaps	640.0	Ft^2
Total Area	688.0	Ft^2
Volume of Aggregate	784.8	Ft^2

Figure 5-3 is a drawing of the pipe arrangement.

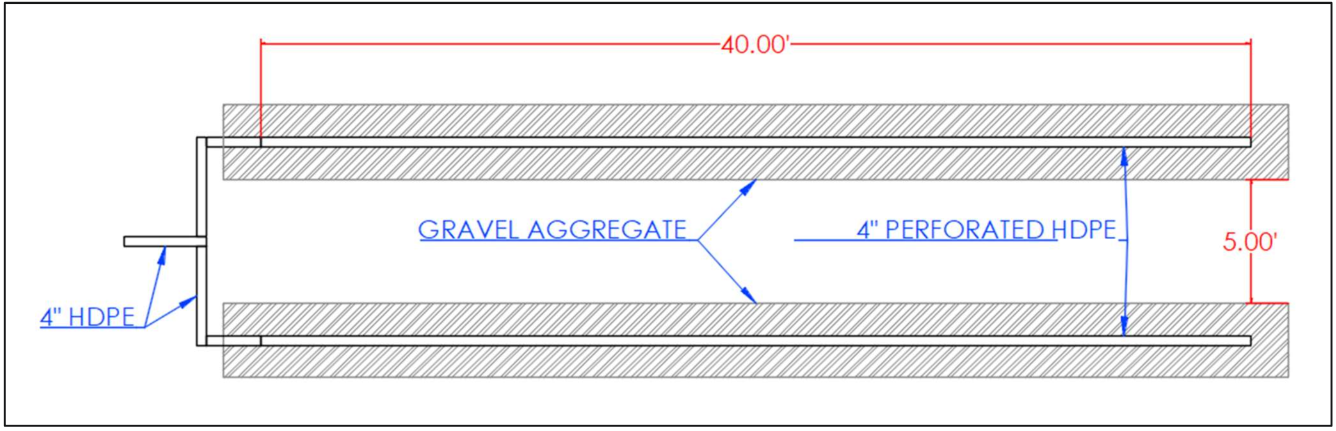


Figure 5-3. Leach Field Top View

The distributor system that allows the flow to enter these pipes is relatively simple, as it only needs to divide flow to two separate pipes. A simple T-junction fulfills this need. The distances required for the distributor pipes can be found in Figure 5-4.

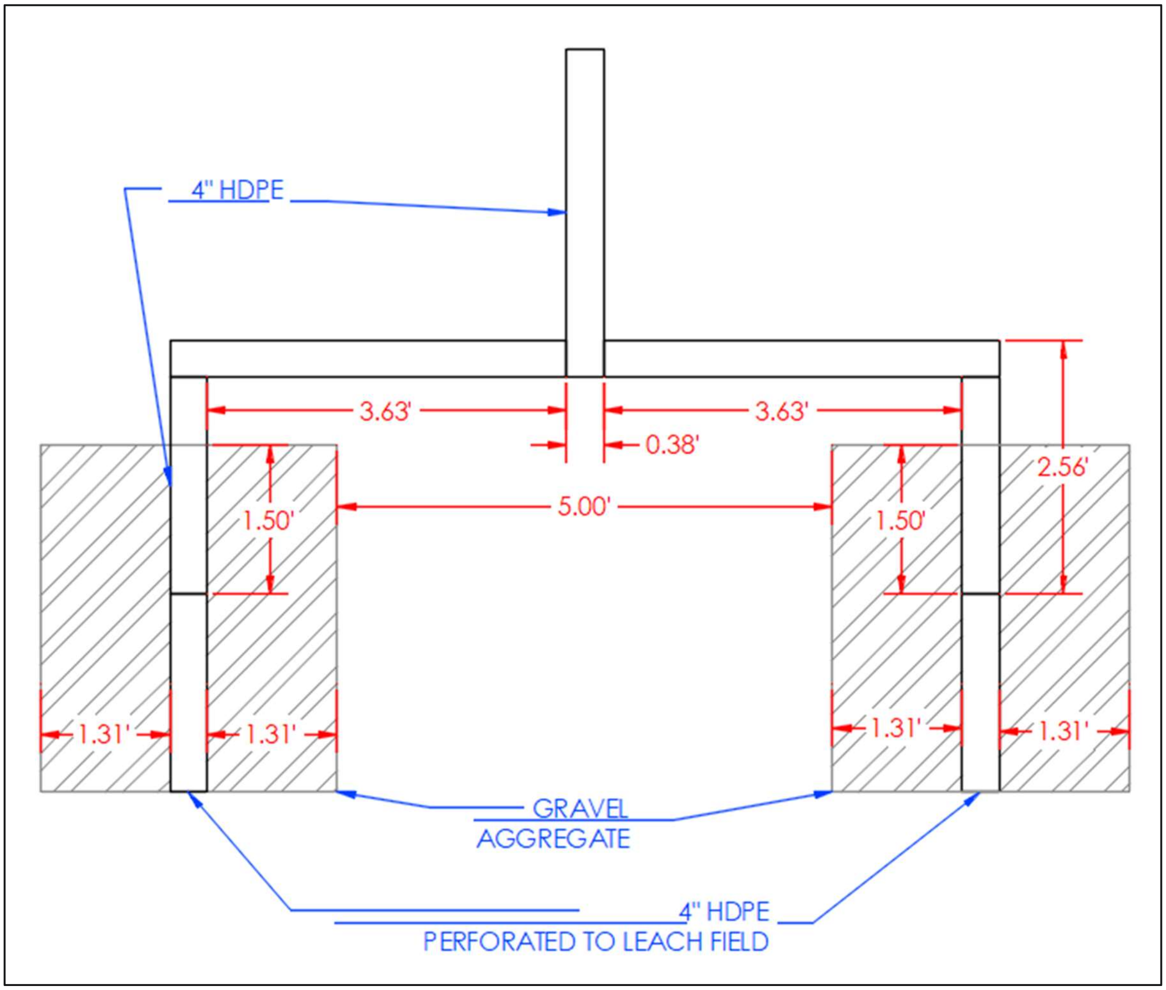


Figure 5-4. Distribution System Top View

The amount of aggregate placed around the distributor pipes is very important and closely controlled by 18 AAC 9 as can be seen in Table 5-5. Figure 5-5 shows the amounts of aggregate that must be around the pipe. The cross section shown is uniform along the entire length of the pipe, however the bury depth may change, but will never be less than 1.5 ft. The total aggregate needed is 785 ft^3. This will be filled using drain gravel that is 1.5 inches in diameter.

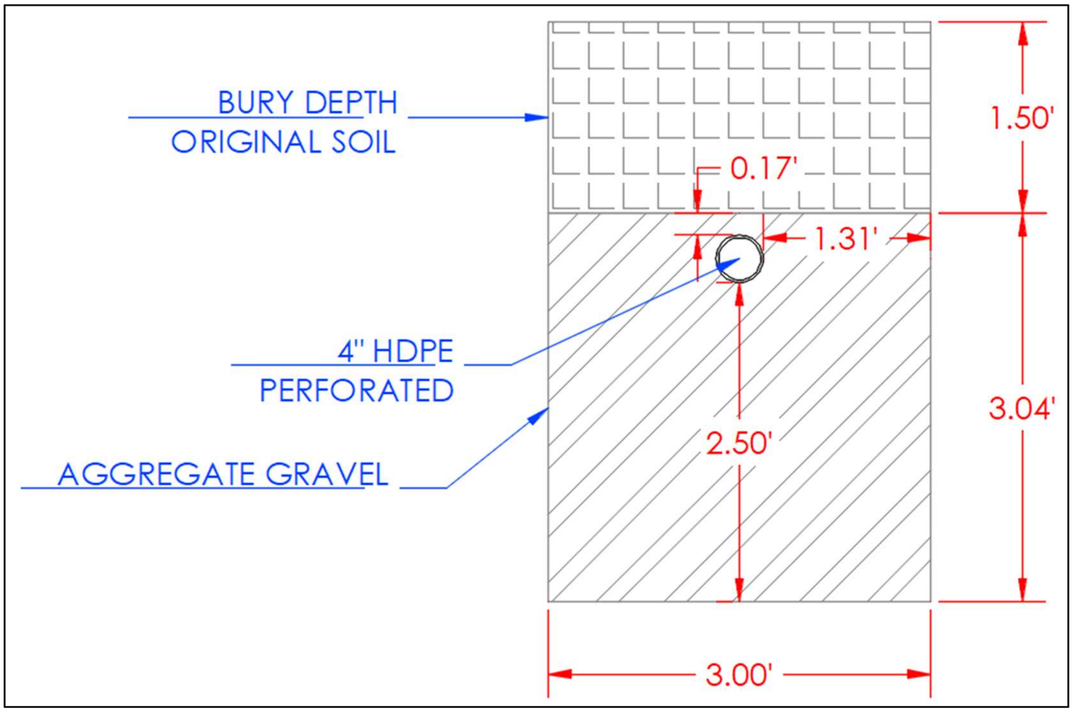


Figure 5-5. Leach Field Pipe Aggregate Amounts

5.2.6 Final Plan Set

A final plan set has been made that incorporates the final design files in both separated drawings and as a complete system.

The plan set also shows the planned location of the system to be installed, as seen in Figure 5-6 below.

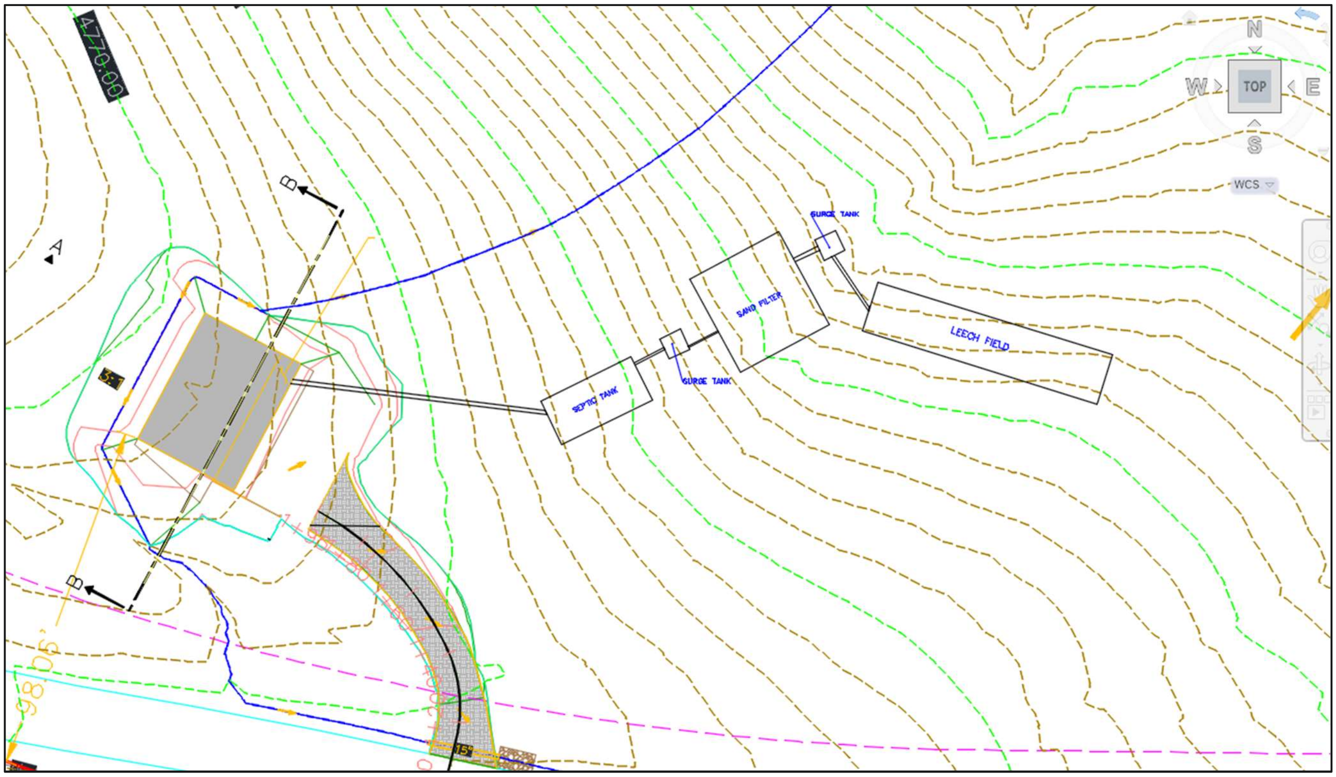


Figure 5-6. System Layout

Figure 5-7 shows the system in regards to the entire plot of land.

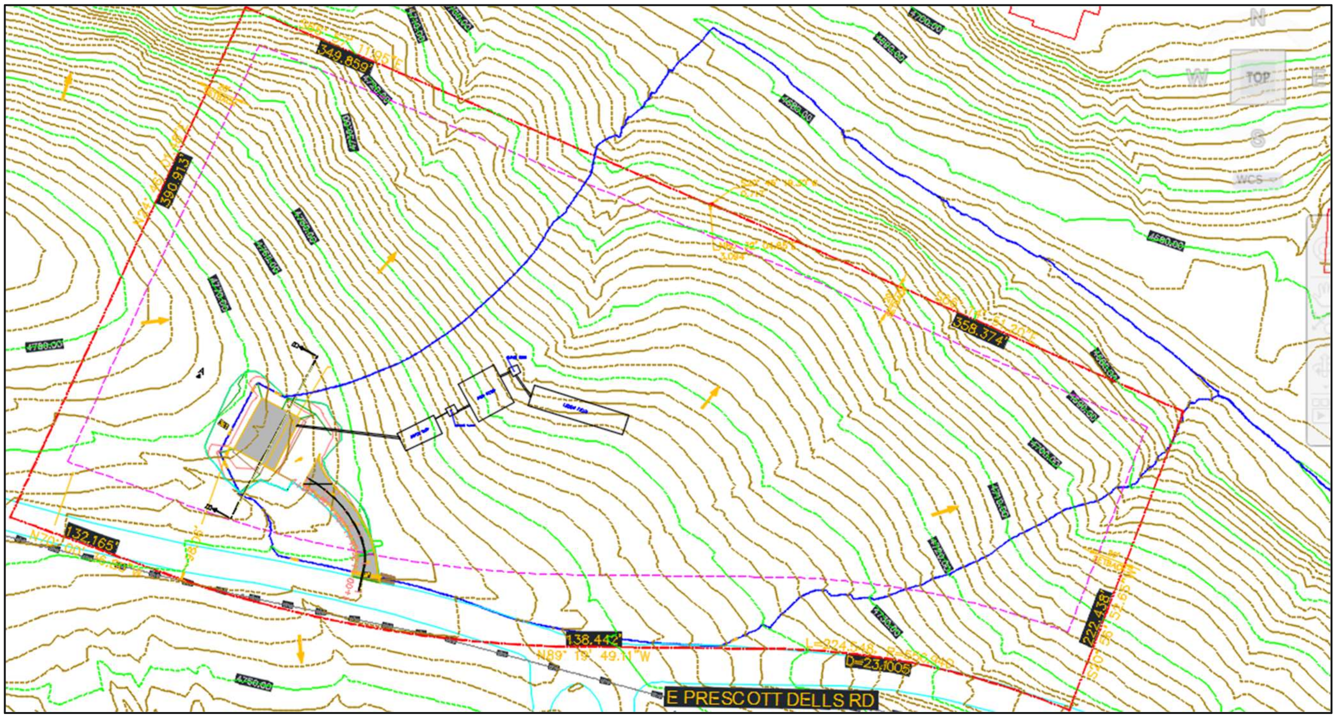


Figure 5-7. System on Total Site

5.2.7 Operation and Maintenance Manual

As a final piece for the clients to use, an Operation and Maintenance Manual has been created. It includes the required care and necessary actions the client will need to take in order to keep the system functioning. It also includes many actions that should not be taken, mainly what not to put down the drains in the house, to avoid damage to the system.

Such Operation and Maintenance Manuals should be kept on-hand by the client in an accessible place so they may refer to it as needed, and can allow a professional to refer to it for insight into working with the system.

6.0 Cost of Implementation

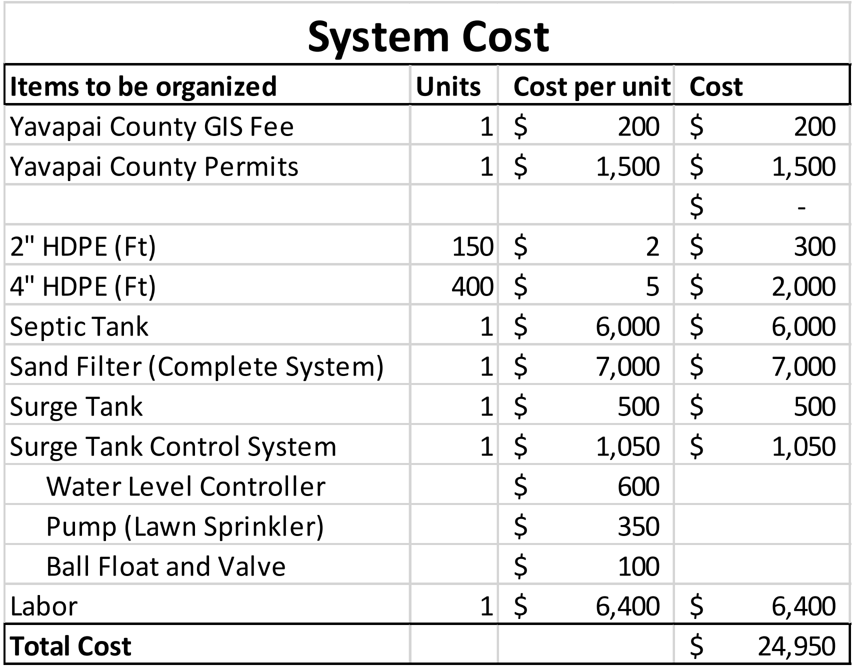
The cost to install the sand filter septic system has been found using average costs and typical examples of specific items found online.

The prices found in Table 6-1 have been sourced from a variety of online sources and represent a very simple average of items found. They are extremely rough estimates and should be taken lightly as a possible general cost. A more in-depth analysis would be done by the contractor to fully flesh out this price accurately.

However, items like the pipe costs have been calculated using the length of pipes required for the system. The cost of the sand filter and septic tank have also been more concretely provided [17]. Labor costs for installation have also been included in the septic tank and sand filter costs, but an additional labor cost has been added to account for the rest of the system as well.

Table 6-1 below shows the tabulation of the costs required for installing this system.

Table 6-1. System Cost



System Cost

Items to be organized	**Units**	**Cost per unit**	**Cost**
Yavapai County GIS Fee	1	$ 200	$ 200
Yavapai County Permits	1	$ 1,500	$ 1,500
			$ -
2" HDPE (Ft)	150	$ 2	$ 300
4" HDPE (Ft)	400	$ 5	$ 2,000
Septic Tank	1	$ 6,000	$ 6,000
Sand Filter (Complete System)	1	$ 7,000	$ 7,000
Surge Tank	1	$ 500	$ 500
Surge Tank Control System	1	$ 1,050	$ 1,050
Water Level Controller		$ 600	
Pump (Lawn Sprinkler)		$ 350	
Ball Float and Valve		$ 100	
Labor	1	$ 6,400	$ 6,400
Total Cost			$ 24,950

This system’s total cost is $24,950.

7.0 Impact Analysis

An analysis of the final recommendation has been made to understand its impact on several sectors. Commonly referred to as a ‘Triple Bottom Line Analysis’, this analysis focuses on finding environmental, economic, and social impacts the system may have. Impacts are not always negative, and further discussion will include both positive and negative impacts.

The most major sector the system will affect will be environmental impacts. Septic systems, and with that nearly all on-site wastewater treatment systems, must ensure the environment is not harmed by the disposal of their effluent. Such systems can sometimes negatively affect the environment as they release chemicals into the earth, as well as other harmful pollutants like pharmaceuticals and plastics. Since these are released into the soil on-site, another negative environmental impact comes from contamination of water sources. Water could make it to the nearby ephemeral stream or the deep aquifer untreated, which could cause damage.

However, the positive environmental impacts of such a system are quite important as well. The main positive impact comes from the fact that treating the water in this way is better than simply dumping untreated wastewater into the environment. For any of the systems above, water is also allowed to percolate down into the earth, where it is treated, before it reaches natural water tables, meaning that such systems help, on a long-time scale, to replenish aquifers. In keeping with water use, the other major positive impact includes the fact that the system will help the client reduce their use of potable water for gardening, and instead use recycled water to do so. This reduction in water consumption is a major positive environmental impact.

For economic impacts, these all mainly influence locals alone. For the clients, they have no need to worry about paying for a sewer line extension to their home, which would be very cost prohibitive for them. Additionally, the clients also have less water consumption, which means less of a water bill for them to pay. These are both very positive impacts that mainly only affect the client. Finally, small businesses focusing on septic tank maintenance and pumping will receive the client as additional customers.

However, on the flip side, the negatives affect both the client and the local municipality of Dewey-Humboldt. Since this system allows the clients to not participate in a city sewer line, no taxes or bills are being paid by the client to the city. While this may be positive for the client, it’s a negative for the city as these payments are how such sewer lines are paid for and maintained. The other major negative impact is that if the system fails, the client is completely responsible for repair cost, which could be a difficult economic burden.

Social impacts very greatly depending on whether the focus is on the client, on neighbors, or on the city. Negative impacts most importantly include the fact that the clients must now actively think about their wastewater as they are in charge of maintaining the system. Wastewater can be seen as disgusting to many, so the client will need to deal with this. Neighbors may be negatively affected as the construction of a new house may obstruct a desirable view. Finally, since the client isn’t paying for a sewer line extension, other new neighbors must also be forced to use a septic system unless they foot the cost of the sewer line extension.

There are positive social impacts as well. The client has the freedom to live wherever they wish without requiring sewer access. The client is also less reliant on city utilities in general, which may bring peace of mind. Leach field outputs could enhance plant growth and beautify the area if well-tended (and ensured to not interfere with the system). Finally, since the system helps reduce the client’s water use, there is more water to go around for other people.

8.0 Summary of Engineering Work

Table 8-1 summarizes and compares the projected to the actual time spent.

Table 8-1. Comparison of Work Hours

Comparison of Work Hours			
Position	**Projected**	**Actual**	**Difference**
SENG	5	15.5	+10.5
ENG	52	186.5	+134.5
LAB	100	23.75	-76.25
INT	443	150	-293
Total	600	375.75	-224.25

The project was, according to the estimates made, under the staffing time by 224.25 hours. In addition, the decision for splitting hours between the Engineer and Intern was more weighted toward giving the engineer hours than the initial estimates. The Engineer worked an additional 134.5 hours, while the Intern worked 293 hours less than anticipated. The last major discrepancy was for the Laboratory Technician, who worked 76.25 hours less than expected, but this is logically due to the lack of on-site work this project allowed.

The major difference between the Engineer and Intern hours came from a decision that the work needed to fully flesh out the AutoCAD designs would likely need to be by someone more experienced in the field. The level of quality required for such designs needs to be higher in order to be a proper system, thus work a fully-fledged engineer should do.

The resulting of less hours work than anticipated likely came from the quickness of receiving several important data sets. Since the county had septic tank tables and values set up already, it was very quick to complete those sections. Articles found also happened to help quicken the process as many included simplified numbers and estimations to use. This ease of access to online data is what likely resulted in the reduction of hours. However, it should be noted that had these hours been used, more alternatives could have been looked at to possibly solve the objectives of this project.

Table 8-2 outlines the actual hours taken to complete this project.

Table 8-2. Actual Hours for Project Completion

	Staffing Time				
Task #	**Task**	**SENG**	**ENG**	**LAB**	**INT**
1	**Research and Preparation**	**3**	**3.5**	**0**	**24.5**
1.1	City and State Regulations	**0**	**0**	**0**	**20**
1.1.1	ADEQ, Yavapai, Dewey-Humboldt Construction Reg	0	0	0	16
1.1.2	Operation Regulation	0	0	0	4
1.2	Site Sampling Plan	0	0	0	3.5
1.3	Laboratory Access Plan	0	0	0	0
1.4	Technology Options Research	3	3.5	0	1
2	**Site Investigation**	**0**	**2**	**3**	**1**
2.1	Surveying	0	2	0	1
2.2	Site Soil Sampling	0	0	3	0
3	**Data Analysis**	**0**	**2**	**12.75**	**4.5**
3.1	Topographical Map	0	0	9.75	1
3.2	Soil Composition Test	0	2	3	3.5
3.3	Percolation Test	0	0	0	0
4	**Design Solutions**	**6.5**	**71**	**2**	**78**
4.1	Design Alternatives	**4**	**38**	**2**	**50**
4.1.1	Final Site Location	0	0	0	0
4.1.2	Separate Design Configurations	4	38	2	50
4.2	Design Decision Matrix	1	9	0	7
4.3	Final Design Recommendation	1.5	24	0	21
5	**Impact Analysis**	**0**	**0**	**0**	**6**
5.1	Economic	0	0	0	2
5.2	Social	0	0	0	2
5.3	Environmental	0	0	0	2
6	**Installation and Operation**	**6**	**1**	**0**	**8**
6.1	Installation Plan Set	0	1	0	3
6.2	Owners and Operators Manual	6	0	0	5
7	**Project Management**	**0**	**1**	**0**	**16**
7.1	Meeting Recording	0	1	0	8
7.2	Schedule Management	0	0	0	5.5
7.3	Resource Management	0	0	0	2.5
8	**Deliverables**	**0**	**106**	**6**	**12**
8.1	30%	**0**	**17**	**0**	**0**
8.1.1.	Milestones: Tasks 1-3	0	0	0	0
8.1.2.	Report and Presentation	0	17	0	0
8.2	60%	**0**	**20**	**0**	**0**
8.2.1.	Milestones: Tasks 4	0	0	0	0
8.2.2.	Report and Presentation	0	20	0	0
8.3	90%	**0**	**54**	**0**	**0**
8.3.1.	Milestones: Tasks 5-7	0	0	0	0
8.3.2.	Report and Presentation	0	54	0	0
8.4	Final Submittal	**0**	**15**	**6**	**12**
8.4.1.	Final Report	0	10	5	0
8.4.2.	Website	0	0	1	7
8.4.3.	Presentation	0	5	0	5
375.75	**Total Hours**	**15.5**	**186.5**	**23.75**	**150**

Table 8-3 shows the projected hours that were expected for this project.

Table 8-3. Projected Hours for Completion

	Projected Staffing Time				
Task #	Task	SENG	ENG	LAB	INT
1	**Research and Preparation**	0	22	0	26
1.1	City and State Regulations	0	2	0	4
1.1.1	ADEQ, Yavapai, Dewey-Humboldt Construction Regs				2
1.1.2	Operation Regulation		2		2
1.2	Site Sampling Plan		2		4
1.3	Laboratory Access Plan		4		2
1.4	Technology Options Research		14		16
2	**Site Investigation**	0	9	23	31
2.1	Surveying		5	13	12
2.2	Site Soil Sampling		4	10	19
3	**Data Analysis**	0	0	26	26
3.1	Topographical Map			10	10
3.2	Soil Composition Test			10	10
3.3	Percolation Test			6	6
4	**Design Solutions**	4	5	0	93
4.1	Design Alternatives	0	0	0	83
4.1.1	Final Site Location				2
4.1.2	Separate Design Configurations				81
4.2	Design Decision Matrix		5		10
4.3	Final Design Recommendation	4			
5	**Impact Analysis**	0	15	0	30
5.1	Economic		5		10
5.2	Social		5		10
5.3	Environmental		5		10
6	**Installation and Operation**	0	0	51	79
6.1	Installation Plan Set			24	36
6.2	Owners and Operators Manual			27	43
7	**Project Management**	0	0	0	34
7.1	Meeting Recording				4
7.2	Schedule Management				15
7.3	Resource Management				15
8	**Deliverables**	1	1	0	124
8.1	30%	0	0	0	35
8.1.1.	Milestones: Tasks 1-3				10
8.1.2.	Report and Presentation				25
8.2	60%	0	0	0	35
8.2.1.	Milestones: Tasks 4				10
8.2.2.	Report and Presentation				25
8.3	90%	0	0	0	35
8.3.1.	Milestones: Tasks 5-7				10
8.3.2.	Report and Presentation				25
8.4	Final Submittal	1	1	0	19
8.4.1.	Final Report				12
8.4.2.	Website				6
8.4.3.	Presentation	1	1		1
600	**Total Hours**	5	52	100	443

9.0 Summary of Engineering Cost

As can be seen from the difference in worked hours from the projected hours, there is expected to be a great difference in the engineering cost of the project. As the weighting of work between the Engineer and the Intern was skewed toward the Engineer, the expectation is that the cost of this project went up.

The original projection of costs is shown in Table 9-1.

Table 9-1. Projected Cost

Projected Engineering Cost					
				Total Cost of Project	
				$ 29,840	
Index	**Item**	**Rate ($/hr)**	**Hours**	**Subcost**	**Cost**
1	**1.0 Personnel**				$ 24,842
2	Senior Engineer (SENG)	$ 240	5	$ 1,200	
3	Engineer (ENG)	$ 137	52	$ 7,124	
4	Lab Technician (LAB)	$ 50	100	$ 5,000	
5	Engineering Intern (INT)	$ 26	443	$ 11,518	
6					
7	**2.0 Travel**				$ 135
8	NAU Travel Reimbursement (79.1 miles x 2	$ 0.445	158.2	$ 70	
9	Chevy Tahoe SSP, NAU Rental (1 day)			$ 65	
10					
11	**3.0 Supplies**				$ 862
12	Expendable Supplies			$ 251	
13	Equipment Usage			$ 611	
14					
15	**4.0 Subcontract**				$ 4,000
16	Installation Cost			$ 4,000	

The new hours have now changed the total costs for engineering work, as seen in Table 9-2.

Table 9-2. Actual Cost

Engineering Cost					
				Total Cost of Project	
				$ 34,850	
Index	**Item**	**Rate ($/hr)**	**Hours**	**Subcost**	**Cost**
1	**1.0 Personnel**				$ 34,358
2	Senior Engineer (SENG)	$ 240	15.5	$ 3,720	
3	Engineer (ENG)	$ 137	186.5	$ 25,551	
4	Lab Technician (LAB)	$ 50	23.75	$ 1,188	
5	Engineering Intern (INT)	$ 26	150	$ 3,900	
6					
11	**2.0 Supplies**				$ 492
12	Expendable Supplies			$ 251	
13	Equipment Usage			$ 241	

The biggest difference was the removal of the $4,000 labor cost, as it was projected originally in engineering cost but is instead actually apart of the System Cost as explained in Section 6. The difference in cost is $5,516 as additional cost due to splitting of the work favoring the more expensive professional. The final engineering cost of services is $34,850.

10.0 Conclusion

This project’s overall goal was to design an on-site wastewater treatment facility to solve the needs of the client for waste disposal and be able to reuse the water for irrigation on-site. With the recommended design, a septic tank and sand filter system, both of these project goals are achieved. Analysis done by ABCC Projects shows that this system will meet requirements.

Additionally, the client will have access to possible ideas for water reuse by searching through the alternatives section of this report. Such info may prove useful should the client find the recommended alternative doesn’t fit their needs based on changes to water reuse, desire for lower budget or simpler systems. The client could decide to pursue the Mini WWTP, which would require its own analysis should they choose.

This project was a great chance for senior-level engineering students to learn how to read and follow the Arizona Administrative Code, as well as research different on-site wastewater treatment options, and learn the processes that can output treated water for different purposes. It is a great introductory assignment that may hopefully work as a starting point for future engineering work for the 4 graduating seniors of this project.

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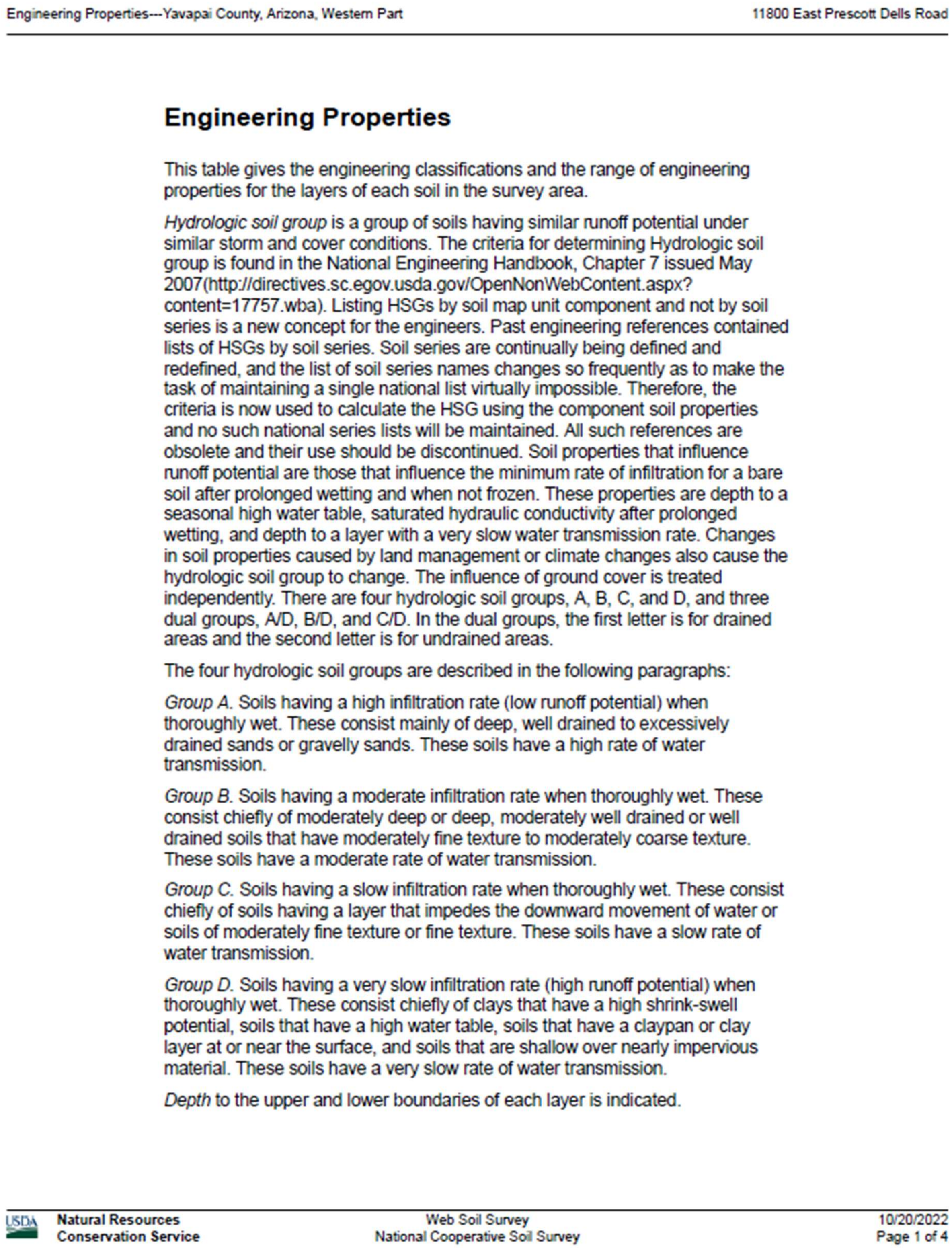
Appendix

Figure 0-1. Parcel Search around Site Location



Engineering Properties

This table gives the engineering classifications and the range of engineering properties for the layers of each soil in the survey area.

Hydrologic soil group is a group of soils having similar runoff potential under similar storm and cover conditions. The criteria for determining Hydrologic soil group is found in the National Engineering Handbook, Chapter 7 issued May 2007(http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17757.wba). Listing HSGs by soil map unit component and not by soil series is a new concept for the engineers. Past engineering references contained lists of HSGs by soil series. Soil series are continually being defined and redefined, and the list of soil series names changes so frequently as to make the task of maintaining a single national list virtually impossible. Therefore, the criteria is now used to calculate the HSG using the component soil properties and no such national series lists will be maintained. All such references are obsolete and their use should be discontinued. Soil properties that influence runoff potential are those that influence the minimum rate of infiltration for a bare soil after prolonged wetting and when not frozen. These properties are depth to a seasonal high water table, saturated hydraulic conductivity after prolonged wetting, and depth to a layer with a very slow water transmission rate. Changes in soil properties caused by land management or climate changes also cause the hydrologic soil group to change. The influence of ground cover is treated independently. There are four hydrologic soil groups, A, B, C, and D, and three dual groups, A/D, B/D, and C/D. In the dual groups, the first letter is for drained areas and the second letter is for undrained areas.

The four hydrologic soil groups are described in the following paragraphs:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

Depth to the upper and lower boundaries of each layer is indicated.

Texture is given in the standard terms used by the U.S. Department of Agriculture. These terms are defined according to percentages of sand, silt, and clay in the fraction of the soil that is less than 2 millimeters in diameter. "Loam," for example, is soil that is 7 to 27 percent clay, 28 to 50 percent silt, and less than 52 percent sand. If the content of particles coarser than sand is 15 percent or more, an appropriate modifier is added, for example, "gravelly."

Classification of the soils is determined according to the Unified soil classification system (ASTM, 2005) and the system adopted by the American Association of State Highway and Transportation Officials (AASHTO, 2004).

The Unified system classifies soils according to properties that affect their use as construction material. Soils are classified according to particle-size distribution of the fraction less than 3 inches in diameter and according to plasticity index, liquid limit, and organic matter content. Sandy and gravelly soils are identified as GW, GP, GM, GC, SW, SP, SM, and SC; silty and clayey soils as ML, CL, OL, MH, CH, and OH; and highly organic soils as PT. Soils exhibiting engineering properties of two groups can have a dual classification, for example, CL-ML.

The AASHTO system classifies soils according to those properties that affect roadway construction and maintenance. In this system, the fraction of a mineral soil that is less than 3 inches in diameter is classified in one of seven groups from A-1 through A-7 on the basis of particle-size distribution, liquid limit, and plasticity index. Soils in group A-1 are coarse grained and low in content of fines (silt and clay). At the other extreme, soils in group A-7 are fine grained. Highly organic soils are classified in group A-8 on the basis of visual inspection.

If laboratory data are available, the A-1, A-2, and A-7 groups are further classified as A-1-a, A-1-b, A-2-4, A-2-5, A-2-6, A-2-7, A-7-5, or A-7-6. As an additional refinement, the suitability of a soil as subgrade material can be indicated by a group index number. Group index numbers range from 0 for the best subgrade material to 20 or higher for the poorest.

Percentage of rock fragments larger than 10 inches in diameter and 3 to 10 inches in diameter are indicated as a percentage of the total soil on a dry-weight basis. The percentages are estimates determined mainly by converting volume percentage in the field to weight percentage. Three values are provided to identify the expected Low (L), Representative Value (R), and High (H).

Percentage (of soil particles) passing designated sieves is the percentage of the soil fraction less than 3 inches in diameter based on an ovendry weight. The sieves, numbers 4, 10, 40, and 200 (USA Standard Series), have openings of 4.76, 2.00, 0.420, and 0.074 millimeters, respectively. Estimates are based on laboratory tests of soils sampled in the survey area and in nearby areas and on estimates made in the field. Three values are provided to identify the expected Low (L), Representative Value (R), and High (H).

Liquid limit and *plasticity index* (Atterberg limits) indicate the plasticity characteristics of a soil. The estimates are based on test data from the survey area or from nearby areas and on field examination. Three values are provided to identify the expected Low (L), Representative Value (R), and High (H).

References:

American Association of State Highway and Transportation Officials (AASHTO). 2004. Standard specifications for transportation materials and methods of sampling and testing. 24th edition.

American Society for Testing and Materials (ASTM). 2005. Standard classification of soils for engineering purposes. ASTM Standard D2487-00.

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Absence of an entry indicates that the data were not estimated. The asterisk '*' denotes the representative texture; other possible textures follow the dash. The criteria for determining the hydrologic soil group for individual soil components is found in the National Engineering Handbook, Chapter 7 issued May 2007(http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17757.wba). Three values are provided to identify the expected Low (L), Representative Value (R), and High (H).

Engineering Properties–Yavapai County, Arizona, Western Part

Map unit symbol and soil name	Pct. of map unit	Hydrologic group	Depth	USDA texture	Classification		Pct Fragments		Percentage passing sieve number—				Liquid limit	Plasticity index
					Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
			In				*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*	*L-R-H*
MkF—Moano very rocky loam, 15 to 60 percent slopes														
Moano	70	D	0-2	Gravelly loam	GC-GM, SC-SM, GC, SC	A-4, A-6	0- 0- 0	0- 5- 10	65-70-75	55-60-65	40-50-60	35-40-45	25-30-35	5-10-15
			2-9	Gravelly loam	GC-GM, SC-SM, GC, SC	A-4, A-6	0- 0- 0	0- 5- 10	65-70-75	55-60-65	40-50-60	35-40-45	25-30-35	5-10-15
			9-16	Unweathered bedrock	—	—	—	—	—	—	—	—	—	—

Data Source Information

Soil Survey Area: Yavapai County, Arizona, Western Part
Survey Area Data: Version 15, Aug 26, 2022