NORTHERN ARIZONA UNIVERSITY

Solutions & Advancements
Water & Wastewater Engineering

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Design Report:
Sun Valley Ranch Water & Wastewater Systems Development Plans

Solutions & Advancements in Water & Wastewater Engineering:

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List of Abbreviations

ADEQ: Arizona Department of Environmental Quality
ADWR: Arizona Department of Water Resources
CSRR: Custom Soil Resource Report
EPA: Environmental Protection Agency
ET: Evapotranspiration Rate
GIS: Geographic Information System
GPM: Gallons per Minute
LLC: Limited Liability Corporation
USDA: United States Department of Agriculture
USGS: United States Geological Survey

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Acknowledgements

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1.0 Project Description

1.1 Project Purpose

The purpose of this project is to evaluate alternatives and prepare preliminary designs for cost effective wastewater and water systems for the Sun Valley Ranch client. These systems are needed because there are currently no existing public systems to which the client can connect. This report includes the project understanding, research and analysis to identify preferred alternatives, the cost of these alternatives and this project, and the preliminary designs for the water and wastewater systems.

1.2 Project Understanding

The Sun Valley Ranch is a proposed self-sufficient ranch in Sun Valley, Arizona. The ranch will be open May through October (about six months) and will host visitors looking for a retreat in writing and art. The client plans to create a central dome house in the middle of the site. There will be four 16-ft diameter smaller dome houses adjoining the 30-ft diameter central dome house.

The client wants the average Arizona family to be able to incorporate similar water supply systems and wastewater systems. He has requested that the systems adhere to the following requirements:

- Non-intrusive
- Scalable
- Support an average of 5-10 people
- Minimize cost
- Minimize maintenance
- Allow for easy startup and shutdown during the off-season months
- Follow sustainable practices

A more in-depth description of these requirements is provided below:

<u>Non-Intrusive</u>
The systems should minimally impact the site's current environment, not cause permanent changes, or require extensive excavations.

<u>Scalable</u>
The client anticipates that the retreat's population will slowly grow in the future, and thus the water supply and wastewater systems must be easily expandable.

<u>Support an Average of 5-10 People Regularly</u>
The client expects an average of 5-10 people to be staying at the retreat between May and October. Therefore, both systems must meet the water demands of this population.

<u>Minimize Cost</u>
Both systems will ideally cost less than conventional systems, which typically include septic tanks and wells. This includes capital, construction, and maintenance costs.

<u>Minimize Maintenance</u>
The client wants the system to be easy to use and maintain for the average American resident.

Allow for Easy Startup and Shutdown during the Off-Season Months

Because the retreat will not be open year-round, it is important that both systems can go offline and easily be returned to service. The wastewater system needs to be designed to make the process of emptying less time consuming and to minimize the volume of wastewater that needs to be emptied at the end of October. The stored drinking water must be able to sit for six months without the possibility of stagnation, or it must be removed to prevent stagnation.

Follows Sustainable Practices

The client would prefer that the retreat is as self-sufficient as possible, and thus each system will limit the usage of energy and other components or materials that are obtained off-site. The systems will reuse and minimize water whenever possible.

The constraints and limitations of the project include verifying that the systems used meet Navajo County, state, and federal regulations. The wastewater system must meet the requirements set by the Arizona Department of Environmental Quality (ADEQ) and Navajo County for on-site wastewater treatment facilities. The potable water used for the water supply system will meet the requirements set by the U.S. Environmental Protection Agency (EPA).

1.2.1 Background Information

Sun Valley, Arizona, is a small town located in the Painted Desert that has a dispersed rural population of approximately 300-350 people, according to the client. As shown in **Figure 1-1**, the town is near Holbrook and the Petrified Forest National Park. Sun Valley Ranch is a 10 acre lot of land located at 7561 Sundown Road. The main stakeholder for the project will be the client, Christopher Fernandes, and his company, Sun Valley Ranch, Limited Liability Company (LLC).

Figure 1-1 Google maps image of the location of Sun Valley in north-eastern Arizona

On October 11th, 2014, the team visited the site to gather information about the site conditions and collect soil samples. **Figure 1-2** shows a picture of the northern corner of Sun Valley Ranch and its conditions. This picture was taken during the site visit in 2014.

Figure 1-2 Photo of northern corner of Sun Valley Ranch, LLC
Photo Credit: Sara Bateman

According to the client, there are no existing infrastructure, such as utilities or wells, on the site and it is flat with no relief over 5 feet. The client provided a Custom Soil Resource Report (CSRR) performed by the United States Department of Agriculture (USDA). This is provided in **Appendix A**. This report indicated that the site contains sandy loam soil. Sandy loam soil can be used for septic systems when depths are adequate. Petrified wood fragments are present on the property.

1.3 Technical Tasks

The team evaluated, analyzed, selected, and developed a preliminary design for the preferred alternative for each of the water and wastewater systems. Unsealed plans and specifications are included in this final report. The plans and specifications are the basis for cost estimates for each system.

The design includes the following:

- Site plan, showing system layouts;
- Analysis of the site and groundwater supplies to identify an appropriate and reliable water supply;
- Design plans for each of the water & wastewater systems, taking into consideration all county, ADEQ & Arizona Department of Water Resources (ADWR) requirements and allowing for optimally functioning systems;
- Evaluations to assess whether the water and wastewater systems designed are likely to meet the water quality standards set by the ADEQ & Navajo County;
- Cost estimate for the fixed costs required for the construction of the systems, projected operational & maintenance costs, and permitting costs;
- Operations & maintenance needs for each system;

The technical tasks for creating this project are identified in a Gantt chart provided in **Appendix B**.

2.0 Research

Research began with evaluating site conditions and client plans, expectations, needs, and resources to determine which water supply and wastewater systems would be most suitable. The following sections provide the research findings.

2.1 Soil Conditions

The USDA CSRR indicated that approximately 80% of the soil was Grieta sandy loam with 1 to 3% slopes. Also, the CSRR indicated that the soil is well drained, meaning that the permeability was suitable for an onsite wastewater treatment system. This sandy loam soil would be appropriate for septic system because sandy soils (that are not too coarse) are desirable for septic systems [1]. The depth to bedrock can be a severe problem if it is under 40 inches [2]. A map overlay in the Esri ArcGIS (geographic information system) provided by the US Natural Resources Conservation Service showed that the depth to the bedrock for the site is only approximately 0-20 inches, and therefore would require additional drilling to be suitable for a septic system [3].

2.2 Water Supplies

Approximately 61% of the population within this region relies on groundwater as their main source of water [4]. The nearby cities of Holbrook and Winslow receive their water solely from groundwater that is pumped from the C-aquifer [4]. The area (Township 18 North and Range 22 East) that Sun Valley Ranch is located in has scattered wells that are mostly exempt according to ADWR. An exempt well has a maximum pump capacity of 35 gallons per minute and is typically used for smaller residences [5]. An analysis, shown in **Appendix C**, on the water level for wells near Sun Valley Ranch was determined using the ADWR well registry. This indicated that 4 of the 19 wells within the Sun Valley Ranch area are dry.

2.3 Alternative Wastewater and Water Supply Systems

Due to the client's preference for nonconventional systems, the team researched alternatives for both the wastewater and water supply systems to determine if they would perform effectively in Sun Valley.

Water Supply Systems

The alternatives for water supplies near the Sun Valley Ranch included connecting to Holbrook's water supply, an on-site well, or importation from Holbrook. Over 10 miles of piping would be required to connect Sun Valley Ranch with Holbrook's water supply system and therefore it was not considered a feasible alternative. Although the on-site well would be expensive, the importation alternative would involve annual transportation costs, so these two alternatives were compared.

Wastewater Systems

The following wastewater systems were considered by the team as possible sources of secondary treatment for the site's wastewater. These include the on-site wastewater systems defined by ADEQ that have flows less than 3000 gallons per day.

- Activated sludge and aerobic system
- Constructed wetland, land treatment, and stabilization pond
- Peat filter, textile filter, trickling filter, and intermittent sand filter
- Evapotranspiration bed lined or with a natural seal, gravelless trench, engineered pad, sand lined trench, nitrate reactive media, and cap system
- Septic tank, sewage vault, and Wisconsin mound
- Subsurface drip irrigation and surface disposal
- Composting

Most of these systems were too expensive or they would function more effectively for a larger population. The team determined that the wastewater system alternatives that would be most suitable for Sun Valley Ranch consisted of stabilization ponds, a septic tank, and composting toilets.

3.0 Analysis of Alternatives

To determine the most suitable alternative for the water supply and wastewater systems, the feasible alternatives for each type of system were described and then evaluated using a decision matrix.

3.1 Identification of Feasible Alternatives

The requirements, advantages, disadvantages, and considerations for each type of water and wastewater system alternatives were determined and are provided below.

3.1.1 Water Supply System Alternatives

Before the feasible alternatives for water supply could be determined, the water demand for the Sun Valley Ranch was calculated. The water demand estimations are shown in **Table 3-1**. These estimated demands were based off information provided by the United States Geological Survey (USGS) [6]. The gal/day/person represents the average per person (gal/min, gal, gal/load, or oz/glass) multiplied by the assumptions. To account for the maximum amount of water that will be used, the water demand includes "other uses." It was assumed that the water demand will vary +/- 2 gallons per person per day. The gal/year for 10 people accounted for the 184 days (~ 6 months) that the site will be occupied.

Table 3-1 Water demand for population of Sun Valley Ranch

	Average per person		Assumptions		gal/day per person	gal/year for 10 people
Shower	2	gal/min	8	min	16	29440
Teeth Brushing	0.5	gal/min	2	min	1	1840
Hands/face washing	1	gal	7	time	7	12880
Face/leg shaving	1	gal	1	time	1	1840
Dishwasher by hand	1.5	gal/min	5	min	7.5	13800
Food prep	0.5	gal/min	5	min	2.5	4600
Clothes washer	25	gal/load	0.25	load	6	11500
Glasses of water drunk	8	oz./glass	8	glass	0.5	920
Cleaning	1	gal	2	time	2	3680
Other Uses	2	gal	2	time	4	7360
				Total:	**48**	**56580**

Well

The first alternative for the water supply system that the team researched was the integration of a well on site. The site may have required additional drilling in the event that a dry well was initially drilled. The well alternative would be basic, like the design shown in **Figure 3-1**, with a casing, screen, pitless adapter, filter pack, and submersible pump. The pump would fill a large storage tank that would be placed near the central dome house and be connected to another pump and piping that would lead to the showers and sinks within the home.

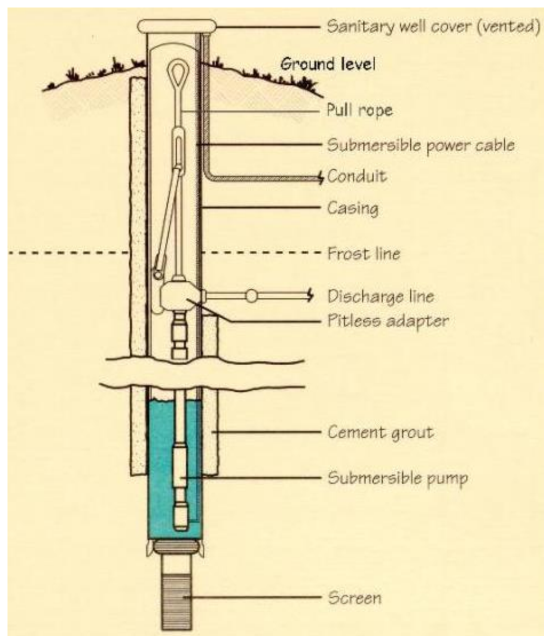

Figure 3-1 Basic well design [7]

Importation

Because Holbrook does receive its water from the C-aquifer groundwater supply and the quality meets the federal standards, importation is also an alternative for Sun Valley Ranch. No water transportation services have been identified near Sun Valley. Therefore, under this alternative, a maintenance worker with access to a truck will be hired to carry the water from Holbrook to Sun Valley. It is assumed that the truck will have four-wheel drive and have a 10,650 lb towing capacity that is representative of most Ford trucks [8]. A 1000 gallon water tank will be placed on a trailer connected to the maintenance worker's truck. The tank will only be filled to 800 gallons because of towing capacity. With the weight of the trailer and water storage tank filled at 800 gallons, the truck will be towing 10,605 lbs. A 5000 gallon water storage tank on the site will be filled each week. Each week the maintenance worker will make 5 roundtrips to and from Holbrook and Sun Valley.

3.1.2 Wastewater System Alternatives

Septic System

A septic tank is part of a soil absorption wastewater system that is underground. The tank would receive all of the wastewater from the central dome housing. Once the waste reached the tank, the solids and liquids would begin to separate. The tank would need to be pumped every 4-5 years depending on the amount of usage and require routine maintenance.

Stabilization Ponds

Stabilization pond systems typically consist of two ponds used for primary treatment and a third for secondary treatment. They would require a significant amount of land on the site, but the area would be smaller than most stabilization ponds because they would be handling a smaller amount of wastewater. During the summer, when these ponds would be in operation on the site, algae would supply the dissolved oxygen required by bacteria [9]. The bacteria would help break down the organic matter within the wastewater during this time. The ponds would need to be de-sludged at the end of October when the retreat is vacated.

Composting Toilets

Composting toilets would be designed to handle the supply of black water from about 10 people within the retreat. There would be 5 composting toilets total. Graywater would be diverted into a graywater reuse system used for irrigation to prevent this additional liquid supply from disrupting the compost mixture. Assuming the human waste is properly composted and the toilet was sized correctly, the end result would be free of pathogens or viruses. After the waste is broken down to 10 to 30% of its original volume, the nutrient-rich fertilizer would be used on plants and trees, buried, or removed by a licensed septage hauler [10].

3.2 Evaluation of Alternatives

The team created decision matrices for the water and wastewater alternatives to determine the most suitable systems for the Sun Valley Ranch. The team also created a preliminary cost analysis that could be used to compare the prices of the alternatives. This was used to determine a more appropriate ranking for the cost constraint of each alternative. This is provided in **Appendix D**.

Table 3-2 below shows the constraints and criteria that were used to evaluate which alternative would be the most suitable for the site. The first column shows the weight of importance that was assigned to each criteria and constraint based on the client's preferences. For each alternative, the ranking and score columns indicated the ranking that was calculated for each criteria and constraint. For the ranking system, each alternative was evaluated based on how well it met the constraint or criteria. A ranking of 1 indicated that the alternative met the criteria/constraint poorly, and a ranking of 3 indicated that it met the criteria/constraint very well. The score is the weight multiplied by the ranking. The overall scores for each alternative are shown at the bottom of the table.

Table 3-2 Water supply system decision matrix

Criteria & Constraints	Weight	Well		Importation	
		Ranking	*Score*	*Ranking*	*Score*
Non-intrusive	0.05	1	0.05	3	0.15
Cost	0.3	1	0.6	2	0.6
Operation & Maintenance Needs	0.2	2	0.4	3	0.6
Lifetime	0.05	3	0.15	3	0.15
Sustainability	0.05	2	0.1	2	0.1
Construction	0.05	1	0.05	3	0.15
Expansion	0.2	1	0.2	2	0.4
Startup & Shutdown	0.1	2	0.2	3	0.3
Overall Scores			1.75		**2.45**
Where: 1= poor, 2= sufficient, 3= very well Ranking*Weight = Score					

As **Table 3-2** shows, the most suitable water supply alternative is importation. This was primarily due to the fact that the well's installation and drilling needs would be so costly, particularly because several wells might need to be drilled with no certainty of success. The importation alternative was a substantially less complex system with less operation and maintenance needs. Also, the construction, startup and shutdown, and expansion would be easier for this alternative because of its simplicity.

Table 3-3 used the same ranking and scoring system as **Table 3-2**. Effectiveness was added to the list of criteria and constraints to provide further clarification on which wastewater system would fit the client's needs. The effectiveness represents how well the system will treat the wastewater supply. The stabilization ponds require large amounts of land and are also more suitable for large populations. And although septic tanks are typically a safe and reliable wastewater system alternative, the depth to bedrock for the site would cause expensive complications. The composting toilets system is unique, effective, and can be designed for a lower cost if non-manufactured toilets are incorporated. This approach also allows for a graywater reuse system to be easily incorporated, which is advantageous to the client's preferences for minimizing water usage. As **Table 3-3** shows, the most suitable wastewater system alternative for the site is composting toilets.

Table 3-3 Wastewater system decision matrix

Criteria & Constraints	Weight	Stabilization Ponds		Composting Toilets & Graywater Reuse		Septic Tanks	
		Ranking	*Score*	*Ranking*	*Score*	*Ranking*	*Score*
Non-intrusive	0.1	1	0.05	2	0.1	1	0.05
Cost	0.25	2	0.5	2	0.5	2	0.5
Operation & Maintenance	0.1	1	0.1	1	0.1	3	0.3
Lifetime	0.05	3	0.15	3	0.15	3	0.15
Sustainability	0.05	3	0.75	3	0.75	3	0.75
Construction	0.045	3	0.15	3	0.15	2	0.1
Expansion	0.1	2	0.2	3	0.3	1	0.1
Startup & Shutdown	0.055	1	0.1	3	0.3	2	0.2
Effectiveness	0.2	2	0.1	2	0.1	3	0.15
Overall Scores			2.1		**2.45**		2.3
Where: 1= poor, 2= sufficient, 3= very well Ranking*Weight = Score							

The team determined that rainwater harvesting and gray water reuse systems could also be incorporated into the design to help minimize water usage. The Sun Valley, Arizona region receives approximately 9 inches of rainfall per year and the plants native to the region would not have a high water demand [11]. So, the team determined that rainwater harvesting would be a reliable source of water that could be used for irrigation. Rainwater harvesting was selected as an additional water supply alternative for Sun Valley Ranch. The incorporation of a gray water reuse system would help divert this wastewater stream from the composting toilet system, where it would disrupt the mixture's necessary composition. This water could be reused for irrigational purposes as well.

SELECTED PREFERRED ALTERNATIVES

After the evaluation of the feasible alternatives, the following systems were determined as the most suitable for Sun Valley Ranch, LLC:

- **Water Supply System**: Importation & Rainwater Harvesting
- **Wastewater System**: Composting Toilets & Graywater Reuse

4.0 Preferred Alternatives

The final design will consist of a wastewater system that includes lower capacity, simply designed composting toilets within each of the dome houses. The graywater reuse system will divert the sources of the water from the bathroom sink, shower, and clothes washing machine to allow this water to be use for irrigational purposes. The water supply will be imported from Holbrook and consist of a large water storage tank near the central dome house that will provide potable water for the sinks, showers, and clothes washing machine. A simple rainwater harvesting system will be incorporated for the main dome house and include rain barrels that will capture water that can be used for irrigation. **Figure 4-1** provides a close up view of all of the components that will be incorporated on the site for the final design. The following sections provide additional details on all of the systems.

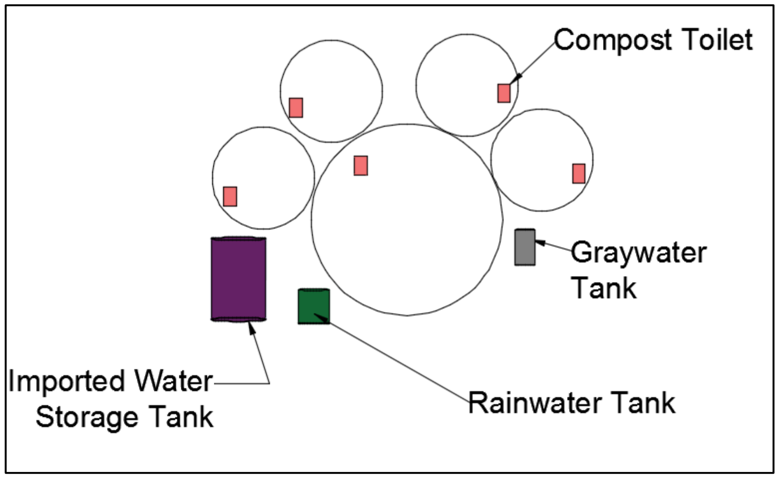

Figure 4-1 Site plan displaying all tanks and toilets that will be included in the dome houses

4.1 Water Supply System

The water supply system consists of the importation of water from Holbrook and the incorporation of the rainwater harvesting system near the central dome house. The following sections provide additional details regarding the imported system's water characteristics, the sizing of the potable water tank, and the method of transport for the imported water. Also, the calculations for the supply, demand, and cumulative storage of rainwater are included.

4.1.1 Importation

The team used the water demand calculated in **Table 3-1** to determine the amount of water that would need to be imported. As was mentioned in Section 3.1.1, the water supply will be imported from Holbrook to the Sun Valley Ranch. Holbrook's water is potable and does meet all federal and state laws [12]. As was mentioned, a 1000 gallon storage tank will be used for the imported water, but it will only be filled to 800 gallons. The team did not find a water storage tank that was above 625 gallons and below 1000 gallons during their research, and therefore they assume a standard 1000 gallon will be used.

The portable water storage tank will be emptied into the 5000 gallon on-site water storage tank in Sun Valley. The on-site storage tank will only be filled to 4800 gallons. Initially, six trips will be need to be made at the beginning of the season to get the tank to 4800 gallons. Afterwards, only four through five trips to and from Sun Valley will be needed. The on-site water storage tank will not be filled to its full capacity to save money on transportation costs. Although this is a frequent number of trips, the team did not find any other water importation transportation alternatives. There were no nearby water hauling services and all water hauling trucks were very expensive.

The weekly water demand, assuming that Sun Valley Ranch will have 10 residents, will be 3360 gallons. The water storage tank will be kept at about 1000 gallons above the expected water demand to account for variances in water demand. The maintenance worker will fill up the on-site water storage tank approximately 123 times on average per year. Near the end of October, the maintenance worker will stop filling the tank and let the remaining water be depleted before the system is shut down for the off-seasons. The importation upfront and annual cost are listed in **Table 5-1** and **Table 5-2**, respectively. Additional details on the importation cost analysis including calculations on average annual water and transportation cost are included in **Appendix E1** and **Appendix E2**.

Regulations

All the regulations listed below are met and guaranteed by the 2013 Annual Drinking Water Quality Report for The City of Holbrook [12].

The regulations for hauled water were specified in the *ADEQ's Safe Drinking Water Regulation* in Section R18-4-214 [13]. These general guidelines are provided below:

Requirements for the Water Supply

- The hauled water that will be delivered to a public water system must meets the standards for a regulated public water system.
- The materials, products, and chemicals that come into contact with the water must meet the standards specified by the National Sanitation Foundation/ American National Standards Institute. These organizations have declared regulations for treatment processes to regulate drinking water supplies [14].
- The water hauler must maintain a residual free chlorine level of 0.2 mg/l- 1.0 mg/l in the water that is taken to the water transport container. Once the water is placed into the transport container, a chlorine disinfectant shall be added to the water. Each time the water is taken from the water transport container, the residual free chlorine level will be measured. The residual free chlorine level, along with the chlorine disinfectant, shall be recorded in a log for the water that is loaded into the water transport container. These records will be kept for at least three years and made available to ADEQ upon request.

Requirements for the Water Supply Container

- The hatches on the container containing the water supply must be well-fitted with a watertight cover.
- The container transporting the water shall be regularly cleaned and contain a bottom drain valve to allow for complete drainage. This water transport container shall only be used for drinking water and properly labeled "For Drinking Water Use Only."
- The hoses use to deliver drinking water must be equipped with a cap and shall remain capped when not in use.

4.1.2 Rainwater Harvesting

To provide an additional source of water, a rainwater harvesting system will be incorporated into the water supply design. This design will be a simple collection system with a gutter system that allows the rain to drain to a barrel next to the central dome house. This system will have one side of the gutter elevated compared to the other so that it will be gravity fed. The barrel will have a connecting outlet where a hose attachment will be simple and easy. The client will be able to easily fill up a container with water and use it for vegetation.

To obtain an estimation of the effectiveness of the rainwater harvesting system, the follow tables, **Tables 4-1, 4-2,** and **4-3,** were constructed estimating the supply, demand, and storage [15].

Table 4-1 shows the estimated values for the total monthly yield of the rainwater harvesting system. The monthly rainfall in inches was based on the number collected for the city of Holbrook. The conversion column is simply a conversion factor used to convert the inches of rainfall and square footage of area to gallons. The runoff coefficient was selected for soil that is flat and bare that will be similar to the surface of the dome house structure. The high estimation for this type of surface was used. The catchment area was determined estimating the circular area of a 30' diameter central house. The values presented in each of the columns in **Table 4-1** were multiplied in excel to determine the total monthly yield in gallons. **Equation 1** was used to calculate the total monthly yield. **Equation 2** provides the equation and calculation performed to determine the catchment area.

Equation 1: **Rainwater Monthly Yield**: $R(in) * C * A(ft^2) * C_R = Y(gal)$ [15]

Where R = rainfall (inches)

C = 0.623, conversion factor to convert inches and squared feet to gallons

A = catchment area (feet^2)

C_R = 0.75, runoff coefficient selected for flat bare soil

Y = total monthly yield of rainwater (gallons)

Equation 2: **Catchment Area**: $A = \pi(r)^2 = 3.14\left(\frac{30}{2}\right)^2 = 706.85\ ft^2$

Table 4-1 Rainwater harvesting supply

	Rainfall (in.)	Total monthly yield (gal)
January	0.71	**234**
February	0.66	**218**
March	0.72	**238**
April	0.37	**122**
May	0.38	**126**
June	0.2	**66**
July	1.17	**386**
August	1.51	**499**
September	1.18	**390**
October	1.07	**353**
November	0.66	**218**
December	0.57	**188**
	Annual Yield :	**2804**

Table 4-2 shows the rainwater harvesting demand for the plants that will be included on the site. **Equation 3** shows the factors used for calculating total monthly demand.

Equation 3: **Total Monthly Landscaping Demand**: $ET(in) * C * A(ft^2) = D(gal)$ [15]

Where ET = evapotranspiration rate (inches)
C = 0.623, conversion factor to convert inches and squared feet to gallons
A = area of landscaping that the plants will cover ($feet^2$)
Y = total monthly landscaping demand (gallons)

An evapotranspiration rate for Holbrook for each month is shown in the first column of **Table 4-2** as ET. The area of landscaping was estimated with the assumption that a few plants native to Arizona will be planted near the dome house structures and on the path leading to the dome house. **Equation 4** shows the equation that was used to determine this area. It was assumed that one desert broom shrub and two agave plants will also be placed on each side of the central dome house [16]. The calculations for the landscaping area are provided in **Appendix E**.

Equation 4: ***Landscaping Area***: $w * h = A\ (ft^2)$

Where w = width of plant
h = height of plant

Table 4-2 Rainwater harvesting demand

	ET (in.)	Total monthly landscaping demand (gal)
January	1.48	**53**
February	2.15	**76**
March	3.27	**116**
April	4.83	**172**
May	6.87	**244**
June	8.09	**287**
July	8.1	**288**
August	7.2	**256**
September	5.81	**206**
October	4.06	**144**
November	2.34	**83**
December	1.48	**53**
	Annual Demand:	**1978**

Table 4-3 shows the estimation of the amount of water that will be in storage for the rainwater harvesting system. This table is used to determine how effectively the rainwater system will be providing the water needed for the plants. It does not represent the actual amount of water that will be placed in a storage container because the water from this system will be distributed to the plants. It assumes that for the first year in January, the system will start off with no water. The yield values from **Table 4-1** and the demand values from **Table 4-2** were incorporated. The third column was determined by using **Equation 5**. This table shows that this system will provide more than enough water to provide water form several additional plants or other activities.

Equation 5 $\boldsymbol{Cumulative\ Storage} = Yield - Demand$

Table 4-3 Rainwater harvesting storage

CUMULATIVE STORAGE WATER REQUIREMENT			
	Yield (gal) (Table 4-1)	**Demand (gal) (Table 4-2)**	**Cumulative Storage (gal)**
Year 1			
January	234	53	181
February	218	76	323
March	238	116	445
April	122	172	396
May	126	244	277
June	66	287	56
July	386	288	154
August	499	256	397
September	390	206	581
October	353	144	790
November	218	83	925
December	188	53	1060

For a better representation of the general pattern that the rainwater harvesting system will exhibit throughout a year, **Figure 4-2** was created. Once again, it is clear that the rainwater harvesting system will supply enough water for the client to plant several bushes and shrubs near the main dome house as well as plant additional plants around the site.

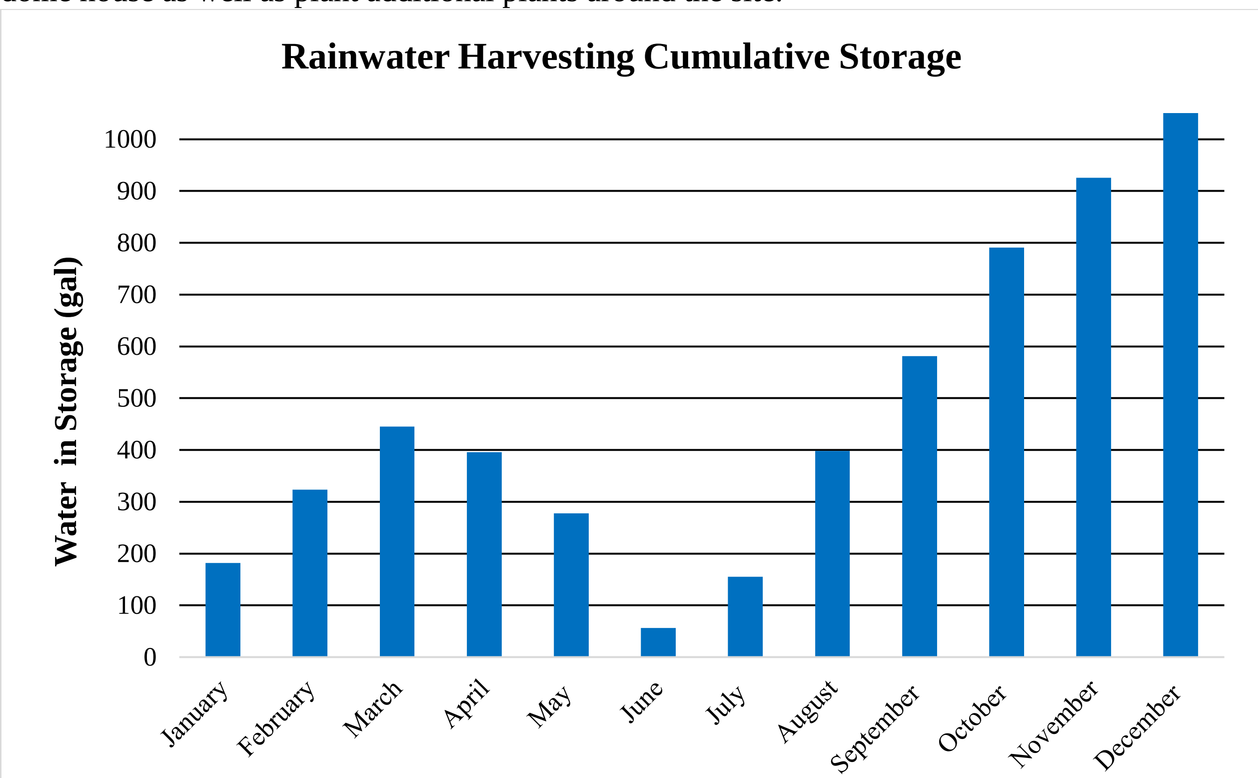

Figure 4-2 Rainwater harvesting cumulative storage over one year

Barrel Capacity
To determine the appropriate barrel capacities for each dome house, the information provided in **Tables 4-1**. This helped determine the required capacity for the barrel near the main dome house. For the central dome house, the maximum volume in the barrel that will be capturing the rain will be about 500 gallons.

Operation & Maintenance
To maintain a rainwater harvesting system, the owner must guarantee that there is no debris in the gutter or tank after each rainy season and check and clean the filter on a weekly basis [17]. If there is a large amount of debris within the rainwater harvesting barrel, it should be flushed out. During these small operation and maintenance tasks, the system should be evaluated to determine whether any components, mainly the filter, needs to be repaired.

Regulations
ADEQ, ADWR and the Arizona Pollutant Discharge Elimination System (APDES) do not require a permit and have no specific requirements for the rainwater harvesting [18].

With the determination of the requirements and calculations for the sizing of the imported water supply and rainwater harvesting systems, these systems were verified as reliable sources for the Sun Valley Ranch water supply to sustain the population of approximately 10 people. Also, the rainwater harvesting system will provide a small irrigation system for a few native plants placed near the central dome house.

4.2 Wastewater System

The wastewater system will consist of the composting toilets that handle the black water supply of wastewater and a graywater reuse system that will handle the graywater supply. The requirements for the composting toilets, graywater system, and disposal and reuse of the urine and kitchen sink water are provided below.

4.2.1 Composting Toilets

The barrel composting toilets were selected as an effective model for the simple and smaller composting toilets that will be incorporated within each of the dome houses. The barrel composting toilet system is a batch type system in which fecal matter is separated from older fecal matter during the primary composting process [19]. **Figure 4-3** demonstrates a three barrel system that will be appropriate for two adults using the toilet fulltime. The design will use a 55-gallon high density polyethylene barrel that will act as a composting chamber. For the estimated two people that will occupy each dome house, there will be one active barrel and two aging

Figure 4-3 Three barrel composting toilet system with demand capacity suitable for 2 adults [19]

barrels. Once the active barrel becomes full, the seat and ventilation assembly will be moved to an empty barrel. This will allow the once active barrel now to become an aging barrel and the empty barrel to become the new active barrel. **Figure 4-3** represents the outdoor application of the composting toilets. The barrels for the composting toilets are buried in **Figure 4-3**, but the actual composting toilets used in the dome houses will be higher. **Figure 4-4** demonstrates the height of the barrels. These barrels will be placed indoors against the wall and include a step to allow for easier access to the toilets, see **Figure 4-5**.

Figure 4-4 Above the ground composting barrel [19]

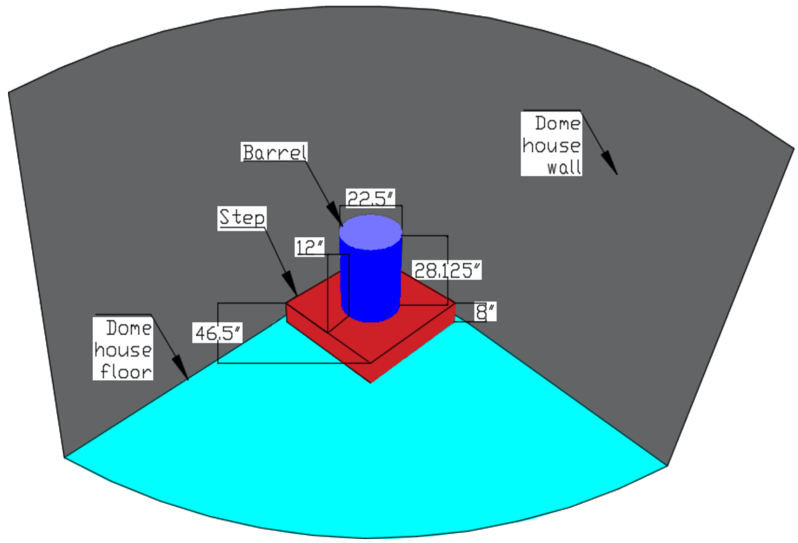

Figure 4-5 Indoor application of composting toilet (blue) and step (red) against the dome house wall (gray)

The matter within the aging barrel will compost for a minimum of 4 months, during which time no additional fresh material is added. The barrel composting toilet system will keep all of the content within the system and there will be a zero leachate discharge to native soil [19]. The system will have full vector control, effective aeration, and moisture distribution. It will be constructed with durable, simple to clean and non-corrosive materials. The barrel system will be incorporated inside each of the dome houses. This type of toilet will allow complete separation of aging material from fresh material which provides an extra degree of safety. For a 2 adult system where a 3-barrel system will be incorporated, materials will cost approximately $325 [19]. Urine will be separated with the use of a urine diversion system to minimize the amount of liquid leachate produced within the system.

Components of Composting Toilet

The barrel composting toilet system will consist of four major components which will include a 55 gallon high-density polyethylene barrel, a toilet seat, a ventilation system and vector control [19]. The toilet seat will contain closed cell adhesive foam around the lid and seat to keep insects out of the toilet [19].

Capacity Calculations

The total capacity for one standard high-density polyethylene barrel is 55 gallons. The effective capacity, of one barrel allows for a 9” clearance between the top of the barrel and the top of the compost and therefore comes to be 41 gal/barrel [20]. The approximate amount of compost generated by each person was estimated as 0.5 gal/day [20]. To determine the number of days that it would take to fill the barrel, the following calculation was completed.

$$Days\ to\ Fill\ Barrel = \frac{41gal}{\frac{0.5\frac{gal}{person} * 2\ person}{day}} = \mathbf{41\ days}$$

This calculation showed that it would take 41 days to fill the active barrel. To calculate the number of days that it would take to reach the design capacity, which represents the actual capacity, **Equation 6** was used where EC represents the days required to reach the effective capacity.

Equation 6 Actual capacity = EC + 0.5EC = $41 + 0.5(41) = \mathbf{62\ days}$

The actual capacity is separate from the effective capacity because as time passes, the compost starts to decompose and significantly shrink due to the heat that is generated during the decomposition process. The number of barrels required for the composting toilet system increases with the number of adults that use the composting toilet. This relationship is demonstrated in **Table 4-4.**

Table 4-4 Barrel system sizing

Number of Adults	Number of Barrels	Barrel Types
1	2	1 active barrel + 1 aging barrel
2	3	1 active barrel + 2 aging barrels
3	4	1 active barrel + 3 aging barrels
4	5	1 active barrel + 4 aging barrels
5	6	1 active barrel + 5 aging barrels

Cover Material Requirements

The absorbency of cover material is used to manage moisture within the composting toilet system. Because the composting toilets on the site will not utilize a leachate drain, the absorbency of the cover material is particularly important. A more absorbent cover material can be used to help dry out compost that is too wet. The absorbency efficiency was tested for four common cover materials which include sawdust, horse manure, wood shavings, and straw [21]. The results of that test are presented in **Table 4-5** below. One cup of sample material was added to one cup of water. Then, the volume of water that passed through the strainer and water absorbed were calculated after twenty four hours had passed.

Table 4-5 Cover material absorbency test results [21]

Material	Volume of Water Passed Through Strainer	Water Absorbed
Sawdust (conifer)	1/4 cup	75%
Horse manure (finely screened)	1/3 cup	66%
Wood shavings (conifer)	2/3 cup	33%
Straw (finely chopped)	2/3 cup	33%

As you can see, sawdust had the highest percentage of absorbency with 75% of water being absorbed and the least amount of water passing through the strainer of ¼ cup after 24 hours. Therefore, sawdust will likely be the absorbency material used for the composting toilets used on the site.

Urine Diversion System

The female application for the urine separation component is integrated with the barrel composting toilet system. For males, a urinal will be used. The female urine separation system is composed of two simple assembles; a urine diverter built into each barrel and a hose to transport urine to an approved drainage system. Each barrel requires one leachate chamber. The diverter created from a rapid fill funnel is available at auto shops. The drain hose is a 1/4" fuel line. The hose diameter is small because high dissolved minerals in urine will precipitate over time on the inside of the drain pipes. The urine diverter will need to be rinsed thoroughly after each use which will require only ¼- ½ cup of water to clean the entire inside surface of the hose. This will prevent mineral formation. Furthermore, a stainless steel screen will prevent clogging of the hose. Also, in the rare event that clogging occurs, a plumbing "snake" can be inexpensively constructed. Another advantage of the small diameter hose is that it prevents insects from getting into the toilet from the leaching chamber via the hose. A urine diversion system is displayed in the figures presented in **Figure 4-6** below. The method of disposal and reuse and disposal will be discussed in Section 4.2.3.

Figure 4-6 Urine diversion system [22]

Operation & Maintenance

A maintenance worker will maintain the composting toilets including adjustments of the cover material, covering the aging barrels when they are full, desludging, and transporting the resulting compost matter.

ADEQ also requires that the following operation and maintenance tasks are completed [23]:

- To prevent potential fires and anaerobic conditions, the owner should provide sufficient mixing, ventilation, temperature control, moisture, and carbon material to the compost
- Replace the full composting toilets as necessary
- Only allow human waste, toilet paper and carbon additive to be placed inside composting toilets
- Ensure that the liquid product is either sprayed back onto composting waste material, removed by a person with the appropriately licensed vehicle, or that it is drained to an appropriate inceptor.

Figure 4-7 Compost crank [24]

Mixing will be applied to the composting toilets by utilizing a crank, similar to the one shown in **Figure 4-7**. Cranking will be applied about every two weeks and several times per week during hot weather to prevent odors [24]. This cranking allows of the appropriate amount of oxygen in the composting toilet. This oxygen is necessary to guarantee that the microbes within the compost can stay alive and perform their functions properly.

Additional operation and maintenance tasks include odor prevention and disposal and reuse of compost.

Odor Prevention

If there is an odor problem, it may be an indication that elements of the composting are out of balance. This could include the carbon/nitrogen ratio being out of balance, and the compost being too moist and not getting enough air. Each and every one of these can be assisted by adding dry, high-carbon cover material followed by a thorough aeration of the compost. Within hotter climates, odor can be prevented by doing additional aeration several times per week. Additional large amounts of absorbent, carbonaceous material may be necessary for extremely wet compost.

Emptying out Barrels and Recommended Disposal and Reuse of Compost

After a minimum time of 4 months, the composted material is emptied from the aging barrel. There is a misconception that this process is unpleasant. However, this isn't true since after 4 months the compost should be relatively lightweight material and the bucket should only be about 2/3 full. The content should be removed with a round bladed shovel into a wheelbarrow. A tarp or large sheet that is at least 8 square feet should be should be set beside the aging barrel that requires emptying. The wheelbarrow is to be placed on the tarp beside the barrel. The rain cover and screen from the barrel is then removed. The shovel is then dug into the compost and emptied into the wheelbarrow. This is done until the barrel is relatively empty. Any spilled compost on the tarp should be gathered and placed into the wheelbarrow. The compost then should be spread in mulch basins around shrubs, vines or trees or deposited into an outdoor composting bin for further composting. The emptied wheelbarrow can now be used as an active barrow again and the cycle continues.

Regulations

The requirements, specified by ADEQ, for composting toilets (Section R18-9-E303) that pertain to the selected composting toilet alternative are listed below [25].

Requirements for Use of Composting Toilet

- The composting toilet may only be used if it handles wastewater according to these specified regulations, the graywater is separated and reused, and the soil conditions support subsurface disposal.

Restrictions

- No more than 50 people may use the toilet per day.
- Only human excrement shall enter the composting toilet.

Performance Requirements

- Discharge of toilet contents to the native soil, except leachate, must be prevented. The leachate may drain to the wastewater disposal.
- The composting toilet must limit access to vectors of the contained waste.
- The wastewater must be disposed of into the subsurface to prevent the wastewater from surfacing.

Notice of Intent to Discharge Requirements

- Before the compost and wastewater materials are discharged, the owner must submit details and paperwork specified by ADEQ, for both the composting toilet and wastewater.

Composting Toilet Design Requirements

- Composting chamber must be
  - Watertight
  - Constructed of durable materials that can that do not easily corrode or decay
  - Prevent vectors (pest) from coming into contact with the system
  - Prevent odors or toxic gas from escaping into the building with the use of airtight seals

Interceptor Requirements

- The system should include an interceptor where wastewater will pass through before it is dispersed in subsurface soil. This includes the kitchen wastewater that will not be incorporated into either the composting toilets or gray water system.
- The interceptor shall remove grease, oil, fibers, and solids from the wastewater supply.
- It must be covered to prevent mosquito and other vector access.
- The interceptor must be approximately 63 gallons in size.

For the requirements that state that soil conditions must support subsurface disposal, the wastewater will not be sent directly to the soil. It will be applied to plants. An interceptor will still be incorporated to trap unwanted matter from the kitchen sink water supply.

4.2.2 Graywater Reuse

The graywater system will handle additional wastewater from the clothes washer, bathroom sinks, and showers. The graywater system incorporated on Sun Valley Ranch will have a flow less than 400 gallons per day and only be used for irrigational purposes gf. There is no need for formal notification to the ADEQ or review or design approval plans for integrating a graywater reuse system on an Arizona site [26]. The storage tank for the graywater system will be covered, sealed, and securely placed near the central dome house, and it will have a connecting outlet to allow for a hosing attachment. From there the water can be distributed to the appropriate plants near the houses. When this water is distributed, it must avoid human contact and the soil that is irrigated with this gray water must also avoid human contact. The client and all residents at Sun Valley Ranch will have to carefully consider the types of substances and detergents that are used in the clothes washer and sinks to guarantee that they do not contain harmful constituents. Certain types of constituents could inhibit the quality of the graywater to a degree that would make it inappropriate to use on plants. It is crucial that no type of fecal contamination enters the graywater system. Therefore, any person that comes into direct contact with the gray water will use the appropriate protective equipment. The maintenance worker will be the only one that handles the gray water, therefore each time he transports the gray water to the tank or provides maintenance on the system, he will wear gloves. Also, all locations using gray water on the site will be properly labeled. The team assumed that no infants would be at the Sun Valley Ranch, and that it will be unlikely that this type of contamination will occur. The suitable plants that can be fed by the graywater are citrus and nut trees along with other plants that handle the acidity of the graywater such as rabbit bush, burning bush, and honeysuckle [26]. A water pump will be utilized for this system to allow water to be delivered to the high end of the garden. Also, a filter will be incorporated on the 250 gallon storage tank.

Operation and Maintenance

After installation of the graywater irrigation system, the owner has an obligation to ensure that the system, and all its components are maintained for the duration of the operation. Graywater diversion components and their related subordinate drip irrigation systems need constant maintenance. Below are some of the maintenance activities should be carried out on graywater installations [27]:

- Ensure the storage tank has a secure cover to guarantee safety and control of mosquitoes
- Regularly clean and replace filters: over time, the filters get blocked with sediments hence they should be removed and cleaned and the physical contaminants such as sand, hair, etc.
- The sludge on the surge tank should be cleaned out regularly.
- Check that water is dripping from the sub-surface irrigation distribution system. After an irrigation exercise, the solids around should be constantly monitored to ensure that the soil is wet.
- To guarantee correct readings and pump operation, the sensor should be regularly cleaned.
- Evaluate the soil condition to ensure the soil is healthy. Soil that portrays signs such as unusual odors, damp, bogginess may be unhealthy.

Regulations

The main requirements for the graywater system include that the flow is less than 400 gallons per day, is not accessible for the public, that it is used on the site where it is generated, only used for irrigation, and is dispersed using drip-irrigation or flood methods [26].

For the reclaimed water general permit, there is no need for formal notification to department, no review or design approval, no public notice, and no reporting or renewal.

4.2.3 Disposal and Reuse Options

The composting toilets have a strict water to solids ratio requirements, and the graywater regulations do not allow kitchen sink water to enter the system. Therefore, the kitchen sink water must be handled separately through different methods. The main concern with the water that goes down the kitchen sink drain is the risk of contamination by types of pathogens from raw meat. The water will consist of all substances washed from hands, vegetables, fruit, meat, and containers. The kitchen sink water is frequently diverted from the graywater supply because it often contains solids and grease as well. Therefore, an interceptor will be incorporated on the container that collects the kitchen sink water. The kitchen sink water will be diverted into its own separate container. **Table 3-1** shows that approximately 100 gallons of water will be used on the site by the 10 people per day for food preparation and dishwashing. To allow for fluctuations in this water supply, the kitchen sink container will need to hold approximately 120 gallons.

The urine that is diverted from the composting toilets will be combined with the kitchen sink water. Urine typically contains higher levels of nitrogen, phosphorous, and potassium which can helpful nutrients for plants [28]. There is the potential fecal contamination concern with the reuse of urine. However, the urine diversion system will prevent almost all potential fecal matter that may enter the urine supply. This system will not prevent 100% of any type of fecal matter because the system is simple to minimize cost. Therefore, the maintenance worker that handles the waste will, as with the gray water syst*e*m handling, use the proper protective equipment when transporting and handling the urine supply. The urine does require an appropriate dilution factor because most urine supplies have a high nitrogen and salt level [29]. The urine will be diluted with the kitchen sink supply with a ratio of 10:1 for most plants and 20:1 for seedlings and more sensitive plants [29]. The urine that is diverted from the composting toilet diversion system and the urinals will be sent to its own separate container as well. Estimating an average of 0.26 gal/day/person results in approximate volume of 26 gallons of urine/person/day. Therefore, to allow for fluctuations in the volume of urine produced per day, the container for urine will need to be approximately 40 gallons.

As stated above, the kitchen sink water supply will be approximately 100 gallons/person/day, and the urine supply will be about 26 gallons/person/day Therefore, the kitchen sink and urine water supply will provide an additional 126 gallons of water per day for plants.

4.3 Piping Distribution & Pump Sizing

To determine the amount of piping that the systems would require on the site, the site plan was incorporated into *BentleyFlowMaster*. This was placed over an image of the site to give an indication of the scale of the dome houses and tanks in relation to the site. The final image is shown in **Figure 4-8**. This shows a zoomed in image of the dome houses and the storage tanks for the systems. The coloring of the items in **Figure 4-8** are similar to those shown in the site plan in **Figure 4-1**. The pink boxes indicate the composting toilets, the purple box indicates the potable water storage tank, the green box indicates the rainwater harvesting barrel, and the gray box indicates graywater storage tank. The information provided in the pipe flex tables indicated that the total length of pipe that would be required was approximately 10 feet. This length was used to incorporate the cost of the piping for the water and wastewater systems.

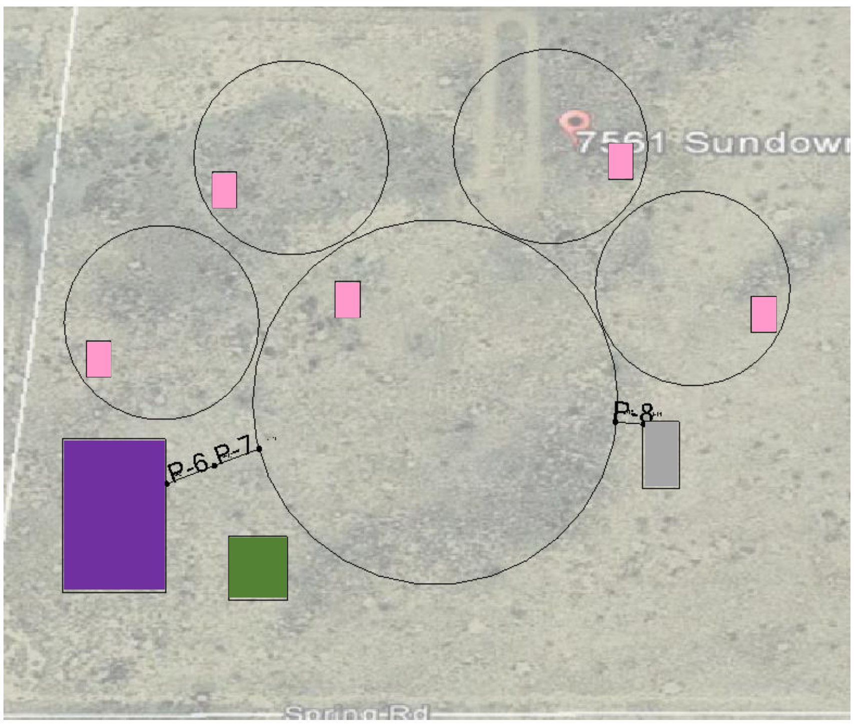

Figure 4-8 Site plan of the dome houses and the tanks for each system with piping

The piping from the water storage tank to the home will be pumped with an average flow rate of approximately 6 gallons per minute (gpm). The pump curve provided in **Appendix G** demonstrated the approximate power required for this type of pump would need to be about 1/3 horsepower. The diameter for the piping was assumed using this same pump curve as well. It was assumed that 4” polyvinylchloride piping would be used for this system. The rainwater harvesting system will not require pumps or piping because the water will go directly from the gutter to the rain barrel. The graywater storage tank will have the same flow rate and thus power requirements as the potable water storage tank. Thus, a similar pump will be used for the graywater storage tank.

5.0 Final Design Capital & Maintenance Costs

To determine the cost of the water and wastewater systems, the initial startup costs were determined and then the annual/periodic costs were determined. These were combined to determine a total lifetime cost for each of the systems. **Table 5-1** provides the upfront costs associated with all of the four systems along with the capacities for each tank, quantities of each item, prices per item, and references for the cost estimates. The composting toilet system was the only system that Navajo County had specified associated permitting fees. The approximate cost per foot of 4" polyvinylchloride piping was $0.64 [39]. This was multiplied by the 10 because there will be 10 feet of piping required for the system to get an approximate cost of $7.

Table 5-1 Capital costs for both water & wastewater system on the Sun Valley Ranch Site

	Quantity	Price	Reference	Capital
Importation				
On-site storage tank (5000 gal)	1	$2,385	[30]	$2,385
Water hauling tank (1000 gal)	1	$680	[31]	$680
Trailer (11,000 lbs maximum weight capacity)	1	$5,000	[32]	$5,000
Pump	1	$180	[33]	$180
Rainwater harvesting				
Barrel (500 gal, includes brass spigot, bulkhead with plug)	1	$875	[34]	$875
Composting toilets				
DIY toilets	5	$325	[19]	$1,625
Urine diversion system	5	$40	[22]	$200
*Installation	5	$60	[35]	$300
Permitting fee	1	$500	[36]	$500
Graywater storage tank	1	$430	[37]	$430
Graywater pump	1	$150	[33]	$150
Graywater filter	1	$20	[38]	$20
Piping	1	$7	[39]	$7
TOTAL:				**$12,352**

*Represents the estimated cost required to hire a worker to build the do-it-yourself toilet. This assumes that they will be paid at about $12/hr and they will be working for about 5 hours.

The additional operation and maintenance and other lifecycle costs can be found in **Table 5-2**. The cost of handling both the composting toilets, graywater, and kitchen sink and urine systems were all included under the composting toilets operation and maintenance section. The total lifecycle costs that include the capital and annual costs for one year will be **$18,131**.

Table 5-2 Lifecycle costs of both water & wastewater system on the Sun Valley Ranch Site

	Maintenance Worker Wage ($/hr)	Duration of Maintenance (hrs)	Frequency per year	Reference	Annual
Importation					
Transportation	Appendix E1 & E2				$1,786
Water hauling service	12	4	22	[34]	$1,056
Water	$1.75/1000 gallons from City of Holbrook				$177
Rainwater harvesting					
Operation & maintenance	12	1	26	[34]	$264
Composting toilets					
Operation & maintenance	12	4	26	[34]	$2,496
				TOTAL:	**$5,779**

6.0 Summary of Project Costs for Engineering Services

Table 6-1 provides the cost for the engineering services that the team has dedicated to the project. This includes the hours that each person has spent as well as travel expenses. This can be compared to the original project cost analysis that was provided in the proposal. This is shown in **Appendix H.** As you can see, the team overestimated the amount of hours that would be required for the project. Therefore, the engineering services would be significantly less what they had originally anticipated.

The original Gantt chart provided in **Appendix B** was followed and no major adjustments were made, however the team did attempt to complete the details for the wastewater system earlier than what was specified on the Gantt chart. The team specifically designated several weeks to both the water and wastewater system designs, and they ended up utilizing the full time they designated in the Gantt chart.

Table 6-1 Engineering services cost for the Sun Valley Ranch water and wastewater systems project

1.0 Personal	Classification	Hours	Rate, $/hr	Cost, $
	Project Manager	108.5	92	9,982
	Engineer	108.5	132	14,322
	Laboratory Assistant	85.5	63	5,387
	Administrative Assistant	158.5	40	6,340
	Total Personnel	461		36,031
2.0 Travel	Site Visit	$0.56/mi		
	1 meeting @ 100 mi/meeting			56
3.0 TOTAL				**$36,087**

7.0 Conclusion

Suitable water and wastewater systems for the Sun Valley Ranch have been determined. The site plan for these systems, analysis of reliable and safe drinking water sources nearby, design plans with regards to county, state, and national codes, cost estimates, and operation and maintenance needs have been completed. With the details on these systems determined, the client can now begin preparations to implement these systems within the site. This report contains plans that could be applied by any small family living in a rural area looking for a feasible, cost-effective, and safe option for supplying water and wastewater systems.

On a local small-scale this project could potentially lead to an increase in the population and economy near Sun Valley and a deeper consideration of non-conventional wastewater systems by the Navajo County. On a larger global level, this project could lead to an awareness of the feasibility that simple, cost-effective systems can be incorporated in small towns that have limited resources and funds.

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9.0 Appendices

Appendix A: Custom Soil Resource Report from the United States Department of Agriculture

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Appendix A: Custom Soil Resource Report from United States Department of Agriculture

Custom Soil Resource Report

Navajo County Area, Arizona, Central Part

20—Grieta sandy loam, 1 to 3 percent slopes

Map Unit Setting

Elevation: 4,800 to 5,500 feet
Mean annual precipitation: 8 to 10 inches
Mean annual air temperature: 53 to 56 degrees F
Frost-free period: 150 to 180 days

Map Unit Composition

Grieta and similar soils: 80 percent

Description of Grieta

Setting

Landform: Fan terraces on plateaus
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Mixed alluvium derived from volcanic and sedimentary rock

Properties and qualities

Slope: 1 to 3 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
Available water capacity: High (about 9.2 inches)

Interpretive groups

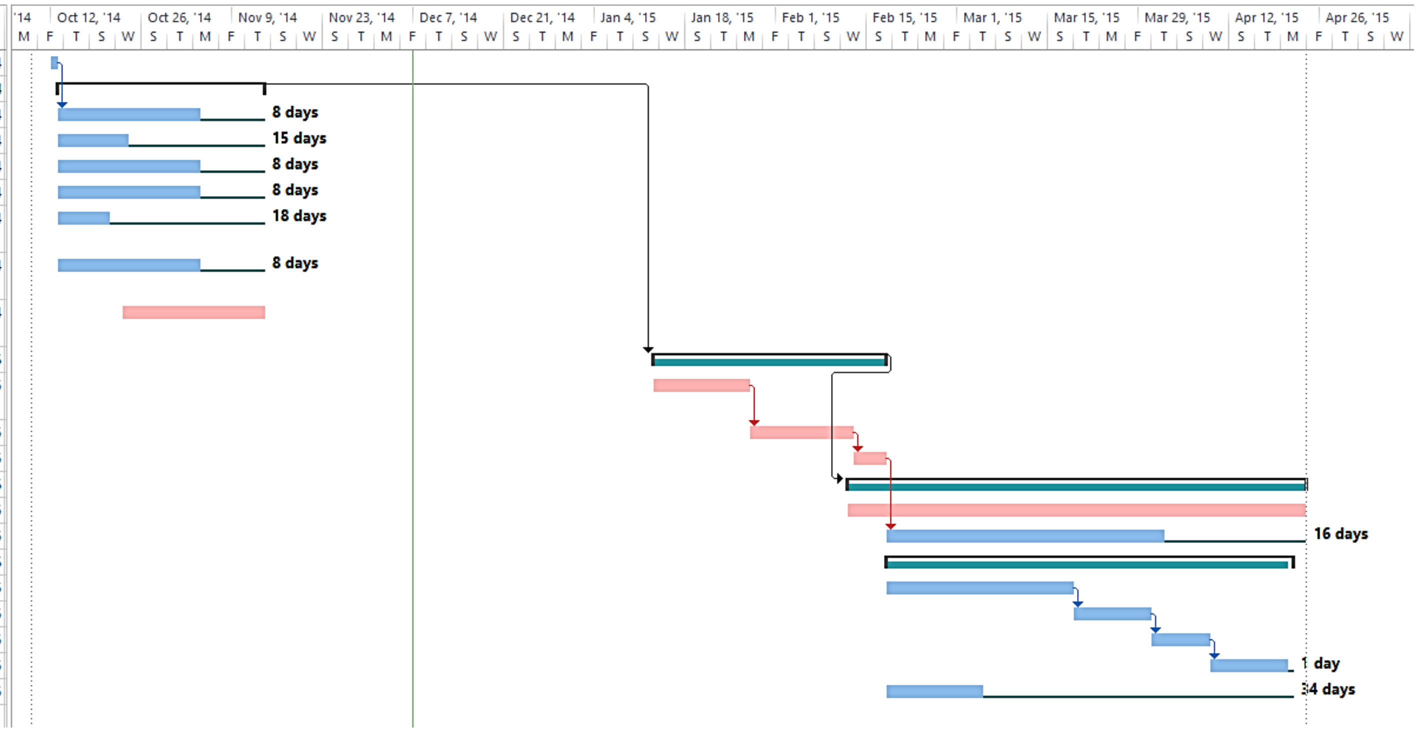
Farmland classification: Prime farmland if irrigated
Land capability classification (irrigated): 3e
Land capability (nonirrigated): 7e
Hydrologic Soil Group: B
Ecological site: Sandy Loam Upland 6-10" p.z. (R035XB219AZ)

Typical profile

0 to 3 inches: Sandy loam
3 to 20 inches: Sandy clay loam
20 to 44 inches: Sandy clay loam
44 to 60 inches: Sandy loam

Appendix B: Gantt Chart

Name	Duration	Start	Finish
1.0 Field Evaluation	1 day	Sun 10/12/14	Sun 10/12/14
2.0 Research	**24 days**	**Mon 10/13/14**	**Thu 11/13/14**
Subtask 2.1 Appropriate Soils	16 days	Mon 10/13/14	Mon 11/3/14
Subtask 2.2 Landscape Features	9 days	Mon 10/13/14	Thu 10/23/14
Subtask 2.3 Water Supplies	16 days	Mon 10/13/14	Mon 11/3/14
Subtask 2.4 Alternative Options	16 days	Mon 10/13/14	Mon 11/3/14
Subtask 2.5 Codes & Requirements	6 days	Mon 10/13/14	Mon 10/20/14
Subtask 2.6 Water Quality	16 days	Mon 10/13/14	Mon 11/3/14
Subtask 2.7 Constraints & Criteria	16 days	Thu 10/23/14	Thu 11/13/14
3.0 Analysis	**26 days**	**Tue 1/13/15**	**Tue 2/17/15**
Subtask 3.1 Evaluation of Options	11 days	Tue 1/13/15	Tue 1/27/15
Subtask 3.2 Testing Alternatives	12 days	Wed 1/28/15	Thu 2/12/15
Subtask 3.3 Selection of Design	3 days	Fri 2/13/15	Tue 2/17/15
4.0 Plans for Final Design	**51 days**	**Thu 2/12/15**	**Thu 4/23/15**
Subtask 4.1 Wastewater Design	51 days	Thu 2/12/15	Thu 4/23/15
Subtask 4.2 Water Supply Design	31 days	Wed 2/18/15	Wed 4/1/15
5.0 Project Management	**45 days**	**Wed 2/18/15**	**Tue 4/21/15**
Subtask 5.1 50% of Final Report	21 days	Wed 2/18/15	Wed 3/18/15
Subtask 5.2 90% of Final Report	8 days	Thu 3/19/15	Mon 3/30/15
Subtask 5.3 100% of Final Report	7 days	Tue 3/31/15	Wed 4/8/15
Subtask 5.4 Final Presentation	8 days	Thu 4/9/15	Mon 4/20/15
Subtask 5.5 Website	11 days	Wed 2/18/15	Wed 3/4/15



Appendix C: Arizona Department of Water Resources Well Registry

REGISTRY ID	OWNER NAME	WELL TYPE GROUP	WELL DEPTH (FT)	DRILL DATE	WATER LEVEL (FT)	PUMPRATE (GPM*)
800251	SUN VLY UTILITIES IC,	EXEMPT	150	1/19/1979	12	0
614309	AZ STATE LAND DEPT	NON-EXEMPT	113	1/1/1958	24	0
623310	STEWART,G	EXEMPT	150	2/28/1976	100	35
627248	ATCHISON-TOPEKA,	NON-EXEMPT	73	1/1/1941	0	0
524770	COX, GLEN,E	EXEMPT	125	7/1/1989	52	9
601990	ETHERIDGE,R B	EXEMPT	80	8/1/1979	0	10
601311	WERTZ,W H	EXEMPT	80	7/15/1976	30	7
596199	SUN VALLEY UTILITIES,	NON-EXEMPT	150		18	
520163	HALPERN, MAURICE,S	EXEMPT	0		0	0
85775	SNADER,L	EXEMPT	100	1/1/1980	50	0
529778	SUN VALLEY UTILITIES,	NON-EXEMPT	137	2/11/1991	46	0
614312	AZ STATE LAND DEPT,	EXEMPT	0	1/1/1952	0	0
604991	LAGAMCO INC NV CORP,	EXEMPT	90		30	25
647171	DONALD & BERNADINE MICHAUD	EXEMPT	100	6/17/1980	15	30
200821	VICTOR BURTON	EXEMPT	320	11/11/2003	212	
506648	POOSER,B	EXEMPT	125	12/15/1983	75	20
85778	MONTGOMERY,G	EXEMPT	90	10/8/1980	65	0
614310	FITZGERALD, RAYMOND,	EXEMPT	0	12/31/1951	29	0
907819	TERRY WALLACE	EXEMPT	105	9/27/2007	105	10

*GPM= gallon per minute

Date Accessed: March 29, 2015

Appendix D: Preliminary Cost Analysis

Wastewater Alternatives

SEPTIC TANK COST ANALYSIS			
Upfront Costs			
Item	**Cost**	**Quantity**	***UPC Total**
Permitting [40]	$225	1	$225
Installation [41]	$6,300	1	$6,300
Toilets	$200	5	$1,000
		Upfront Cost Total:	**$7,525**
20-Yr Lifecycle Costs			
Item	**Cost per Operation**	**Frequency (per 20 years)**	****LIC Total**
Pumping [42]	$500	4	**$2,000**
		*****OVERALL TOTAL**	**$9,525**

*Cost x Quantity = UPC Total **Cost per Operation x Frequency = LIC Total

***UPC Total +LIC Total = Overall Total

STABILIZATION POND COST ANALYSIS			
Upfront Costs			
Item	**Cost**	**Quantity**	***UPC Total**
Construction [43]	$2,636	1	$2,636
		Upfront Cost Total:	**$2,636**
20-Yr Lifecycle Costs			
Item	**Cost per Operation**	**Frequency (per 20 years)**	****LIC Total**
Pumping [44]	$2,214	4	**$8,856**
		*****OVERALL TOTAL**	**$11,492**

*Cost x Quantity = UPC Total **Cost per Operation x Frequency = LIC Total

***UPC Total +LIC Total = Overall Total

COMPOSTING COST ANALYSIS			
Upfront Costs			
Item	**Cost**	**Quantity**	***UPC Total**
Do-It-Yourself Toilet [45]	$325	5	$1,625
**Installation [34]	$60	5	$300
Graywater Storage Tank [46]	$310	1	$310
		Upfront Cost Total:	**$2,235**
20-Yr Lifecycle Costs			
Item	**Cost per Operation**	**Frequency (per 20 years)**	*****LIC Total**
Operation & Maintenance [34]	$120	20	$2,400
		******OVERALL TOTAL**	**$4,635**

*Cost x Quantity = UPC Total
**Installation was estimated to require approximately 5 hours per do-it-yourself model while paying the installer at a rate of $12/hr. It was assumed that there would be an installation fee for the industrialized toilet that would cost approximately $60 as well.
***Cost per Operation x Frequency = LIC Total
****UPC Total +LIC Total = Overall Total

Water Supply Alternatives

WELL COST ANALYSIS			
Upfront Costs			
Item	**Cost**	**Quantity**	***UPC Total**
Installation [47]	$2,800	1	$2,800
Drilling [48]	$21,500	2	$43,000
Storage Tank [49]	$670	5	$3,350
Booster Pump [49]	$280	1	$280
		Upfront Cost Total:	**$49,430**
20-Yr Lifecycle Costs			
Item	**Cost per Operation**	**Frequency (per 20 years)**	****LIC Total**
***Water Quality Testing [50]	$201	20	$4,020
****Maintenance Check [34]	$36	20	$720
		20-Yr-Lifecycle Cost Total:	**$4,740**
		*******OVERALL TOTAL**	**$54,170**

*Cost x Quantity = UPC Total
** Cost per Operation x Frequency = LIC Total
*** Standard water quality testing typically costs about $80. It was assumed that over the 20 year period at least one extensive water quality test would be needed. These cost approximately $2500. With $80/yr for 19 years ($1520) and $2500/yr for one year, the total water quality testing cost for 20 years would be $4020. On an annual basis this ($4020/20 years) is $201.
****It is assumed that the well will require approximately 2 hours of operation and maintenance needs. A well maintenance worker will be paid $18/hr. This resulted in a total of 2*18 = $36 every year.
*****UPC Total +LIC Total = Overall Total

IMPORTATION COST ANALYSIS			
Upfront Costs			
Item	**Cost**	**Quantity**	***UPC Total**
On-Site Above Ground Storage Tank [31]	$6,689	1	$6,689
Water Hauling Tank [51]	$1,637	1	$1,637
			$8,326
20-Yr Lifecycle Costs			
Item	**Cost per Operation**	**Frequency (per 20 years)**	****LIC Total**
***Transportation	$1786	20	$35,720
***Potable Water	$177	20	$3,540
****Water Hauling Service [34]	$48	22	$720
			$39,980
		*******OVERALL TOTAL**	**$48,306**

*Cost x Quantity = UPC Total

** Cost per Operation x Frequency = LIC Total

*** See Appendix E1 & E2

**** It is assumed that the maintenance worker will spend approximately 4 hours hauling water to Sun Valley Ranch from Holbrook. It is assumed that they will be paid $12/hr for this service. Therefore, each time the tank is filled, it will cost $12 x 4= $48.

*****UPC Total +LIC Total = Overall Total

Appendix E1: Water Importation Cost Analysis

The following tables show the considerations, estimated values, and calculated values for the transportation of the imported water from Holbrook to Sun Valley Ranch.

Site and Vehicle Considerations

Item	Capacity (gal)	Variable
Delivery Vehicle Water Capacity	800	D_w
On Site Water Tank Size	4800	S_T

Estimated Transportation Parameters

Item	**Quantity (units)**	**Variable**
Site to Source Distance	26 (miles)	l
Vehicle/Fuel Cost	$0.56/mi	C_V
Vehicle/Fuel Cost (Round Trip)**	$14.56	$C_{VR} = l \cdot C_V$
Source Water Price	$1.75 (per 1000 gal)	C_W

Estimated Site Considerations

Item	**Quantity (units)**	**Variable**
Sun Valley Population*	5-10 (people)	N_P
Specific Water Demand*	55±10 (gal/(person·day))	W_u
Total Water Demand*	225~650 (gal/day)	$W_d = N_P \cdot W_u$
Minimum Site Water Reserve**	7~21 (days)	$S_R = \frac{S_T}{W_d}$
Expected Occupation Length	184 (days)	D_O

Water importation costs based on actual and estimated considerations of site and vehicle.

Item	**Quantity**	**Variable**
Expected Number of Annual Water Deliveries**	53~158	$A_D = \frac{S_T}{D_W} \cdot \frac{D_o}{S_R}$
Annual Transportation Expenses**	$771.68~$2300.48	$AT_E = A_D \cdot (C_{VR})$
Annual Water Expenses**	$72.45~$209.30	$AW_E = (C_W \cdot W_d \cdot D_O)$

*Estimated Value

**Calculated Based on estimation

Annual water expenses neglect the cost of vehicle maintenance. The upper and lower limits are appropriately used to justify water expenses where the declared variable may appear in formulas for subsequent variables.

Appendix E2: Calculations for Water Importation Cost Analysis

The calculations for an estimated population of 10 people with a water demand of 55 gal/person/day are provided below using the information provided in **Appendix E1**.

$$\textit{Assuming population of } 10 \textit{ people } (N_P) \textit{and a per capita water demand of } \frac{55 \frac{gal}{person}}{day}$$

$$\text{Total Water Demand: } W_d = N_P \cdot W_u = 10\, people * \frac{55 \frac{gal}{person}}{day} = 550\, gal/day$$

$$\text{Minimum Site Water Reserve: } S_R = \frac{S_T}{W_d} = \frac{4800\, gal}{550 \frac{gal}{day}} = 8.72\, days \approx 9\, days$$

$$\text{Expected Number of Annual Deliveries: } A_D = \frac{S_T}{D_W} \cdot \frac{D_o}{S_R} = \left(\frac{4800\, gal}{800\, gal} * \frac{184\, days}{9\, days} \right) = 122.67$$

$$\textit{Assuming average fuel price } (P_F) \textit{ and average vehicle efficiency } (\eta_F)$$

$$\text{Round Trip Fuel Cost: } C_{VR} = l \cdot C_{VR} = 26\, miles * \frac{\$0.56}{mile} = \$14.56$$

$$\textbf{Annual Transportation Expenses}: AT_E = A_D \cdot (C_{VR}) = 122.67 * (\$14.56) = \$\mathbf{1786.08}$$

Annual Water Expenses:

$$AW_E = (C_W \cdot W_d \cdot D_O) = \frac{\$1.75}{1000 gal} * \ 550 \frac{gal}{day} * 184\, days = \$\mathbf{177.10}$$

Appendix F: Calculations for Rainwater Harvesting Landscaping Area

The dimensions for the plants were determined through an inventory for native Arizona plants [16].

Desert broom shrub:

Quantity: 3

Height: ~ 5’

Width: ~ 3’

Area = 3* 5’ * 3’ = 45ft^2

Parry’s agave plant:

Quantity: 3

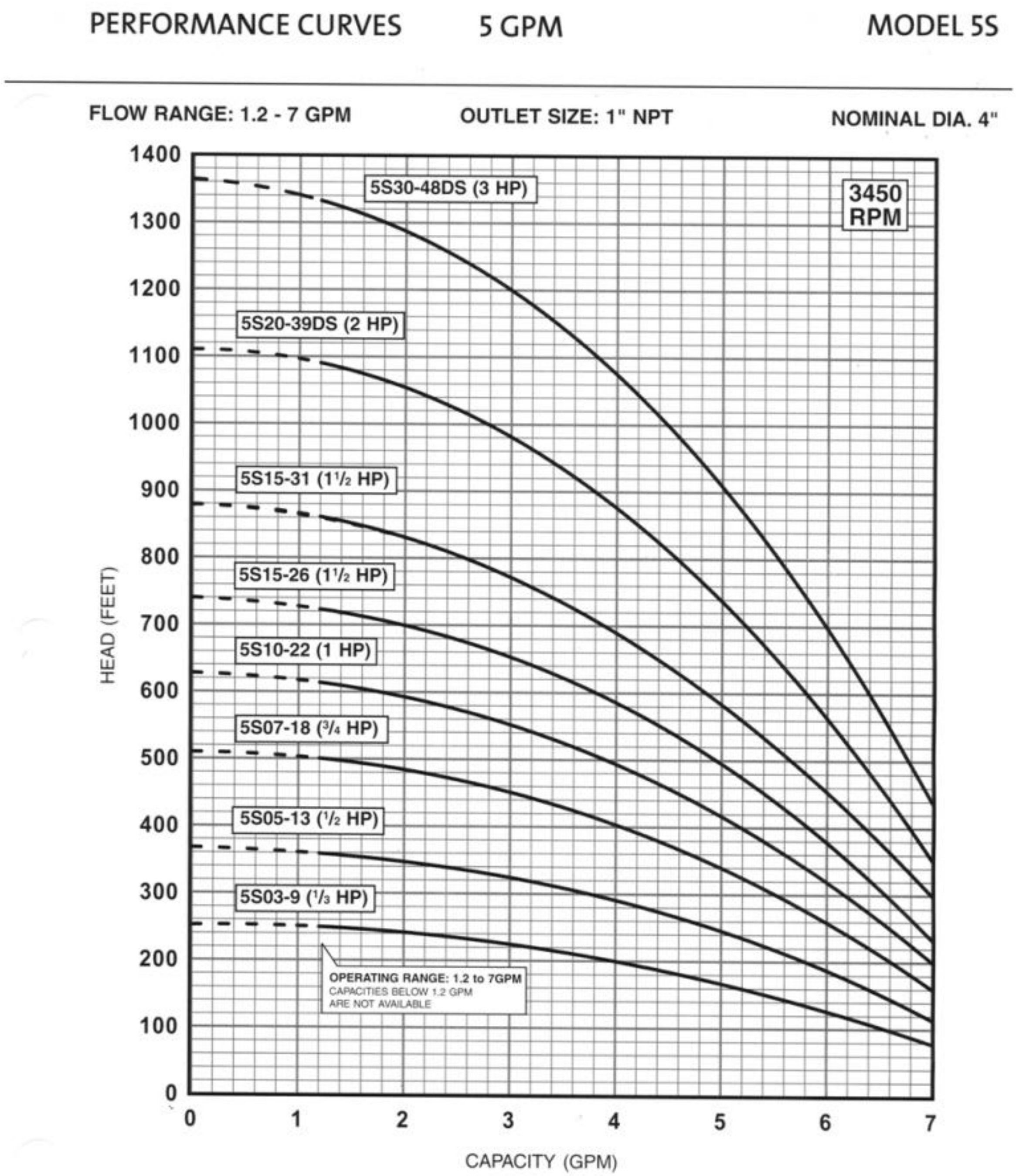
Height: ~ 2’

Width: ~ 2’

Area= 3* 2’ * 2’= 12ft^2

Total landscaping area: 45+12 = **57ft^2**

Appendix G: Pump Performance Curve



Appendix H: Original Project Cost

1.0 Personnel	**Classification**	**Hours**	**Rate $/hr**	**Cost**
	PM	168	92	**$15,456**
	ENG	184	132	**$24,288**
	LAB	160	63	**$10,080**
	AA	184	40	**$7,360**
	Total Personnel	696		**$57,184**
2.0 Travel	2 meetings @ 100 mi/meeting	$0.56/mi		**$112**
3.0 Subcontract	Geotechnical Analysis			**$5,000**
4.0 TOTAL				**$62,296**