Chiricahua National Monument RV Housing Utility Final Design Report

CENE 486

Northern Arizona University

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Final Design Report

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List of Abbreviations

C3W: Chiricahua Wastewater Wizards

ADEQ: Arizona Department of Environmental Quality

RV: Recreational Vehicle

ASTM: A developer of international voluntary consensus standards.

EPA: U.S. Environmental Protection Agency

NAU: Northern Arizona University

NPS: National Park Service

HDPE: High-Density Polyethylene

SAR: Soil Absorption Ratio

Acknowledgements

1.0 Project Introduction

The purpose of this project is to design a wastewater treatment system for Chiricahua National Monument. The facilities manager at Chiricahua National Monument has indicated the system will provide enough capacity for five to seven RV pads with full utility hookups, as well as water distribution from an existing wellhead and treatment building located on site. The housing is for both seasonal and volunteer staff.

1.1 Project Location

This project is located at Chiricahua National Monument, approximately 30 miles southeast of Willcox, Arizona. This is within the southeast corner of Arizona. Figure 1-1 details its location in the state as shown below.

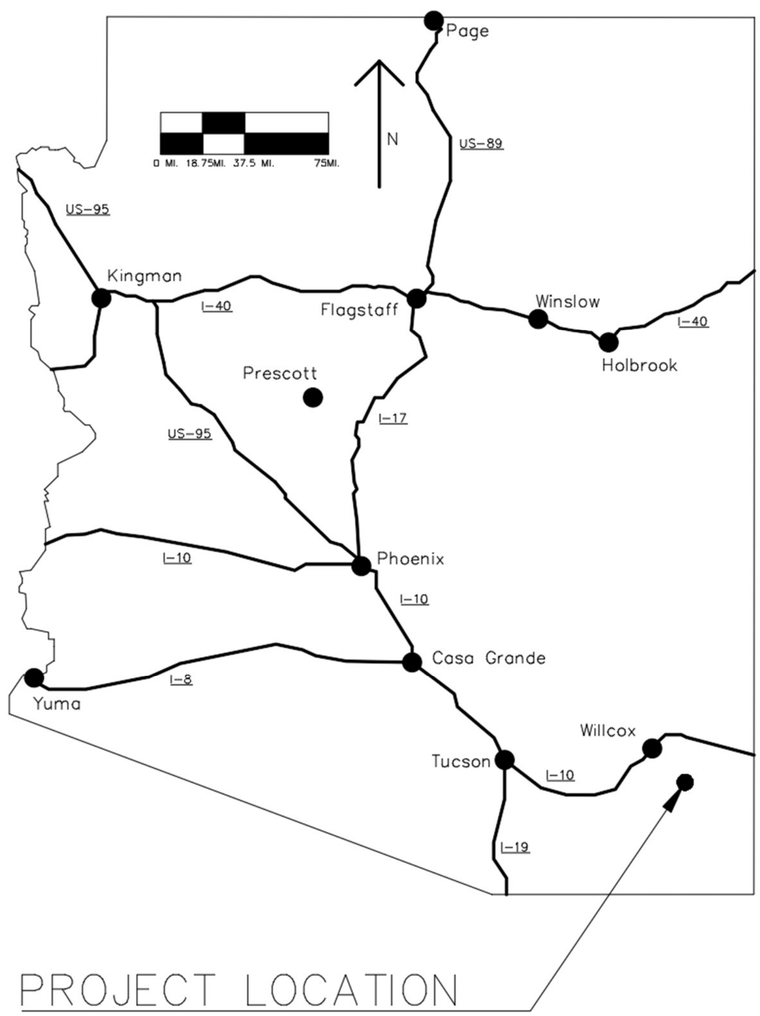


Figure 1- 1:Location Map

Figure 1-2 below illustrates an area map of the nearby relevant towns and features on the outside of the monument, including the Chiricahua Mountains.

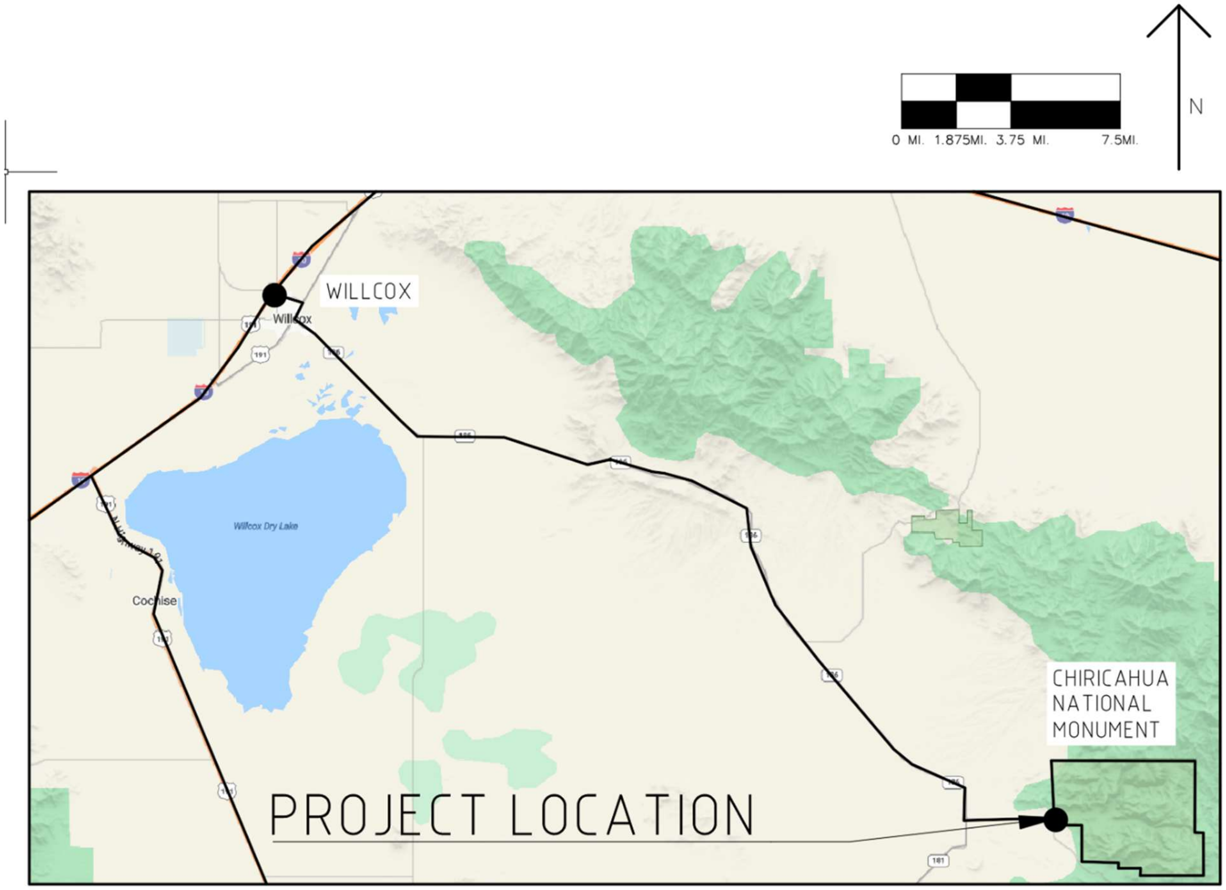


Figure 1- 2: Area Map

Figure 1-3 below shows the site map of the project site and its surrounding conditions.

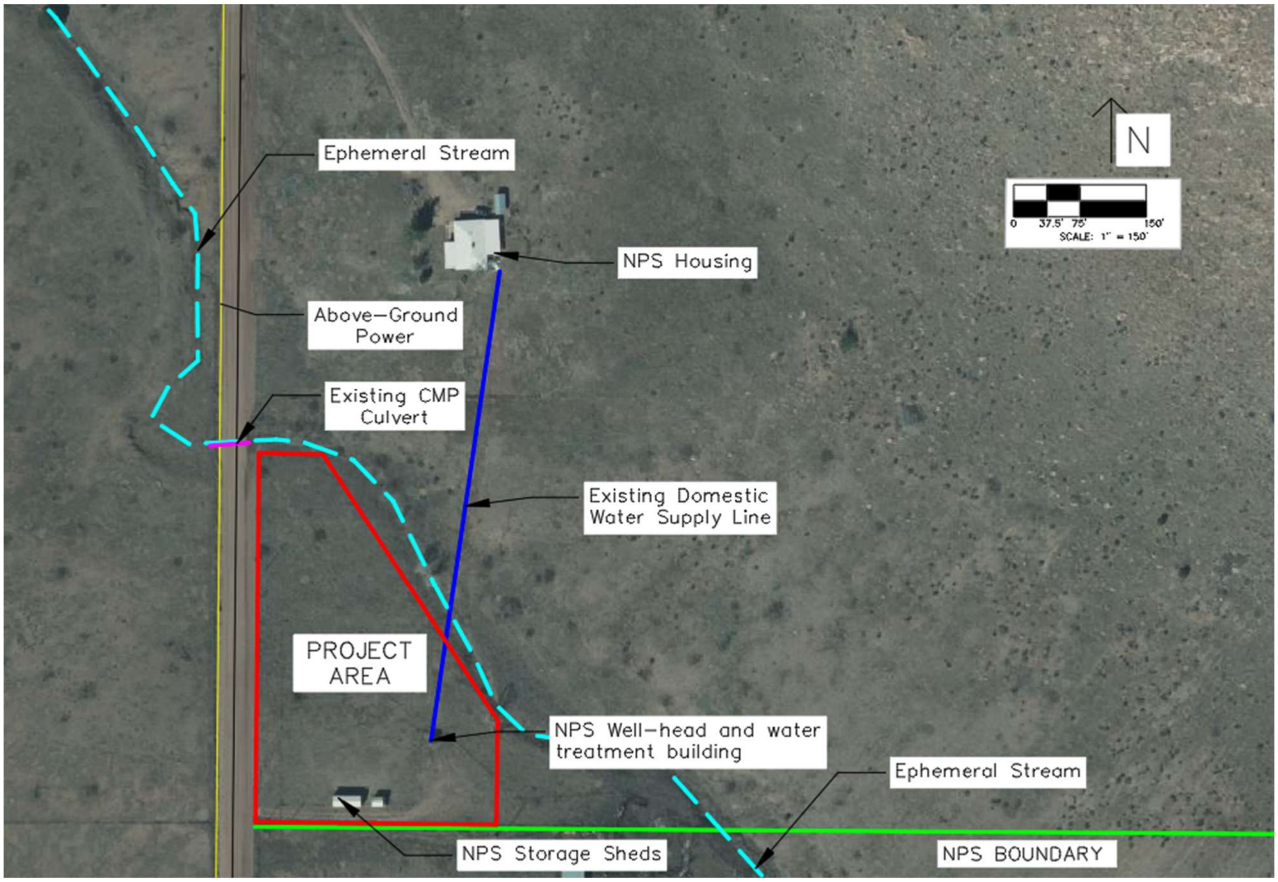


Figure 1- 3: Site Map

The site is neighbored by an ephemeral stream channel, which is highlighted in light blue in Figure 1-3. As a result of preexisting infrastructure project constraints must be implemented, which is further discussed in Section 1.3.

1.2 Project Objectives

The project will account for full hookups, design for water pumping and distribution, as well as wastewater collection and treatment from the existing wellhead and treatment building. Wastewater collection and treatment is to take place at the site, requested by the client.

1.3 Constraints and Limitations

There are several constraints that this project faces, most coming from the septic treatment design. The soil cannot drain too fast or too slowly, and the treatment system must be located 100 feet [1] from the ephemeral stream to avoid any chance of contamination. The project must stay entirely within the project area, as there is private land located to the south, a roadway to the west, and the National Monument to the west. Since the scope of this project only includes the water and septic design, the design also relies on accurate and quality information to be provided from the site design team. Since this can vary, as well as other things that can arise, float is built into the schedule, and work can be done over breaks.

2.0 Site Investigation

This section details all methods conducted when performing the site investigation and field work at Chiricahua National Monument by the Chiricahua Wastewater Wizards.

2.1 Percolation Testing

A percolation test was conducted at the project site following ADEQ's R-18-9-A310 "Site Investigation for Type 4 Wastewater Treatment Facilities" and ASTM D5921 standards. Two test pit locations were chosen at the site. The first test pit was excavated using a shovel and hammer, each member of the team assisted with excavation until the test pit was the necessary size. This location was chosen due to its closeness to the existing wellhead building on site.

The approximate percolation testing locations at the project site are shown by the purple star icons for reference in Figure 2-1 below.

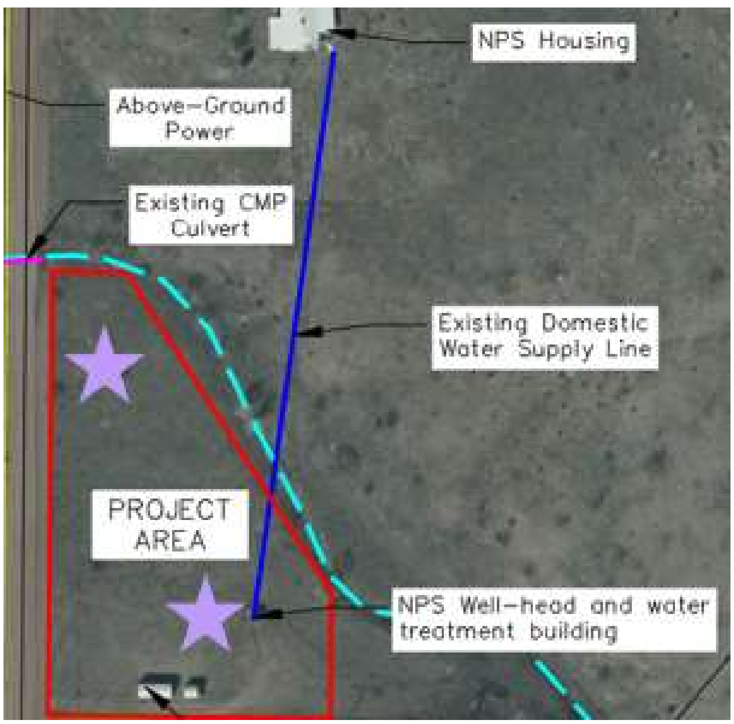


Figure 2- 1: Percolation Test Locations

The first test pit location is shown in Figure 2-2 below.

Figure 2- 2: First Test Pit

Two five-gallon buckets were used by the team to collect the obtained soil samples from the test pit locations. Figure 2-3 below shows the same test pit in relation to the wellhead building on site.

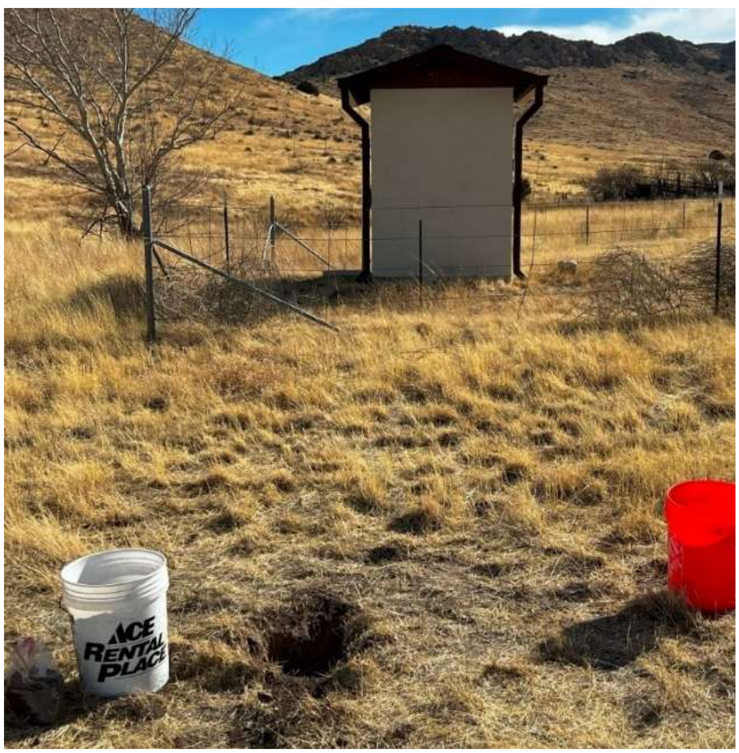


Figure 2- 3: Test Pit and Wellhead Building

The soil located at test pit one was found to be coarse and with several pieces of large aggregates within it. As such the team chose a second test pit location further away, in order to increase both variability of results because of the soil and choosing a reliable spot for the proposed leach field location. The second test pit was excavated using the same method as the first, and soil was more susceptible to digging as well as having finer aggregates. As such, the percolation testing was conducted at test pit two.

The second test pit, measuring 12" x 12" after excavation was pre-soaked by filling the hole twice to saturate the surrounding soil. After pre-soaking, the water level was stabilized at 6 inches below the ground surface to begin testing. The time required for the water level to drop by 1 inch was recorded for three trials. The below figure shows test pit two post excavation after being filled with water for percolation testing.

Figure 2- 4: Second Test Pit and Testing

The second test pit was pre-soaked for approximately sixty-minute intervals twice to allow for proper soil absorption as well as following and meeting Arizona administrative code percolation testing requirements. Once the test pit was properly saturated, testing was conducted,

The three trials conducted are shown below in Table 2-1 and show the percolation test results at the second test pit.

Table 2- 1: Percolation Times

Percolation Test (Time / inch)	
Trial number	Time
Trial 1	11 minutes 40 seconds
Trial 2	12 minutes 38 seconds
Trial 3	12 minutes 10 seconds

The percolation rate was found using Arizona Administrative Code 18-9-A310. The below equation was used,

Equation 2- 1: Percolation Test Rate [2]

$$P = \left(\frac{15}{DS}\right) \times IS$$

Where the variables are below,

P = Percolation Test Rate (minutes per inch)

DS = Diameter of seepage pit (inches)

IS = Seepage pit infiltration rate (minutes per inch)

The average percolation rate was calculated as 12 minutes 16 seconds per inch using Equation 2-1, with a DS of 12 inches for the seepage pit diameter.

2.2 Site Observations and Land Survey

The site is adjacent to an ephemeral stream and NPS storage shed for water, as stated under Section 1.3. Existing freshwater infrastructure consists of a direct-bury polyethylene pipe connected to the wellhead building that currently supplies water only to the nearby monument housing building.

The percolation test pit locations were selected based on potential leach field design, one next to the wellhead building and another adjacent to the road and monument housing building. All surveying was conducted by a site design team, in which the survey data is used to create a topographical map using Autodesk Civil 3D 2025.

Figure 2-5 was provided by the Site Design team and details a topographical map of the site.

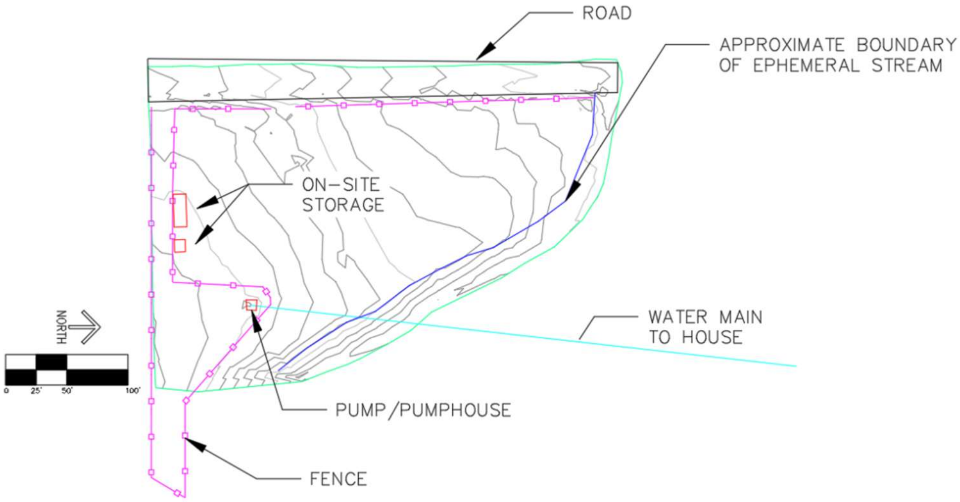


Figure 2- 5: Topo Map

Figure’s 2-6 and 2-7 below show the ephemeral stream and NPS pump house observed at the site, respectfully.

Figure 2- 6: Nearby Ephemeral Stream

Figure 2- 7: NPS Pumphouse and Wellhead Building

After percolation testing was completed C3W filled in both of the test holes with the Chiricahua site soil and took two soil samples from each test location, in Ziploc bags, and transported them to NAU for further soil testing and analysis.

2.3 Proctor Compaction Testing

To obtain the soil's optimum moisture content (the moisture content at which the soil is densest) and find the soil's maximum dry density, proctor compaction testing was done. The goal is to establish the ideal moisture content for the soil sample, while assessing the soil's ability to perform under compaction and weight. As the second test pit location is where the proposed leach field will be located, proctor compaction testing was done to verify that the chosen location will be suitable for being compacted, as it is located near the new roadway.

The modified proctor compaction testing was done using ASTM D1557, which is known as "Standard Test Methods for Laboratory Compaction Characteristics of Soil using Modified Effort (56,000 ft-lbf/ft^3) [3]." The soil used was from the percolation test pit number two where the leach field design is located. It was sifted through a number four sieve, before water was added to reach optimum moisture content in three percent, six percent, nine percent, twelve percent, and fifteen percent moisture contents. The soil was saturated with water and then placed into the testing apparatus. 25 blows, in five layers each, were dealt to the soil using the modified proctor compaction hammer.

Figure 2-8 below shows the team delivering the blows with the proctor compaction hammer,

Figure 2- 8: Proctor Compaction Testing

Once the soil was compacted it was removed from the apparatus and moisture content cans were taken, a sample of the soil was placed in cans and left in an oven at 105 degrees Celsius for twenty-four hours, to determine how much moisture was lost.

Figure 2-9 below shows the samples before being placed in the drying oven,

Figure 2- 9: Pre-dry Samples

Figure 2-10 below shows the drying oven used to dry the samples,

Figure 2- 10: Drying Oven

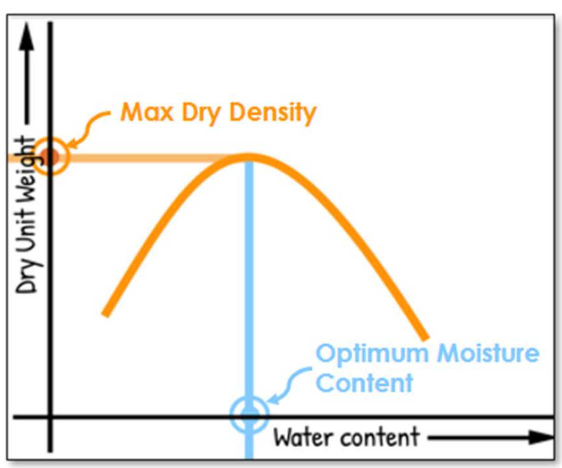
After obtaining the data it was recorded and can be summarized in the below table 2-2 and in Appendix A.

Table 2- 11: Modified Proctor Compaction Data

Proctor Data					
MODIFIED	1 (6%)	2 (9%)	3 (12%)	4 (15%)	5 (18%)
Amt. of soil collected	2 kg				
Added water volume (g)	102				
W1 (g)	4609.1				
D (in)	4				
H (in)	6.63				
W2 (g)	6571.4	6584.2	6565.5	6496.9	6467.1
Moisture Content Data					
Can weight (g)	13.2	13.4	13.4	13.7	13.8
Can + wet soil	50.4	48.2	47.7	58.4	64.4
Can + dried soil	46.9	43.4	42.6	50.6	55.2

Where W1 is the initial weight of the proctor compaction mold with no soil in it, D is the diameter of the mold, and H is the height of the mold. W2 is the weight of the mold with compacted moistened soil. As shown in the table, the optimum moisture content for the site soil was found to be between six and nine percent moisture, before the team continued on to twelve, fifteen, and eighteen percent moisture for the remaining trials. This moisture content is suitable for consolidation and the proposed leach field location is optimum based on this moisture content data. A graph of the moisture content and maximum dry density is shown below in Figure 2-11.

Figure 2- 111: Moisture Content Graph



3.0 Freshwater Delivery System Design

This section details all freshwater distribution design for the project, as well as developing the required water demand for the RV units and examining the existing waterline infrastructure on site.

3.1 Existing Water Infrastructure

The current water infrastructure at the site consists of a wellhead building that supplies water specifically to the residence, connected to a 1.5-inch high-density polyethylene (HDPE) pipe. There is also an on-site well, which is able to provide approximately 20 gallons of water per minute. Typical tank operating pressure is between 40 psi and 60 psi.

3.2 Development of Required Demand

Demand calculations were gathered from Water Flow Rate & Sizing Guide 2-307, from MARLO Incorporated [4]. This source provided fixture units per appurtenance, then translated total fixture units into a demand in gallons per minute. It was assumed that the two primary water usage fixture units per trailer were a kitchen sink and bathroom group. Total per trailer demand can be found in Table 4-1.

Table 4-1 - Per Trailer Peak Demand

Water Supply Fixture Units - Per Trailer	
Appurtenance	**Fixture Units**
Kitchen Sink	1.5
Bathroom Group: Shower Stall, Lavatory, and Water closet - flush tank	3.5
TOTAL FIXTURE UNITS	**5**
PEAK GALLONS PER MINUTE	**4.5**

The maximum flow for the laundry, shower, and bath building was done similarly. There were several assumed appurtenances, listed on the left on Table 4-2.

Table 4-2 - Laundry, Shower, and Bath Building Maximum Flow

Water Supply Fixture Units - Laundry, Shower, and Bath Building			
Appurtenance	**Quantity**	**Fixture Units Each**	**Total**
Automatic Clothes Washer - Individual	3	3	9
Lavatory	6	1	6
Shower, per head	6	3	18
Sinks, bar and fountain	4	2	8
Hose Bibb, 1/2 inch diameter	1	3	3
Urinal - Washdown	2	2	4
TOTAL FIXTURE UNITS			48
PEAK GALLONS PER MINUTE			30

Finally, this process was also done for the house that is also fed by this well, so that an accurate demand rate at the well could be determined. This is found in Table 4-3.

Table 4-3 – NPS House Maximum Flow

Water Supply Fixture Units - House			
Appurtenance	**Quantity**	**Fixture Units Each**	**Total**
Automatic Clothes Washer	1	1.5	1.5
Bar Sink	1	1	1
Dishwasher Machine	1	1	1
Kitchen Sink	1	1.5	1.5
Shower Stall, Lavatory and Water closet - Flush Tank	2	3.5	7
TOTAL FIXTURE UNITS			12
PEAK GALLONS PER MINUTE			9.50

Thus, the ultimate demand at the well is found in Table 4-4.

Table 4-4 – Ultimate Demand at Well

TOTAL PEAK DEMAND AT WELL			
ITEM	**QUANTITY**	**DEMAND (GPM)**	**DEMAND (CFS)**
TRAILER	7	31.50	0.070
LAUNDRY, SHOWER, BATH BUILDING	1	30.00	0.067
NPS HOUSE (NOT IN NEW SYSTEM)	1	9.50	0.021
TOTALS		71.00	0.158

However, since it is not realistic to assume that all appurtenances, a demand ratio was applied using Table 5 from the United States Department of Agriculture Forest Service document 0773-2326 [5]. This table suggested a reduction of 1.3, which produces the demands found in Table 4-5.

Table 4-5 - Average Demand at Well

AVERAGE DEMAND AT WELL		
ITEM	**ULTIMATE DEMAND (GPM)**	**AVERAGE DEMAND (GPM)**
TRAILER	31.50	24.00
LAUNDRY, SHOWER, BATH BUILDING	30.00	23.00
NPS HOUSE (NOT IN NEW SYSTEM)	9.50	7.00
TOTALS	71.00	54.00

To allow for sizing of new pressure tank by the client, daily design flow was also calculated using values from the United States Department of Agriculture Forest Service document 0773-2326 [5]. This results in a design flow of 1260 gallons per day, found in Table 4-6. This assumes a capacity of two people per trailer, and a maximum of six people using the on-site facilities.

Table 4-6 - Daily Flow Rate

Daily Water Capacity				
Item	**Gallons per Day per Unit**	**Unit**	**Number of Units**	**Design Flow (gal/day)**
Trailer with Water and Sewer Connection	50	Persons at One Time	14	700
Camping Facility with Flush Toilets and Showers	40	Persons at One Time	6	240
Design Flow (Gallons per day)				940

Using these flow rates, the energy equation was used to determine the corresponding pressures at each location based on the pressure at the well tank. This allowed pipes to be correctly sized. The equation can be found in Equation 4-1 below.

Equation 4-1 - Energy Equation

$$\frac{P_1}{\gamma} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{v_2^2}{2g} + z_2 + h_L$$

Where:

P_1 = Pressure at Point 1, lb/ft^2

P_2 = Pressure at Point 2, lb/ft^2

v_1 = Velocity at Point 1, feet per second.

v_2 = Velocity at Point 2, feet per second.

z_1 = Elevation at Point 1, ft.

z_2 = Elevation at Point 2, ft.

h_L = Head Loss, see equation 4-2.

g = Acceleration due to Gravity, 32.2 ft per second^2.

γ = Density of Water, 62.4 lb per ft^3

Head-Loss was calculated using the Hazen-Williams Equation, Equation 4-2, with a friction coefficient of 150 per Engineering Toolbox [6].

Equation 4-2 – Hazen-Williams

$$h_L = \frac{4.73LQ^{1.852}}{C^{1.852}D^{1.852}}$$

h_L = Head Loss, Friction

L = Pipe Length, ft

Q = Flow, ft^3 per second

C = Hazen-Williams Friction Coefficient (150)

D = Pipe Diameter (ft)

This resulted in the following pressures at each end in Table 4-7 below. The pressure when the well is at 40psi and 60psi are listed, as well as approximate elevations based on new terrain data and elevations from the site design team.

A sample calculation can be found in Appendix B.

Table 4-7: Pressures

Location	End Elevation (ft)	Pressures (psi)	
		Well @ 40psi	Well @ 60psi
Trailer 1	5145.36	40.11	60.11
Trailer 2	5145.92	39.79	59.79
Trailer 3	5144.68	39.87	59.87
Trailer 4	5144.71	40.06	60.12
Trailer 5	5143.20	39.57	59.80
Trailer 6	5141.91	40.04	60.27
Trailer 7	5139.87	40.52	60.75
Laundry	5141.49	39.86	60.21

3.3 Freshwater Design Recommendations

Project Title Sheets can be found in Appendix C.

Full plans showing the complete design recommendations can be found in Appendix D.

4.0 On-site Wastewater Treatment System Selection

Both online and on-site investigation was performed to analyze potential on-site wastewater treatment system options. The final design was selected using a decision matrix table.

4.1 Criteria for Selection

Considering client needs, environmental impacts, and maintenance requirements and cost, the chosen design alternative is determined using the following criteria;

- System longevity, assessing the system's ability to ensure it can meet future needs and how long it takes before maintenance is necessary and the frequency of maintenance.
- Space requirements, assessing the system's ability to fit within the allotted space on the project site considering setback requirements.
- Maintenance costs, assessing the cost of system maintenance, including cleaning cycles and technology requirements based on frequency.
- Total cost of implementation, how much building the design will cost in total to install.

After these criteria were established, they were weighted. The team emphasized space requirements (weighted at 3) followed by the total costs and system longevity (weighted at 2 and 1, respectively.) in order of importance, with one being the least important, two being in the middle, and three being the most important, in order to ensure the chosen design is able to fit within the space on site, while meeting client cost requirements. All designs for consideration meet state (ADEQ) regulatory compliance for on-site wastewater treatment systems. The team's decision matrix and scoring parameters are found under Section 3.3.

4.2 Alternative Designs

This section details all alternative designs that have been selected for further analysis, these include a traditional septic system, a mound system, a recirculating sand filter, and biomass filtration.

4.2.1 Traditional Septic

Traditional septic systems consist of a tank + infiltration field and require soil infiltration rates between 1-30 min/inch (ADEQ R18-9-A310) from the ADEQ Site Investigation Guidance Manual [7]. A typical septic tank for reference is shown in Figure 3-1 below.

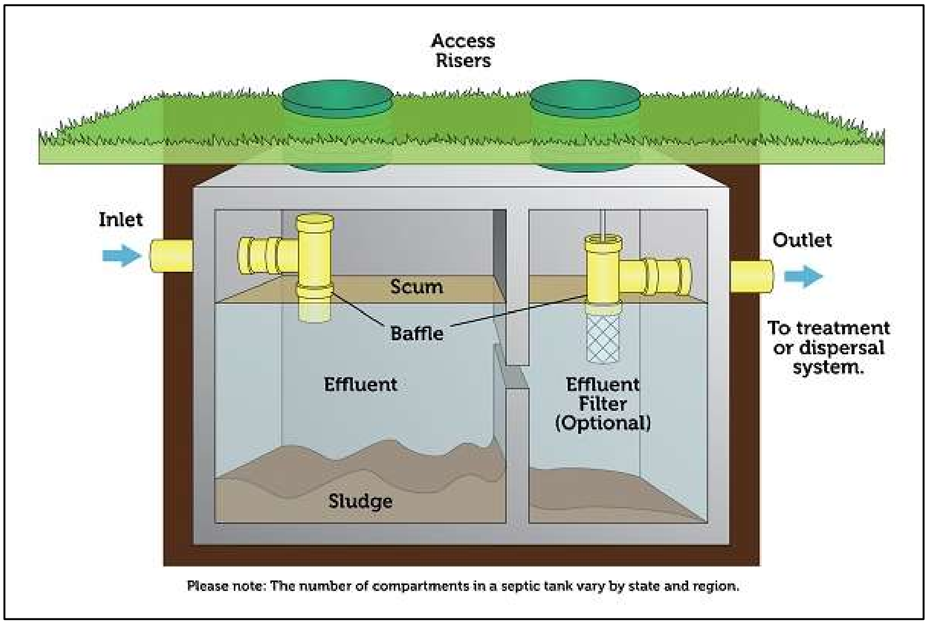


Figure 3- 1: Traditional Septic Tank [8]

The construction cost of conventional septic tanks is low, estimated between $3,615 and $12,408. It is also simple to operate and maintain, with an annual maintenance cost of about $500 [9].

Advantages

- Low construction costs
- Operation and maintenance costs low
- Percolation rate allows for leach field

Disadvantages

- Requires setback from ephemeral stream of 100 feet [10].

4.2.2 Mound System

A mound system is a treatment option for low permeability soils that increases infiltration capacity by placing layers of sand and crushed stone underground. The sand mound that's created includes a trench, and effluent from a septic chamber is pumped to the mound. The design is particularly suitable for areas with high groundwater levels or poor soil permeability to ensure that wastewater does not remain on the surface or contaminate groundwater sources [11].

A typical mound system is shown in Figure 3-2 located below,

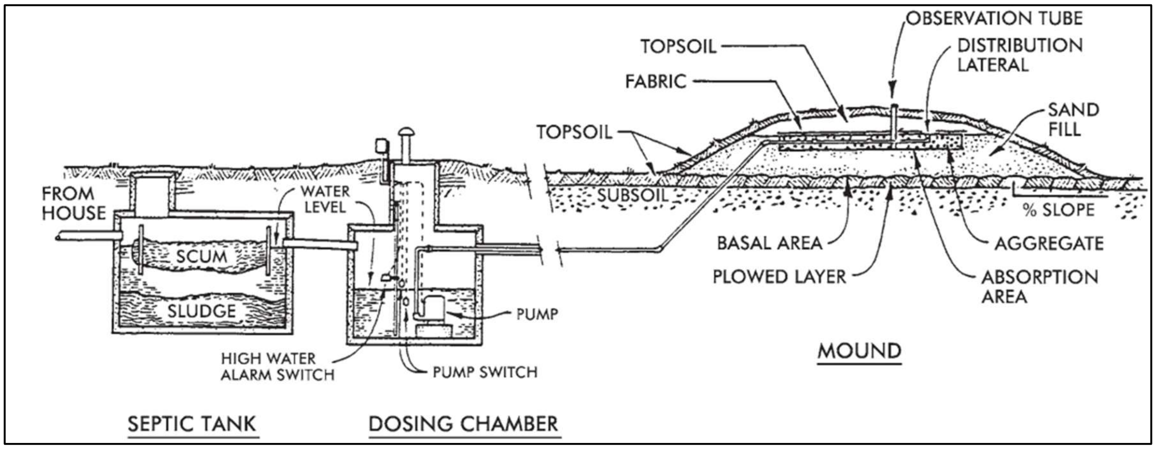


Figure 3- 2: Mound System

Estimated construction costs range from $10,000 to $20,000 [12]. The system requires extensive earthwork, including building the mound, installing the gravel layer, and laying the pipes, making it expensive to build.

Advantages

- Suitable for poor soil permeability
- Tolerates higher groundwater levels

Disadvantages

- Extensive earthwork and gravel installation
- Construction costs higher

4.2.3 Recirculating Sand Filtration

The circulating sand filtration system is a highly efficient sewage treatment system suitable for low permeability soils and sites that require efficient sewage filtration. The system mainly relies on sand and gravel layers and biodegradation to filter and treat sewage and has a strong pollutant removal capacity. The sewage first enters a sedimentation tank to remove larger particles and then passes through the sand filter layer for physical and biological filtration. Finally, the treated sewage can be returned to the system to improve treatment efficiency or discharged to the infiltration site [Water Environment Federation (WEF). "Wastewater Treatment Processes and Technologies." 2020].

A recirculating sand filtration system is shown in Figure 3-3 below,

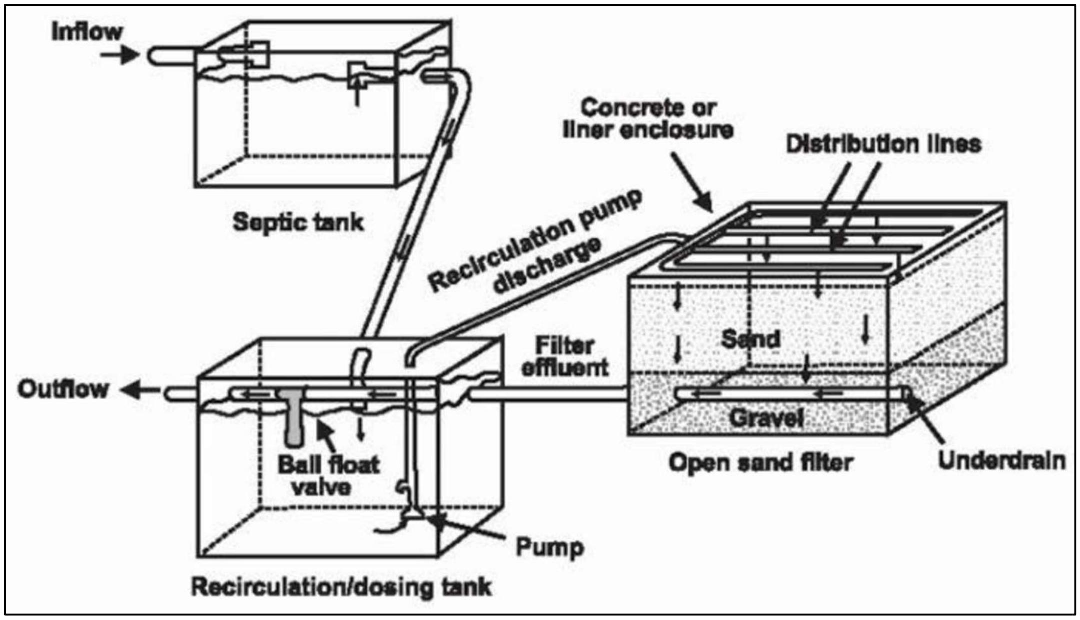


Figure 3- 3: Recirculating media filter [13]

The system has high initial construction costs, including the installation of the sand filter, circulating pump, and pipes, but low long-term operating costs [14]. Maintenance mainly includes cleaning the pipes, replacing the sand filter (about every 5-10 years), and regularly monitoring water quality [15].

Advantages

- Suitable for low permeability soils
- High effluent quality, reducing the risk of groundwater contamination
- Relatively low maintenance costs

Disadvantages

- High initial installation costs

4.2.4 Biomass Filtration

Biomass filtration systems use microorganisms and biofilm technology to degrade organic pollutants in sewage and are widely used in sewage treatment plants and ecologically sensitive areas. Sewage is filtered through biofilm reactors or wetlands, where microorganisms decompose pollutants. The treated sewage can be reused, discharged or further filtered.

Advantages

- Can be used in ecologically sensitive areas

Disadvantages

- High initial installation costs including biological media, aeration devices and a water circulation system [16].

4.3 Select Best Alternative

A decision matrix was used to rank each treatment design, allowing for selection of the best alternative. The team scored the four alternatives for each criterion found under Section 4.1. The explanation of decision matrix scoring is found below.

Scored 1 to 5:

- **1 - Least Optimum (Worst)**

A score of one is the least optimum score, it represents the most expensive design, the layout and spacing requirements are not being met, and the maintenance frequency is most often. The maintenance costs for a score of one are outside the range of constructability for the project site and are more than $20,000. Installation costs for a score of one are more than $30,000. The spacing requirements for a score of one do not comply with setback requirements.

- **2 - Worse**

A score of two represents being worse than the score of three but better than a one and its criteria range between scores one and three.

- **3 - Neutral**

A score of three represents the middle of scoring, the annual maintenance costs for a score of three fall within the more than $800 less than $1500 range. Installation costs for a score of three fall within the more than $10,000 less than $20,000 range. The system longevity for a score of three falls within the more than 10 years range. Spacing requirements for a three require needing some space on the project site to meet setback requirements once properly configured (ex. the septic system receives a score of three as it requires instillation of a leach field that is at minimum 50 feet away from the intermittent stream channel by ADEQ standards).

- **4 - Better**

A score of four represents being better than the score of three, but worse than a score of five, this score's criteria ranges fall between the values for scores three and five.

- **5 - Optimum**

A score of five is the most optimum score, it represents the most cost effective and cheap design, that fits within the space, and the maintenance frequency is least often. The annual maintenance costs for a score of five are within the less than $800 range. The installation costs for a score of five are less than $10,000. The system longevity for a five is within the more than twenty years range. Spacing requirements for a score of five represent not needing a lot of space on the project site to meet setback requirements (ex. the sand filter receives a score of five for spacing requirements as it does not require the installation of a leach field).

The team's decision matrix table can be found in figure 3-1 below.

Table 3- 1: Decision matrix table

Design Decision Matrix		**Septic System**		**Sand Filter**		**Mound System**		**Biomass Filtration**	
Criteria	**Weight**	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Maintenance Costs	**2**	5	10	3	6	2	4	2	4
Space Requirements	**3**	2	6	5	15	3	9	5	15
System Longevity	**1**	4	4	3	3	3	3	2	2
Implementation Costs	**2**	5	10	2	4	4	8	3	6
Total Score			**30**		**28**		**24**		**27**

After the designs were all scored and weighted, the total score row at the bottom of the matrix illustrates that the septic system design is the best possible alternative, with the highest score of 30.

5.0 On-site Wastewater System Design

The on-site wastewater treatment system design is detailed under this section; this includes all design calculations and the system design as well as final design recommendations.

5.1 Wastewater Design Calculations

Demand for wastewater treatment was determined through internet research. Campground flow for campers was determined using ADEQ R18-9-E323, Table 1.

The ADEQ R18-9 Table 1 for unit design flows is found below,

Table 5- 1: R19-9 Table for Unit Design Flows

Wastewater Source	Applicable Unit	Sewage Design Flow per Applicable Unit, (gallons per day)
Airport	Passenger (average daily number) Employee	4 15
Auto Wash	Facility	Per manufacturer, if consistent with this Chapter
Bar/Lounge	Seat	30
Barber Shop	Chair	35
Beauty Parlor	Chair	100
Bowling Alley (snack bar only)	Lane	75
Camp Day camp, no cooking facilities Campground, overnight, flush toilets Campground, overnight, flush toilets, and shower Campground, luxury Camp, youth, summer, or seasonal	Camping unit Camping unit Camping unit Person Person	30 75 150 100-150 50

This resulted in the following design flow, found in Table 5-2 below.

Table 5- 2: Camper Flow

Design Flow - Units				
Design Flow Type from A18-9	**Quantity per Unit (GPD)**	**Unit**	**Units on Site**	**Total Consumption (gal./day)**
Campground, overnight, flush toilets and shower	150	Per Site	7	1050

5.2 On-site Wastewater Collection

The collection system collects all sewage generated by the seven RV spaces (and all associated restroom facilities) and conveys it by gravity to septic tanks for treatment. The system is a gravity-fed network consisting of a main sewer line with multiple branch connections. The design focused on proper pipe sizing, slope, and configuration to ensure reliable flow and meet regulatory standards. Key design features of the collection system include:

- Pipe Material and Diameter: All sewer lines in the collection network are 4-inch diameter polyethylene HDPE pipe. This pipe size is sufficient to handle peak sewer flow (approximately 1050 gpd) and is a standard diameter for small community sewer lines. It meets the recommended sizing guidelines of state regulations. HDPE pipe was selected for its high durability, corrosion resistance, and flexibility, making it suitable for underground installation and long service life.

- Gravity Feed Slope: The main collection line is installed with a slope of at least 1% (i.e., a 1-foot drop for every 100-foot length). This minimum slope ensures that gravity directs the flow to the septic tanks, preventing water or sediment accumulation in the lines. Based on engineering practice and EPA recommendations, small gravity sewer pipes should have a slope of at least 1%. In this design, the slope cannot be uniform due to topography, and the specific slope values are shown in Figure 5-1, 5-2 and 5-3.

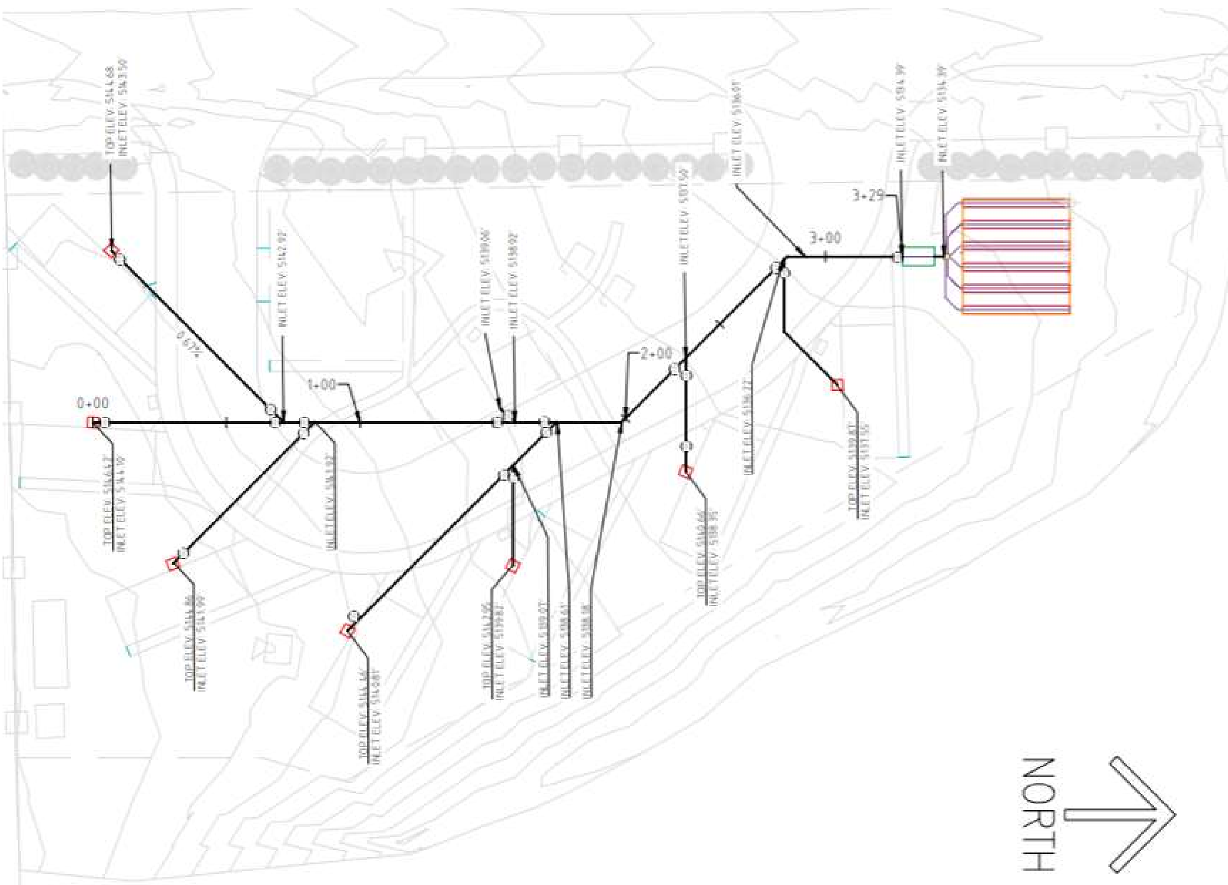


Figure 5- 1：Summary of On-site Wastewater Collection System

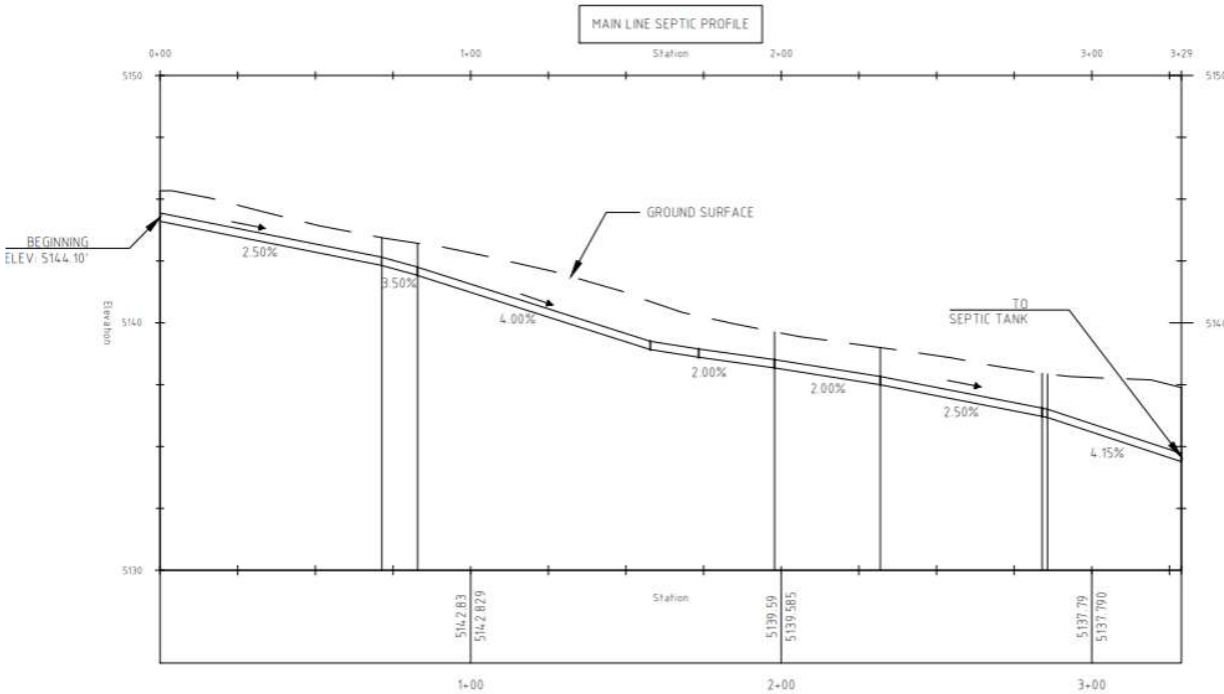


Figure 5- 2：Details of On-site Wastewater Collection System Slope

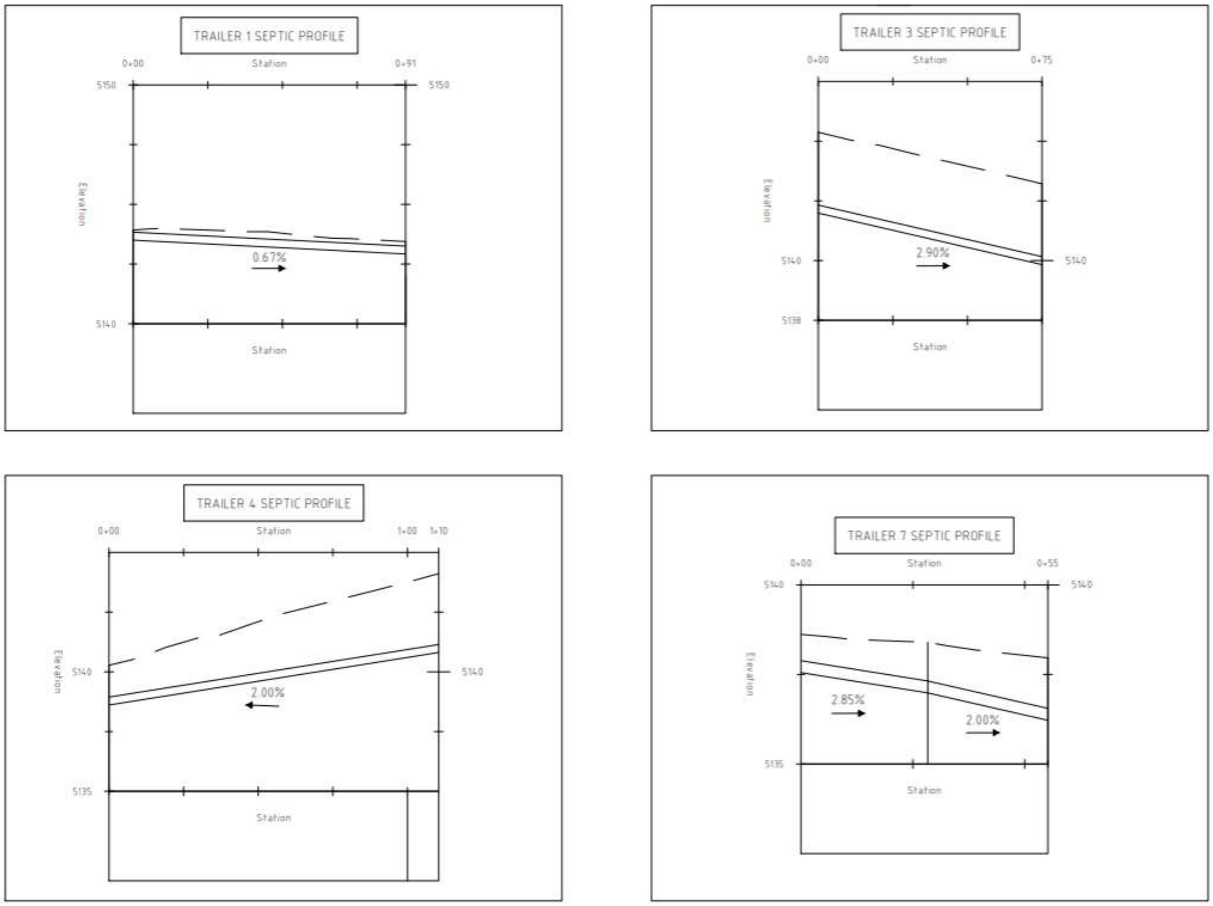


Figure 5- 3：Details of On-site Wastewater Collection System Slope

- Pipeline Layout and Bends: The network layout includes two 45° HDPE bends and seven 45° HDPE wye junctions to arrange and merge branch pipes while minimizing head loss and maintaining efficient hydraulic conveyance. The use of 45° wye junction allows for a smoother directional transition of water flow to the main line, helping to reduce turbulence and sediment accumulation, the pipe layout and the specific locations of bends and wye junctions are shown in Figure 5-1. The design of the Wye junction and bend is shown in Figure 5-4.

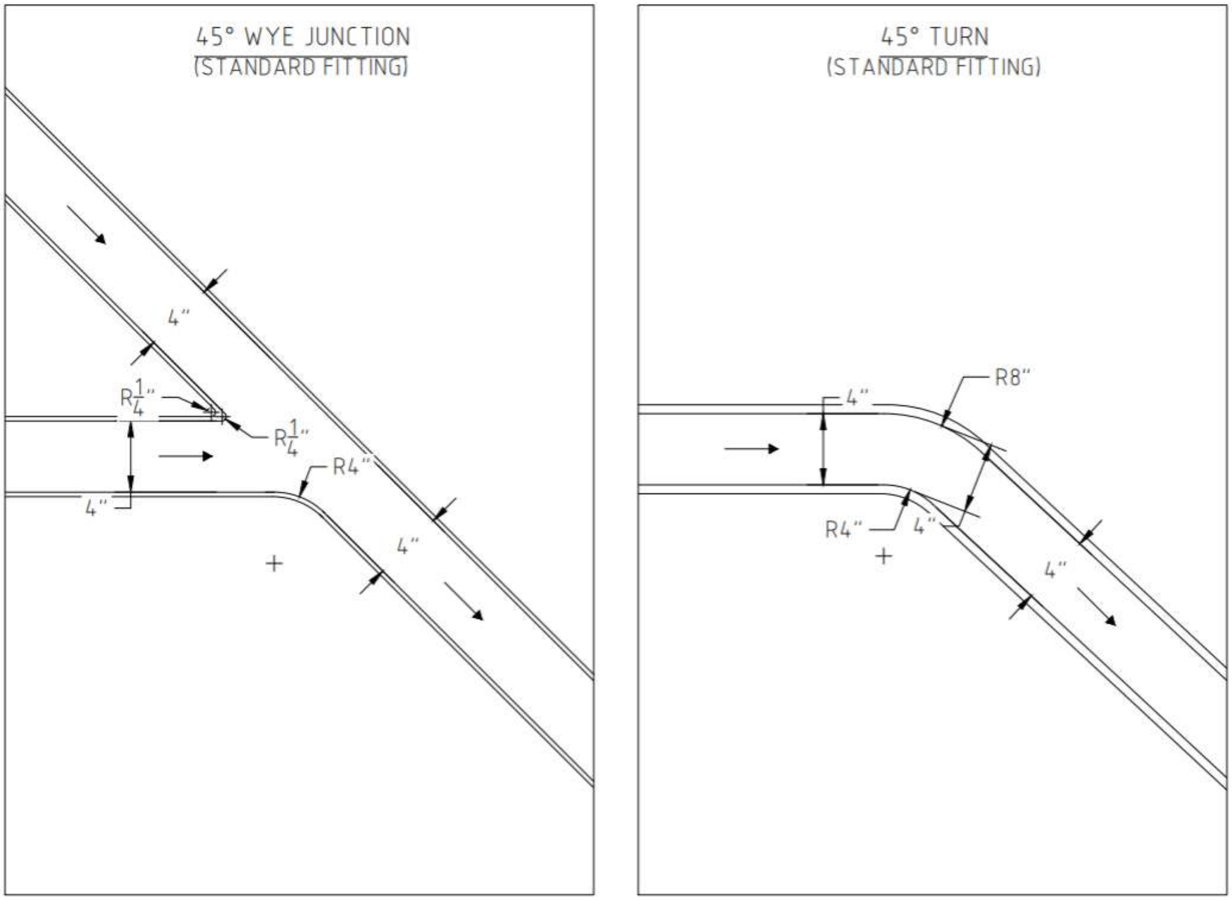


Figure 5- 4：Details of wye junction and bend

The plan view of the on-site wastewater collection map can be found in Appendix E.

5.3 Treatment System Design

This section details all the design for the treatment system.

5.3.1 Septic Tank Design

According to Arizona regulations, the effective volume of a septic tank should be no less than 2.1 times the daily design flow rate [10]. For a design flow rate of 1050 GPD, this means that the total volume of the septic tank is approximately:

- Daily design flow rate = 1,050 gallons/day
- Required septic tank volume = 1,050 × 2.1 ≈ 2205 gallons.

When selecting a septic tank, a standard capacity of about 2205 gallons (common specifications) can be used to meet this calculation requirement. This volume provides a retention time of more than about 2 days, which is enough time to complete solid-liquid separation and preliminary anaerobic treatment, exceeding the generally required minimum hydraulic retention time of 24–36 hours [17].

To achieve an effective volume of about 2205 gallons, the septic tank is rectangular in plan, with a length of about 2 to 3 times the width, a liquid depth of 4 to 6 feet, and a free board height of at least 1 foot [18]. The recommended dimensions and calculations are as follows:

- **Internal dimensions**: approximately 10 feet long, 5 feet wide, and a liquid depth of approximately 6 feet. This gives an internal effective volume of approximately $10 \times 5 \times 6 = 300$ cubic feet, or approximately 2244 gallons (1 cubic foot $\approx$ 7.48 gallons), which is slightly higher than the required 2205-gallon capacity and meets the requirements. A liquid depth of 6 feet is within the allowable range of the specification and provides sufficient residence time [18]. If 6 feet is considered as the effective liquid level and the volume above is not counted, the effective volume is slightly higher than 2205 gallons, meeting the 2.1 times daily flow rate standard.
- **Freeboard**: About 1 foot of free space (about 0.3 m) is reserved above the 6-foot liquid depth as a buffer for scum accumulation and flow fluctuations. The total internal height is about 7 feet (6 feet of liquid depth + 1 foot of freeboard). The freeboard height is not less than 0.8 to 1 foot to meet the specification requirements [18], and it accounts for about 10% of the liquid volume, which is enough to accommodate scum [19].
- **External dimensions**: Considering the thickness of the wall and the bottom plate, the total length of the septic tank is about 11 feet, the total width is about 6 feet, and the total height (including the top plate) is about 8 feet. This ensures the above-mentioned internal dimension requirements. The ratio of length to width is about 1.8:1, which is in line with the conventional design ratio range. If the site conditions require the adjustment of the dimension ratio (for example, increasing the depth to reduce the footprint), it should be ensured that the liquid depth does not exceed 8 feet and the part exceeding 6 feet is not included in the effective volume [20].

The design of the septic tank is shown in Figure 5-5, 5-6.

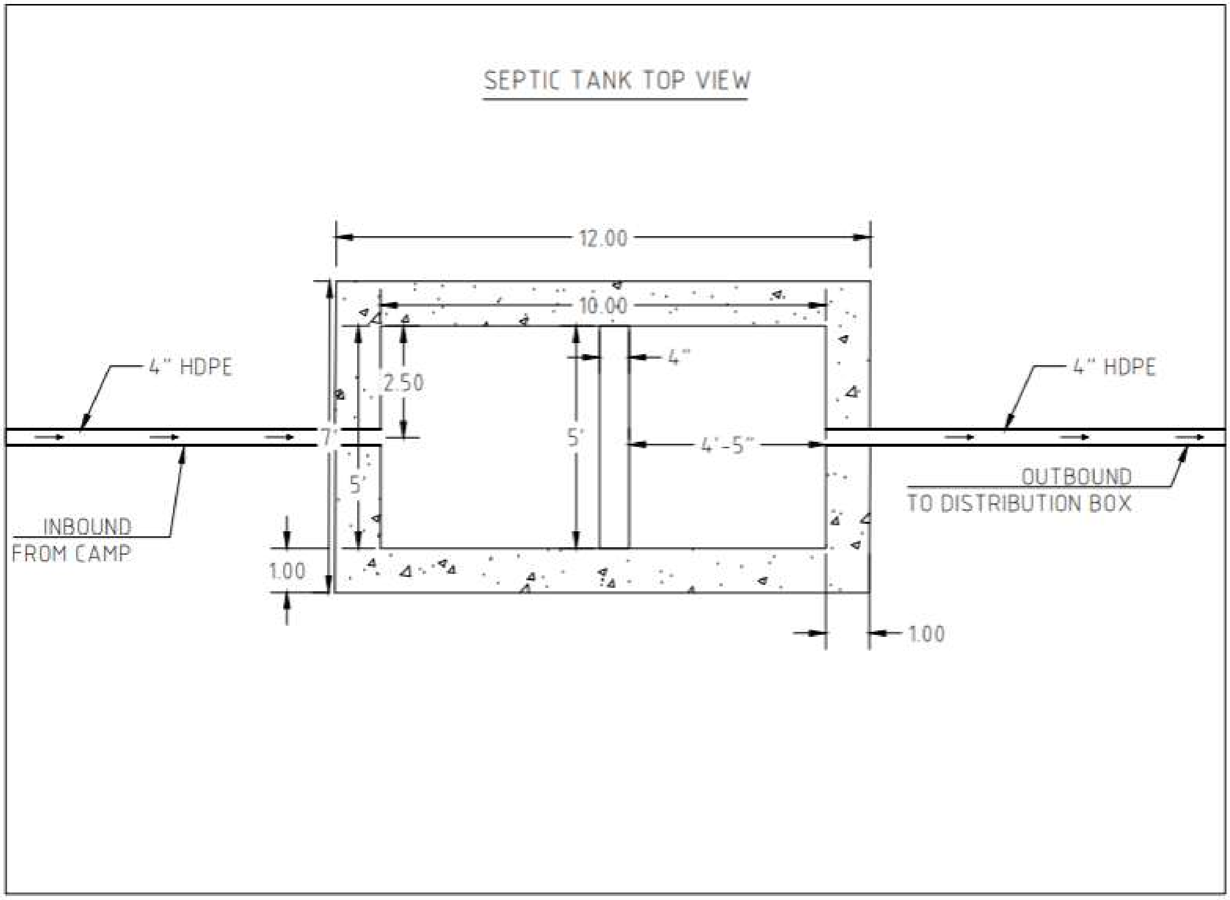


Figure 5- 5：Septic tank top view

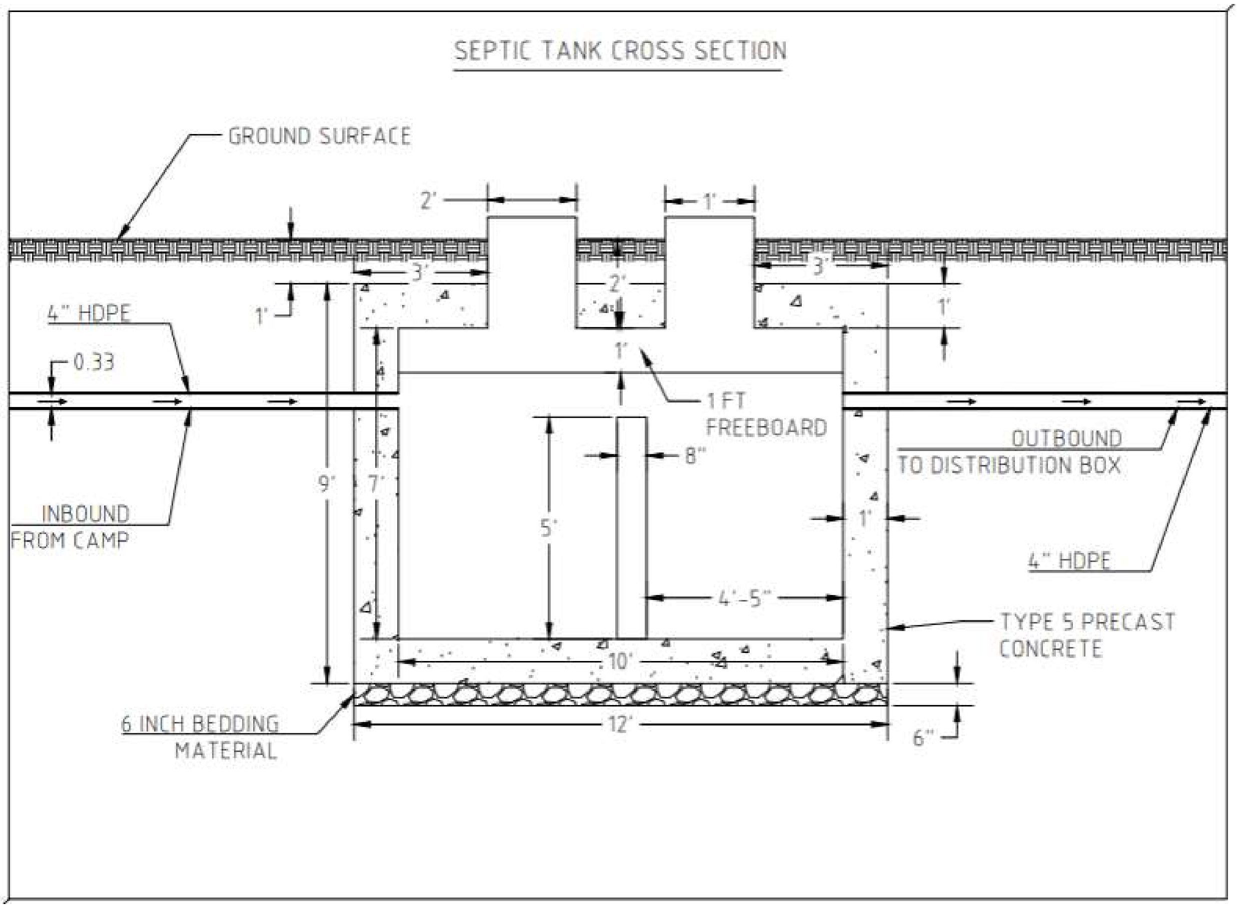


Figure 5- 6：Septic tank cross section

All the detail sheets regarding the Septic tank are shown in Appendix E. Table 5-3 below summarizes all the data of the septic tank.

Table 5- 3: Septic tank design data

Internal design data	
Long (ft)	10
Wide (ft)	5
Depth (ft)	6
Volume (ft^3)	300
Volume (Gallon)	2240
External design data (include Internal)	
Total length (ft)	11
Total wide (ft)	6
Total depth (ft)	8
Volume (ft^2)	528
Free plate	
Depth (ft)	1

5.3.2 Leach Field Area and Leach Channel Design

The soils absorption ratio (SAR) was determined using Arizona Administrative Code R18-9-A312(D)(2)(a) [21]. SAR is the rate at which soil is able to absorb effluent (sewage).

Under Section 2.1.1, the percolation testing rate was found to be 12 minutes and 16 seconds per inch, which is equivalent to 15 minutes per inch according to Arizona Admin. Code 18-9-A310, as it falls between 10 and 15 minutes per inch. Rounding up is done to obtain the SAR that is most conservative. Using R18-9-A310, the SAR is found in table 5-4 below.

Table 5- 4: Soil Absorption Ratio

Percolation Test Rate (Minutes per inch)	**SAR, Trench, Chamber, and Pit** (Gal/day/ft^2)
15.0	0.50

Soil Infiltration Rate Assumptions: Given a soil absorption rate SAR = 0.50 gpft/d. Calculate the total absorption area required for the infiltration field according to the code = Design Flow (GPD) ÷ SAR [22].

- Design Flow = 1,050 GPD
- SAR = 0.50 gpft/d
- Required Infiltration Area = 1,050 ÷ 0.50 = 2,100 ft2

So, a total infiltration area of approximately 2,100 square feet is required to adequately handle the effluent at this flow rate. To achieve this area, an infiltration field consisting of multiple parallel infiltration channels (gravel trenches) can be designed. The specific configuration of the infiltration channels is as follows:

- **Trench Dimensions**: The width of each trench bottom is typically in the range of 1–3 feet (ADEQ specifies 12–36 inches). To reduce the number of trenches required, this design uses a wider value, a 3 feet wide trench bottom. As required by the code, each trench is lined with crushed stone and perforated pipe, with a minimum of 12 inches of crushed stone below the pipe, and a minimum of 2 inches of crushed stone above the pipe, and a 12-inch cover of soil as a protective layer. The trench depth was controlled to within 6 feet of the surface to ensure an unsaturated soil layer above, and 4 feet of crushed stone was provided below the perforated pipe. [23].
- **Total length and number of infiltration trenches**: According to ADEQ, the absorption area per foot of trench is 11 square feet. Therefore, considering that 2,100 square feet of infiltration area is required, it is calculated that approximately 234 linear feet of infiltration trench is required. Considering the size of the site, the width of the infiltration trench is 3 feet, and the length of

each infiltration trench is designed to be 40 feet. At the same time, there are 6 infiltration trenches to meet the total infiltration [24].

- **Spacing and arrangement of infiltration channels**: The centers of adjacent infiltration channels should be spaced sufficiently apart to ensure that the lateral absorption capacity of the soil is not disturbed. The minimum clear distance between infiltration channels should be no less than 2 times the effective depth of the infiltration channel or 5 feet, whichever is greater. The infiltration channels in this design are moderately deep and can be arranged at a spacing of no less than about 5 feet [24] [23].

The design of the septic tank is shown in Figure 5-7, 5-8, 5-9.

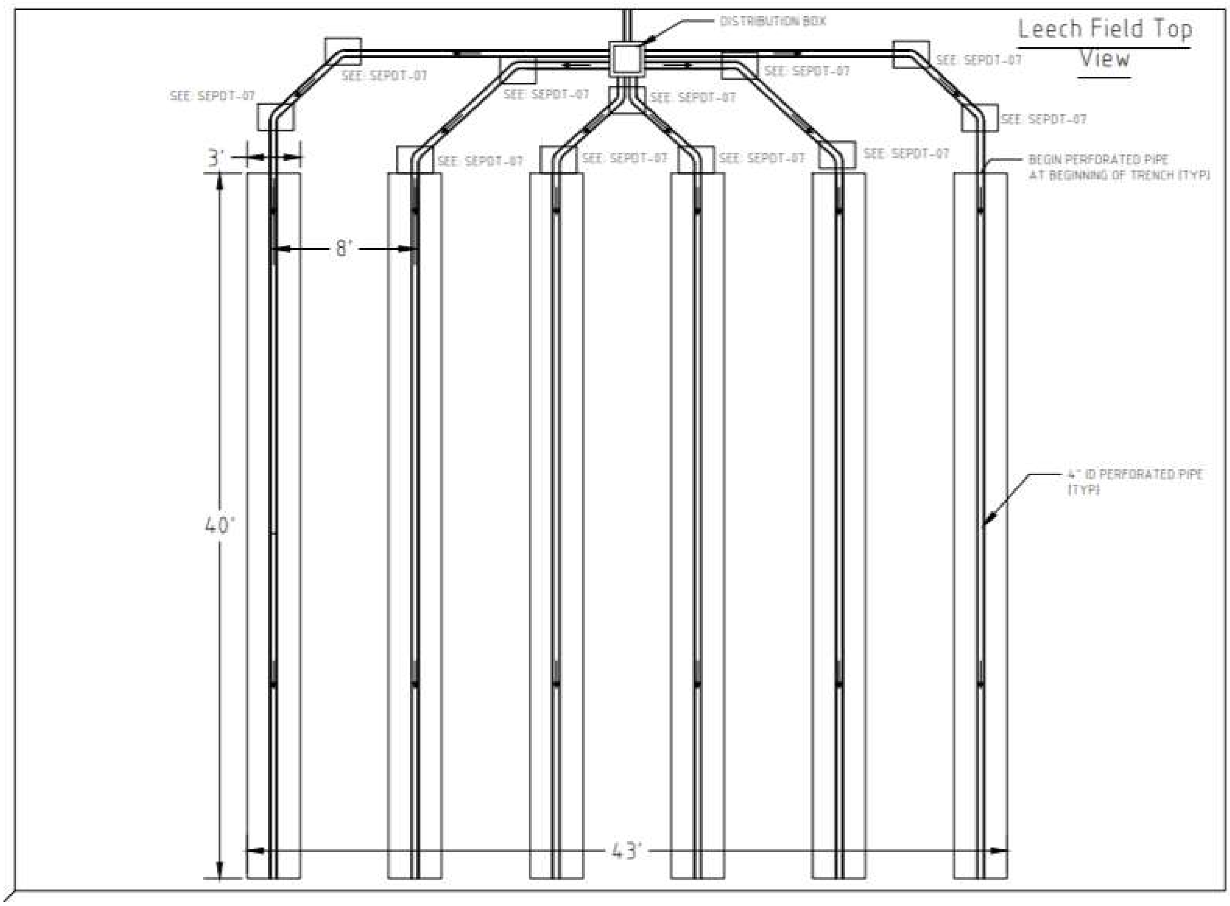


Figure 5- 7：Leach field top view

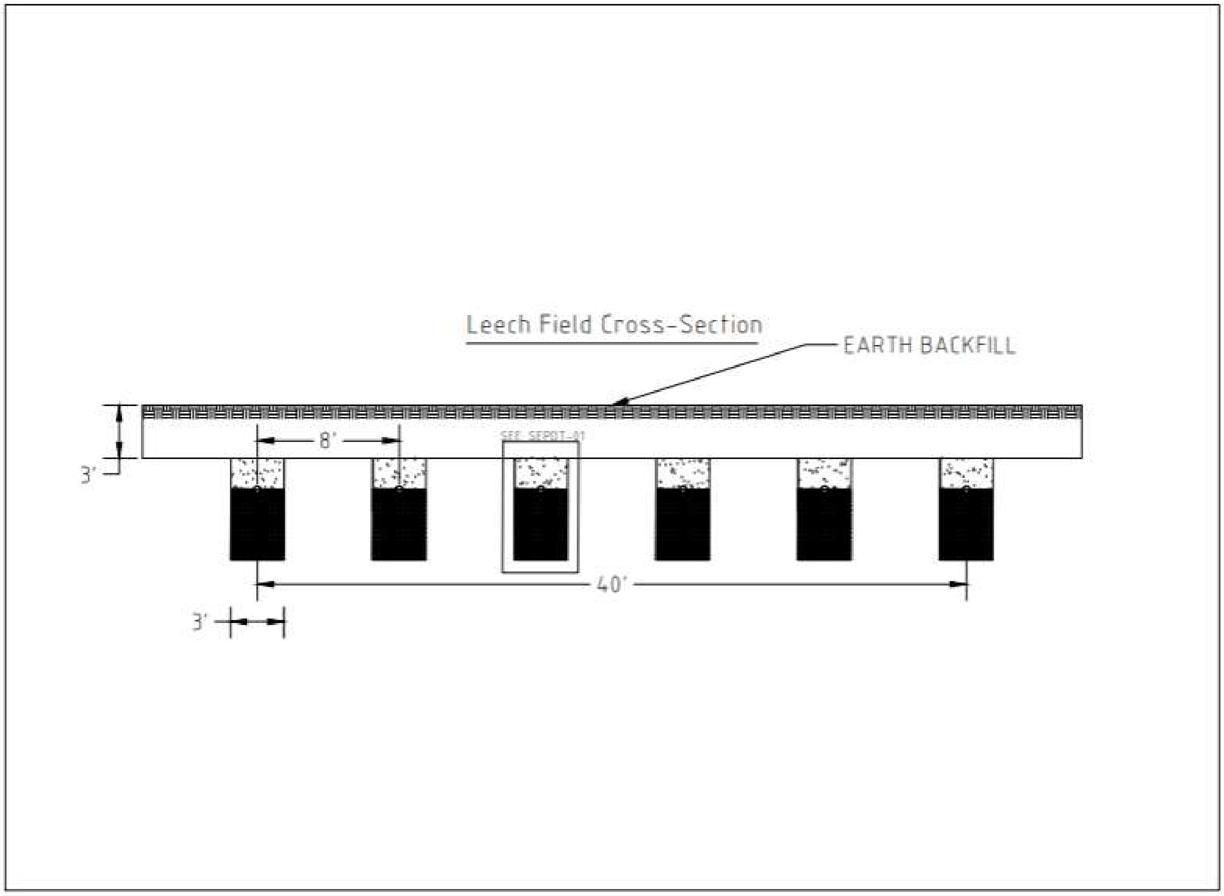


Figure 5- 8：Leach field cross section- 1

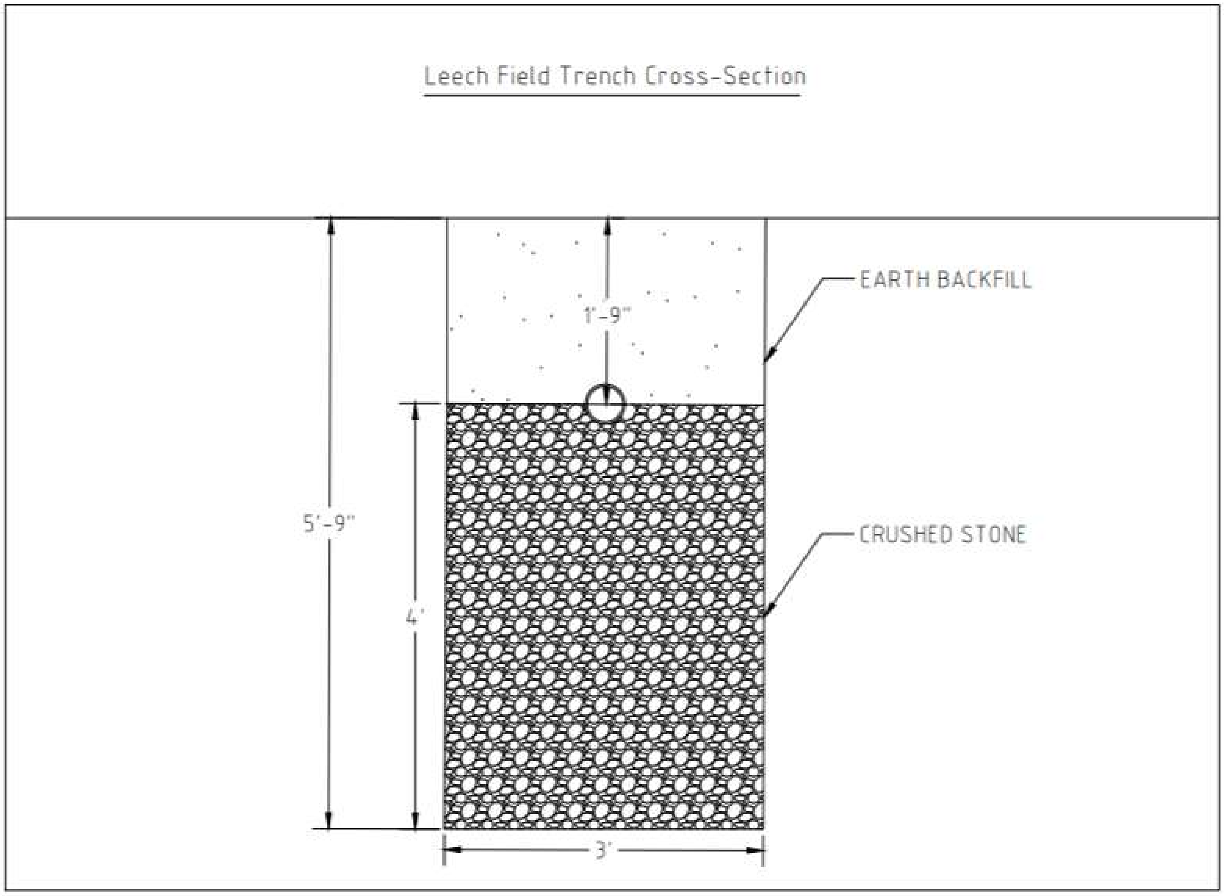


Figure 5- 9：Leach cross section -2

All the detailed design maps about Leach Field are shown in Appendix E.

Table 5-5 below summarizes all the data of the leach field area in a more intuitive way.

Table 5-5: Leach field design data

Infiltration trench	
Long (ft)	40
Wide (ft)	3
Depth (ft)	6
Trench number	6
Space between trenches (ft)	5
Leach field	
Total length (ft)	40
Total wide (ft)	43
Area (ft^2)	1720

5.3.3 Pipeline

- **Slope requirements**: The pipe should maintain sufficient slope to achieve gravity flow and prevent sedimentation. According to engineering and EPA recommendations, the minimum slope of small gravity sewer pipes is not less than 1% (i.e., at least 1 foot down for every 100 feet of length). In this design [24]:
    1. The septic tank outlet pipe (septic tank to distribution box) should also have a slope of about 1% to ensure a continuous one-way slope to avoid backslope water accumulation.
    2. The infiltration channel distribution pipe (perforated pipe from distribution box to each infiltration channel) is basically kept horizontal. The specification requires that the maximum slope of this section of perforated pipe should not exceed 0.5%, that is, close to horizontal. This ensures uniform outflow and infiltration along the length of the infiltration channel. The end of each infiltration channel pipe is blocked, and appropriate holes are opened at the highest end of the pipe for ventilation to promote uniform gravity distribution and soil aeration.
- **Pipe diameter in septic system**: All pipes in the entire septic system are of the same size, i.e. 4 inches, made of HDPE.

All the detailed design maps about septic tank system pipeline are shown in Appendix E.

Table 5-6 below summarizes all the data of the pipe in a more intuitive way.

Table 5- 6: Pipe design data

Pipe Design	
Diameter (inch)	4
Pipe from septic tank to distribution box	
Slope	2%
Length (ft)	78.17
Pipe from distribution box to leach field	
Length (ft)	6.3
Slope	0.5%
Pipe in Leach field	
Total length (ft)	240

5.3.4 Distribution Box Design

Since the infiltration field uses multiple infiltration trenches in parallel, a distribution box is required to evenly distribute the effluent from the septic tank to each infiltration trench. The distribution box should have sufficient size and number of outlets to connect all infiltration trench pipes. According to the above infiltration field design, 6 infiltration trenches will be required, so the distribution box needs to have at least 6 outlets and 1 inlet.

ADEQ specifically stipulates the design criteria for septic tank-infiltration trench systems with a design flow rate of less than 3,000 gallons per day, requiring that when there are two or more infiltration trench pipelines, a distribution box approved by the competent authority must be set up to accommodate all outlet branches and evenly distribute the flow; at the same time, it is stipulated that the bottom elevation of all outlet pipes of the distribution box should be at the same level, and the bottom elevation of the inlet pipe should be at least 1 inch higher than the outlet. ADEQ does not limit the distance between pipes.

Therefore, considering that 6 outlets and 1 inlet are required, the diameter of each outlet and inlet is 4 inches, each side of the distribution box is designed to accommodate two 4-inch openings, and the distance between the outlets is designed to be 4 inches, so the final design of the distribution box is a square with a single side of 2 feet [23].

The design of the septic tank is shown in Figure 5-10.

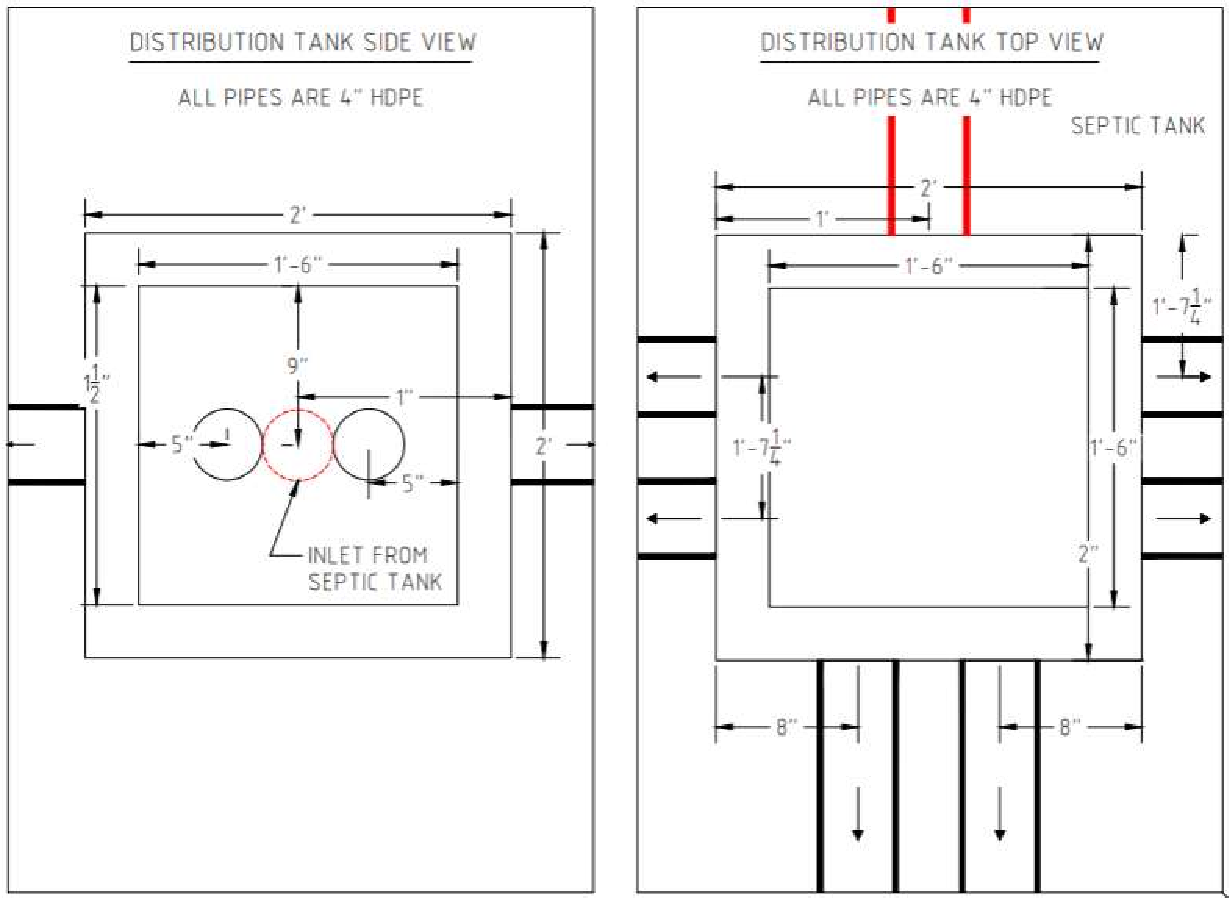


Figure 5- 10：Distribution Tank Design

All the design maps about distribution box are shown in Appendix E.

6.0 Construction Cost Estimate

The costs for this project consist of two main components, the wastewater collection system costs as well as the freshwater system costs and any additional construction costs required to build and design this project.

6.1 Wastewater Collection Costs

The sewer pipes will eventually flow into a septic tank treatment system that is appropriate for the campground's flow rate. The system consists of a septic tank and an underground infiltration field (drain field) to treat and discharge wastewater:

- Septic tank: Based on research, a 1,500-gallon concrete septic tank costs about $1,500-$2,500, which translates to about $3,000 for a 2,240-gallon concrete septic tank. Labor and installation costs are 50 percent of the septic tank price, or $1,500 [25], which means it costs $4,500 to order and install.
- Leach field: The calculation of the infiltration field cost is divided into excavation, backfill and gravel costs. It is calculated that 4,320 cubic feet of excavation are required, 2,880 square feet of gravel is buried under the pipe, and 1,440 cubic feet of backfill space are required. According to the research, the price of excavation and backfill is the same, both at $15 per cubic yard [26]. The price of crushed stone is $65 per cubic yard.
- Distribution box: Regarding the price of the distribution box, it varies depending on the material, considering that a 2’*2’*2’ concrete distribution box with 6 outlets and 1 inlet is about $300 [27].
- Labor fee: Labor costs usually account for 50%-70% of the system cost. Since excavation costs are not included, the labor cost is 50%, which is $18,997. [25].

Table 6-1 below provides a detailed breakdown of the costs.

Table 6-1. Wastewater Collection System Construction Cost Estimate

Wastewater Collection System Construction Cost Estimate					
Component	Unit	Quantity Estimate	Unit Cost ($)	Cost ($)	Notes
4'' HDPE Pipe	ft	870	10	8,700	The 4-inch diameter HDPE gravity sewer pipe collects sewage from various RV campgrounds and ancillary facilities into the septic tank (buried underground), covering the perforated HDPE pipe laid in the infiltration field trench to disperse the sewage and infiltrate it into the soil.
4’’ HDPE perforated Pipe	ft	240	10	2,400	The 4-inch diameter perforated HDPE pipe laid in the infiltration field trench disperses sewage and infiltrates it into the soil.
Septic Tank (2240 gallons)	unit	1	4,500	4,500	Precast concrete includes transport and set.

Wastewater Collection System Construction Cost Estimate (continued)					
Distribution Box (2' *2', 7 outlets)	unit	1	200	200	Effluent distribution box to split flow into leach trenches.
Crushed Stone (Leach Field Bedding)	CY	107	65	6,955	Clean crushed stone for leach field trench bedding and backfill around perforated pipes.
Earthwork (Excavation)	CY	161	15	2,415	Excavation for septic tank foundation pits, infiltration trenches, and wastewater pipes.
Earthwork (Backfill)	CY	54	15	810	After installation is completed, backfill the original soil.
45-degree bend	unit	4	23	92	4" fusion elbow fittings.
45-degree wye junction	unit	7	186	1,302	For multiple branch connections.
45° HDPE Bend (for 90° turn: 2 each)	unit	14	23	322	Two 45° elbows form a vertical drop from surface to sewer line.
Threaded Cleanout Adapter	unit	7	18	126	Threaded adapter to allow RV sewer hose connection.
HDPE Cap	unit	7	7	49	Cap to cover unused hookup when not in use.
Concrete Housekeeping Pad (2'x2')	unit	7	65	455	Pad at each RV sewer hookup to protect piping and provide level base.
Labor fee				14,163	
			Total cost	**$42,489**	

6.2 Freshwater Costs

The freshwater system will provide potable water to each RV site and provide the necessary water supply facilities. The design includes a network of water mains, individual service connections to the RV sites, and valves for isolation and control. The cost of the water supply system is based on the standard unit price of water supply pipe construction (calculated in 2025 US dollars), and the specific costs are as follows:

- Water supply main: The campsite will use HDPE water pipes with diameters of 2'', 1'' and 0.75'', with a total length of approximately 518.34 feet. Because different diameter water pipes are used, the material of each diameter water pipe is also different. The water pipe cost is estimated to be $ [28] [29] [30]. Due to design reasons, it is necessary to connect the fittings of different diameter water pipes and bends and tees of different diameters and angles, so this is also calculated in the cost expenditure, which is shown in Table 6-2. Since the water pipes are mainly buried, the total cost of excavation and reburying is $ [31] [32] [33] [34] [35].
- Valves: To partition the water supply system, multiple gate valves will be installed on the main pipe (such as at branch points and loop ends). It is expected that 8 2'' brass gate valves will be used, and the cost of each valve unit is approximately $65, which is a total cost of $520 [36].
- Service Hookups (RV Pads): Each of the seven RV pads comes with a water hookup, including a vertical riser and frost-proof faucet, at $150 per set, for a total of $1,050.
- Labor Fee: The cost of installing the pipes manually is usually between $45 and $200 per hour. Since this includes the cost of materials, the estimated labor cost is $50 per hour after deducting the material cost. If a team of four people needs three days to complete the entire freshwater system, the labor cost is $14,400 [37].

Table 6-2 below provides a detailed breakdown of the costs.

Table 6-2. Freshwater cost estimates

Freshwater Costs					
Component	Unit	Quantity Estimate	Unit Cost ($)	Cost ($)	Notes
2'' HDPE pipe	Ft	363	2.2	799	HDPE water supply pipes are laid underground from the well water supply to each RV campground and service facilities
1'' HDPE pipe	Ft	146	0.8	117	HDPE water supply pipes are laid underground from the well water supply to each RV campground

Freshwater Costs (continued)					
0.75'' HDPE pipe	Ft	10	0.6	6	HDPE water supply pipes are laid underground from the well water supply to each RV campground and service facilities
Valve (Brass)	Unit	8	65	520	2-inch brass gate valve installed close to the water source connection provides isolation control for the new water supply line.
Service Hookups (RV Pads)	Unit	7	150	1,050	Water connection at each of 7 RV sites, including vertical riser pipe and freeze-proof spigot
Earthwork (Excavation)	CY	4	15	60	Trenching for water pipe installation
Earthwork (Backfill)	CY	4	15	60	Backfilling/compacting after pipe placement.
1'' 25 Degree Bend	unit	1	6.2	7	1" 25-degree bend are not common, so choose a 1" 45-degree bend, but it is made of metal and is used to bend to 25 degrees.
1'' 45 Degree Bend	unit	1	6.2	7	Metal
2'' 45 Degree Bend	unit	4	13.2	53	HDPE
2'' 90 Degree Bend	unit	1	7.4	8	HDPE
1'' 90 Degree Bend	unit	2	6.2	13	HDPE
2'' 90 Degree Tee	unit	6	13.2	80	HDPE
2'' to 1'' Fitting	unit	2	9.2	19	HDPE
2'' to 0.75'' Fitting	unit	5	9	45	HDPE
Labor fee				14,400	
			Total cost	**17,244**	

7.0 Summary of Engineering Work

The engineering work for this project was performed by four team members. The proposed table of engineering work shows the initial project hours scoped by the team among four engineering roles; the proposed engineering work was created with more limited knowledge of the processes that were needed to complete all design work. The initial engineering work is shown in Table 7-1 below.

Table 7- 1: Proposed Engineering Work

Task	Senior Engineer	Engineer	EIT	Intern	TOTAL HOURS BY TASK
Task 1 Research and Existing Data	0	2	7	8	17
Task 2 Site Visit	1	8	26	13	48
Task 3 Geotechnical Sampling Analysis	2	3	4	4	13
Task 4 Topographical Map Development	1	1	4	16	22
Task 5 Freshwater Distribution Design	10	21	66	33	130
Task 6 Onsite Wastewater Treatment Design	11	19	19	15	64
Task 7 Wastewater Collection System Design	2	5	2	3	12
Task 8 Develop Construction Cost Estimate	1	2	5	2	10
Task 9 Plan Set Development	3	13	38	43	96
Task 10 Evaluate Project Impacts	3	6	2	0	11
Task 11 Deliverables	8	8	16	24	56
Task 12 Project Management	6	11	3	0	20
TOTAL	51	103	196	165	**514**

Table 7-2 below shows the actual engineering work hours.

Table 7- 2: Actual Engineering Work

Task	Senior Engineer	Engineer	EIT	Intern	TOTAL HOURS BY TASK
Task 1 Research and Existing Data	0	10	28	0	38
Task 2 Site Visit	5	9	45	10	69
Task 3 Geotechnical Sampling Analysis	4	5	10	7	26
Task 4 Topographical Map Development	0	0	2	1	3
Task 5 Freshwater Distribution Design	3	8	12	0	23
Task 6 Onsite Wastewater Treatment Design	5	23	15	2	45
Task 7 Wastewater Collection System Design	0	11	3	10	24
Task 8 Develop Construction Cost Estimate	0	0	0	3	3
Task 9 Plan Set Development	0	13	26	0	39
Task 10 Evaluate Project Impacts	0	0	0	5	5
Task 11 Deliverables	6	8	13	28	55
Task 12 Project Management	16	18	27	18	73
TOTAL	39	105	181	84	**409**

After completing this project and all technical work, the team logged a total of 409 project hours for each of the four roles. The hours distribution for each of the roles is accurate to the proposal, the EIT worked the most hours while the senior engineer worked the least. This difference in the total hours difference from the initial proposal to the actual hours worked is 105 hours. The result of having less hours is due to a few things such as including buffer and float time for tasks that did not require additional float time for project completion. Another factor is that when working through the project several subtasks were combined into one over-arching task, resulting in less hours per task. There was also an increase in learning throughout the project, and the team's efficiency in using communication skills to delegate and distribute task workload better among the roles allowed for quicker completion than initially proposed.

8.0 Summary of Engineering Costs

The summary of engineering costs section details a full summation of the initial project costs considering personnel, travel, and supplies proposed during the initial proposal, and compares them to the actual cost of engineering services considering the actual project hours for each role.

Table 8-1 below shows the initial projected project hours created by the team for the initial project proposal.

Table 8- 3: Estimated Staffing Hours Summary Table

	Senior Engineer	Engineer	EIT	Intern	TOTAL HOURS BY TASK
TOTAL	51	103	196	165	**514**

Table 8-2 below shows the actual staffing hours for project completion.

Table 8- 4: Actual Staffing Hours Summary Table

	Senior Engineer	Engineer	EIT	Intern	TOTAL HOURS BY TASK
TOTAL	39	105	181	84	**409**

The new cost of engineering services has also been updated to reflect the accurate and current engineering hours for this project, as personnel hours have decreased. Another notable change is under supplies, when performing lab testing the soils lab rental did not take ten days, and lab work performed by the team was able to be completed over the course of two days including the time spent on the soil samples to stay overnight in the drying oven. The proposed cost of engineering services can be found below in Table 8-3.

Table 8- 3: Proposed Cost of Engineering Services

1.0 Personnel	Classification	Hours	Rate, $/Hour	Cost, $
	SENG	50.5	240	$12,120
	ENG	102.5	180	$18,450
	EIT	196	141	$27,636
	INT	165	82	$13,530
			Personnel Total	$71,736
2.0 Travel	Classification	Items	Cost Per, $	Cost, $
	Car Rental	Mini Van, 3 Days	$49.75/day	$150
	Hotel	3 Rooms, 2 Nights	$145/room/day	$870
	Mileage	744 miles	$0.26/mile	$194
	Per Diem	3 Person, 3 Days	$54/person/day	$486
			Travel Total	$1,700
3.0 Supplies	Classification	Items	Cost Per, $	Cost, $
	5 Gallon Bucket	1 Unit	$4.00	$4
	Quart Ziplock Bags	40 bags	$0.1/bag	$4
	Surveying Equipment	3 Days	$100/day	$300
	Soils Lab Rental	10 Days	$100/day	$1,000
			Supplies Total	$1308
Total Cost				$74,774

The updated cost of engineering services along with the updated supplies can be found below in Table 8-4.

Table 8-4: Actual Cost of Engineering Services

1.0 Personnel	Classification	Hours	Rate, $/Hour	Cost, $
	SENG	39	240	$9,360
	ENG	92	180	$16,560
	EIT	181	141	$25,521
	INT	84	82	$6,888
			Personnel Total	$58,329
2.0 Travel	Classification	Items	Cost Per, $	Cost, $
	Car Rental	Mini Van, 3 Days	$49.75/day	$150
	Hotel	3 Rooms, 2 Nights	$145/room/day	$870
	Mileage	744 miles	$0.26/mile	$194
	Per Diem	3 Person, 3 Days	$54/person/day	$486
			Travel Total	$1,700
3.0 Supplies	Classification	Items	Cost Per, $	Cost, $
	5 Gallon Bucket	1 Unit	$4.00	$4
	Quart Ziplock Bags	40 bags	$0.1/bag	$4
	Soils Lab Rental	2 Days	$100/day	$200
			Supplies Total	$208
Total Cost				$60,237

When completing the actual cost of engineering services table, the total cost is in total $60,537, considering the updated hours and supplies. The surveying equipment was also removed, as a site design team performed surveying. The cost of this project has decreased from the initial proposal, this being due to the initial engineering hours projected to be larger and lab testing predicted to take longer. The total cost difference between the proposal and the actual cost has decreased by $14,537.

9.0 Project Impacts

This section details the impacts of this project, including environmental, economic, and societal impacts. Commonly referred to as a 'Triple Bottom Line Analysis', this method analyzes how the implementation of this septic project affects people, the planet, and cost, both in positive and negative ways. After evaluating all three of these sectors, it can be noted that the positive impacts for implementing this project outweigh the negative impacts.

9.1 Environmental Impacts

Environmental impacts for this project are unavoidable, as design of an on-site wastewater treatment system requires careful examination of how the environment is affected by the disposal of effluent, and it is necessary to make sure it is disposed of correctly. The type of on-site wastewater treatment system varies in effluent and treatment technology, and in cases of failure can release detrimental chemicals that will negatively affect the environment. But ensuring that this effluent is treated, through the usage of a septic tank and leach field system, removes harmful discharge to the local soil. As this is an NPS site, making sure there is minimal site disturbance for the local plants or wildlife is essential and is a positive of having a smaller system. Putting in these RV pads also involves not building larger scale housing projects, and there is less land lost by putting in these pads.

9.2 Economic Impacts

There are a few key positive economic impacts for this project, because of the smaller site area the costs for installing and maintaining this project will be relatively cheap compared to large scale commercial wastewater treatment plants, the value for small sites is key instead of connecting to a centralized sewage system. The implementation of this project at the site also provides jobs for local contractors and park service employees who will live in RV housing. But there is a potential negative impact, if the system fails and leaches, the need for an upgrade in the future will require additional costs, this is true for any failure of an on-site wastewater treatment system. Another positive, however, is that there are more long-term savings for the NPS, as the low operation and maintenance costs for a septic system outweigh the costs of a large-scale water treatment system.

9.3 Societal Impacts

Societal impacts for this project include a positive in public health and local health, as there is no risk of exposure to untreated wastewater or sewage to those living in the area. The seasonal employees will be positively affected as there is clean and safe water on site, which promotes the workforce's wellbeing. In addition to the on-site wastewater treatment system, the RV hookups will provide drinking water, and volunteers can enjoy the neighboring plants and vegetation being planted on the project site as well. One potential negative impact of implementing this project is that workers will have no access to new housing, and they would require continuing to travel long distances to the project site and the monument. By implementing this project, the visitation numbers for Chiricahua National Monument will also increase as having more seasonal staff during the summer season allows for more servicing to monument visitors. By putting in this project visitors are boosting this National Monument's local tourism.

10.0 Conclusion

In conclusion, the team was able to design a delivery and wastewater system for this site. We also learned many valuable lessons in utility design. Though no one in the group prioritizes either potable or wastewater as their primary focus in engineering, it is still something that is critically important for all engineers to understand, as essentially every major project involves utilities in some way. Lessons such as demand calculations on such a small scale, though it took several attempts to get, septic design, and many others are just a few examples of lessons learned.

References

[1] AZDEQ, "R18-9-A312. Facility Design for Type 4 Onsite Wastewater Treatment Facilities.".

[2] "Ariz. Admin Code 18-9-A310," [Online]. Available: https://casetext.com/regulation/arizona-administrative-code/title-18-environmental-quality/chapter-9-department-of-environmental-quality-water-pollution-control/article-3-aquifer-protection-permits-general-permits/part-a-general-provisions/section-r18-9-a.

[3] A. International, "Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort," [Online]. Available: file:///C:/Users/jeeva/Downloads/Modified%20Proctor%20ASTM%201557%20(1).pdf.

[4] MARLO INCORPERATED, "Water Flow Rate & Sizing Guide," [Online]. Available: https://www.marlo-inc.com/sites/default/files/inline-files/Water%20Flow%20Rate%20%20Sizing%20Guide%202-307.pdf. [Accessed 4 May 2025].

[5] K. Snodgrass, "Water Use in Forest Service Recreation Areas:," Septemner 2007. [Online]. Available: https://www.fs.usda.gov/t-d/pubs/pdfpubs/pdf07732326/pdf07732326dpi72.pdf. [Accessed 22 April 2025].

[6] Engineering Toolbox, "Hazen-Williams Friction Loss Coefficients: Data & Reference Guide," [Online]. Available: https://www.engineeringtoolbox.com/hazen-williams-coefficients-d_798.html. [Accessed April 22 2025].

[7] ADEQ, "Site Investigation Guidance Manual," [Online]. Available: https://legacy.azdeq.gov/environ/waste/cleanup/download/si_guidance_manual.pdf.

[8] https://www.epa.gov/septic/types-septic-systems, Artist, *Septic Tank.* [Art].

[9] B. B. Zito, "How Much Does a Septic System Cost? [2025 Data]," 8 October 2024. [Online]. Available: https://www.angi.com/articles/what-does-it-cost-install-septic-system.htm.

[10] "Arizona Administrative Code Title 18-9," 2023. [Online]. Available: https://apps.azsos.gov/public_services/title_18/18-09.pdf.

[11] "Onsite Wastewater Treatment Systems Manual," February 2002. [Online]. Available: https://www.epa.gov/sites/default/files/2015-06/documents/2004_07_07_septics_septic_2002_osdm_all.pdf.

[12] J. Cattanach, "How Does a Mound Septic System Work?," 4 June 2024. [Online]. Available: https://www.angi.com/articles/mound-septic-system.htm.

[13] "Recirculating Media Filter Operation and Maintenance - PUB2738," [Online]. Available: https://dnr.mo.gov/document-search/recirculating-media-filter-operation-maintenance-pub2738/pub2738. [Accessed 2025].

[14] "Wastewater Regulations," [Online]. Available: https://www.nowra.org/library/resources-for-industry-professionals/regulation/.

[15] EPA, "Decentralized Systems Technology Fact Sheet Recirculating Sand Filters," [Online]. Available: https://www3.epa.gov/npdes/pubs/finalr_7e6.pdf.

[16] WRF, "Understanding the Impacts of Wastewater Treatment Performance on Advanced Water Treatment Processes and Finished Water Quality," [Online]. Available: https://www.waterrf.org/system/files/resource/2023-07/DRPT-4833.pdf.

[17] "Department of Environmental Quality – Water Pollution Control,TITLE 18. ENVIRONMENTAL QUALITY,CHAPTER 9. DEPARTMENT OF ENVIRONMENTAL QUALITY," [Online]. Available: https://www.maricopa.gov/DocumentCenter/View/7495/Arizona-Administrative-Code-Title-18-Chapter-9-Articles-1-2-3-4-PDF#:~:text=b,tank%20is%20at%20least%2067.

[18] "12VAC5-610-815. Septic tank design.," [Online]. Available: https://law.lis.virginia.gov/admincode/title12/agency5/chapter610/section815/#:~:text=longitudinal%20view,3.

[19] "WAC 246-272C-0220," [Online]. Available: https://app.leg.wa.gov/wac/default.aspx?cite=246-272C-0220#:~:text=damage%20or%20functional%20failure.

[20] "septic_tank_design_requirements," [Online]. Available: https://www.deq.gov.mp/assets/ww-forms/septic_tank_design_requirements.pdf#:~:text=Quality%20www,considered%20for%20calculating%20tank%20capacity.

[21] "Ariz. Admin. Code § 18-9-A312," 10 January 2025. [Online]. Available: https://casetext.com/regulation/arizona-administrative-code/title-18-environmental-quality/chapter-9-department-of-environmental-quality-water-pollution-control/article-3-aquifer-protection-permits-general-permits/part-a-general-provisions/section-r18-9-a.

[22] "Septic System Sizing Charts for Leach Bed Disposal," [Online]. Available: https://www.maricopa.gov/DocumentCenter/View/7460/Residential-Sizing-Charts-for-Leach-Bed-Disposal-PDF#:~:text=Design%20Flow%20,NOT%20ALLOWED%20FOR%20CONVENTIONAL%20DISPOSAL.

[23] "R18-9-E302. 4.02 General Permit: Septic Tank With Disposal by Trench, Bed, Chamber Technology, or Seepage Pit,," [Online]. Available: https://legacy.azdeq.gov/environ/water/permits/download/rules/4.02.pdf#:~:text=Shallow%20and%20Deep%20Trenches%20Minimum,trench%2012%20inches%2036%20inches.

[24] "AED Design Requirements Sanitary Sewer & Septic Systems," [Online]. Available: https://www.tad.usace.army.mil/Portals/53/docs/TAA/AEDDesignRequirements/AED%20Design%20Requirements%20-%20Sanitary%20Sewer%20and%20Septic%20Systems_Jun-

10.pdf#:~:text=evenly%20over%20the%20absorption%20trenches,no%20longer%20than%2030%20meters.

[25] B. B. Zito, "How Much Does a Septic System Cost? [2025 Data]," [Online]. Available: https://www.angi.com/articles/what-does-it-cost-install-septic-system.htm.

[26] K. Cramer, "Excavation cost," [Online]. Available: https://homeguide.com/costs/excavation-cost#:~:text=Cost%20factors-,Excavation%20cost,and%20amount%20of%20earth%20moved..

[27] M. Grant, "How Much Does a Septic Distribution Box Replacement Cost? [2025 Data]," [Online]. Available: https://www.angi.com/articles/septic-distribution-box-replacement-cost.htm.

[28] "3/4" IPS SDR11 PE4710 Black Hdpe Pipe Straight Length Per Foot," [Online]. Available: https://hdpesupply.com/3-4-ips-sdr11-pe4710-black-hdpe-pipe-straight-length-per-foot/.

[29] "2" IPS SDR11 PE4710 Black Hdpe Pipe Straight Length Per Foot," [Online]. Available: https://hdpesupply.com/2-ips-sdr11-pe4710-black-hdpe-pipe-straight-length-per-foot/.

[30] "1" IPS SDR11 PE4710 Black Hdpe Pipe 500' Coil," [Online]. Available: https://hdpesupply.com/1-ips-sdr11-pe4710-black-hdpe-pipe-500-coil/.

[31] "Butt Fusion 45deg Elbow 2" IPS, DR11," [Online]. Available: https://hdpesupply.com/butt-fusion-45deg-elbow-2-ips-dr11/.

[32] "2" IPS 90 DEGREE ELBOW HDPE BUTT DR11," [Online]. Available: https://www.polypipesupply.com/products/2-ips-90-degree-elbow-hdpe-butt-dr11?srsltid=AfmBOor9P__BGuwJNo6FPk7QhNo4S4pIQj9MMkh9DDqWaFbMBQJxR02w.

[33] "Butt Fusion 90deg Elbow 1" IPS, DR11," [Online]. Available: https://hdpesupply.com/butt-fusion-90deg-elbow-1-ips-dr11/.

[34] "1 Butt Fusion Reducer 2" IPS x 1" IPS DR11," [Online]. Available: https://hdpesupply.com/butt-fusion-reducer-2-ips-x-1-ips-dr11/.

[35] "HDPE SDR 11 IPS Butt Fusion Tee," [Online]. Available: https://getpipe.com/hdpe-sdr-11-ips-butt-fusion-tee/?sku=HDF211T&gad_source=1&gad_campaignid=18343613695&gbraid=0AAAAAo4zm-TvJFJronwiX37jtZIOvhpKW&gclid=Cj0KCQjwt8zABhDKARIsAHXuD7ar1J9r8AAU_ijDp2m5QWt5njd9SQAvycSWvfdH4oqdvv-iV6P4JFcaAtJFEALw_wcB.

[36] "2 in. FIP x 2 in. FIP Full Port Lead Free Brass Ball Valve," [Online]. Available: https://www.homedepot.com/p/2-in-FIP-x-2-in-FIP-Full-Port-Lead-Free-Brass-Ball-Valve-116-2-2-EB/205815467.

[37] W. D. P. R. C. f. a. S. P. o. P. [. Data]. [Online]. Available: https://www.angi.com/articles/how-much-does-installing-or-replacing-plumbing-pipes-cost.htm.

[38] US EPA, "Showerheads," United States Enviornmental Protection Agency, [Online]. Available: https://www.epa.gov/watersense/showerheads. [Accessed 20 March 2025].

[39] US EPA, "Bathroom Faucets," United States Enviornmental Protection Agency, [Online]. Available: https://www.epa.gov/watersense/bathroom-faucets#:~:text=Specification%20Revision-,Faucet%20Flows,per%20minute%20without%20sacrificing%20performance.. [Accessed 20 March 2025].

[40] R. Carollo, "What is a Typical Home Water Flow Rate?," Aquasana, [Online]. Available: https://www.aquasana.com/info/what-is-a-typical-home-water-flow-rate-pd.html#:~:text=Shower%3A%201.5-3%20GPM,Washing%20machine%3A%203-5%20GPM. [Accessed 20 March 2025].

[41] Premier, "What's Considered a Good Household Water Flow Rate?," [Online]. Available: https://www.premierh2o.com/blogs/news/what-s-considered-a-good-household-water-flow-rate#:~:text=Average%20Water%20Flow%20Rate&text=It%27s%20measured%20in%20gallons%20per,flow%20rate%20in%20your%20home.. [Accessed 20 March 2025].

Appendices