White Mountain Apache Reservation
Conceptual Design Report

Figure 1: The Great Seal of the White Mountain Apache Tribe

Civil Engineering
CVE 400 Civil Engineering System Design I
Project Team: Nicholas Fisher, Zachary Michali, and Joshua Sims

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I. Introduction and Project Overview

A. Introduction

Members of the White Mountain Apache Tribe (WMAT) and the Highland Support Project (HSP), a non-governmental organization, have asked the Civil Engineering Department at York College of Pennsylvania (YCP) to provide design services for two projects located within the White Mountain Apache Tribe Reservation. The YCP student engineering project team selected for the McNary, Arizona site will be performed by Nicholas Fisher, Zachary Michali, and Joshua Sims.

B. Project Overview

The project is located at the White Mountain Apache Tribe Reservation located in eastern Arizona (Figure 1). The 1.6-million-acre reservation site is the ancestral and current home for approximately 16,000 members of the White Mountain Apache Tribe (WMAT). The reservation land consists mostly of pine forests and mountainous terrain and boasts over 26 lakes, and 400 miles of streams. Also located on the reservation are several sites of historical significance, including Fort Apache Historical Park and the Kinishba Ruins (White Mountain Apache Tribe 2021).

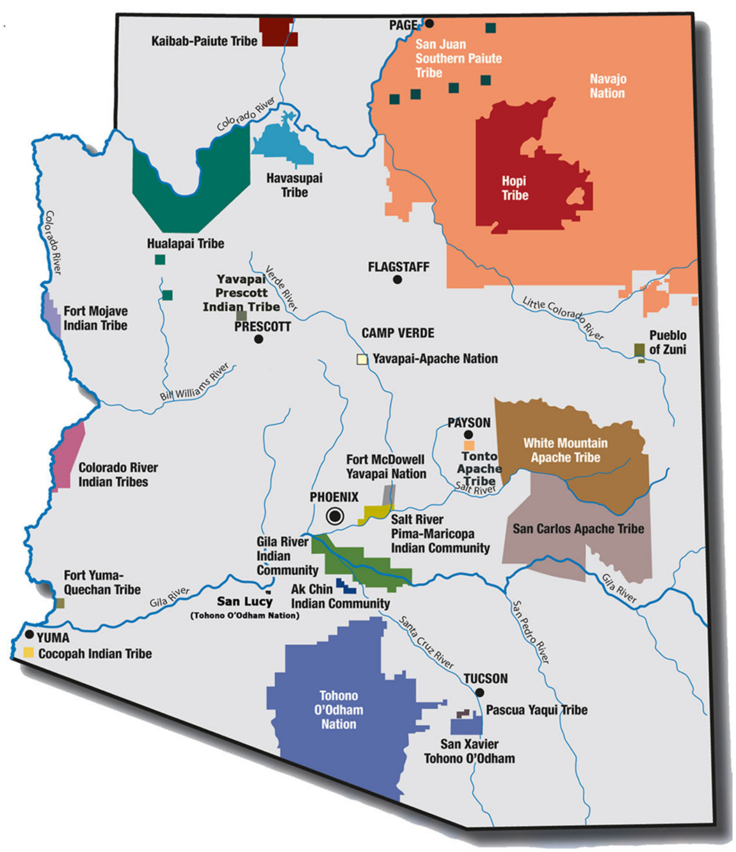

Figure 2. Location of the White Mountain Apache Tribe (Compulsive Cartographer, 2014)

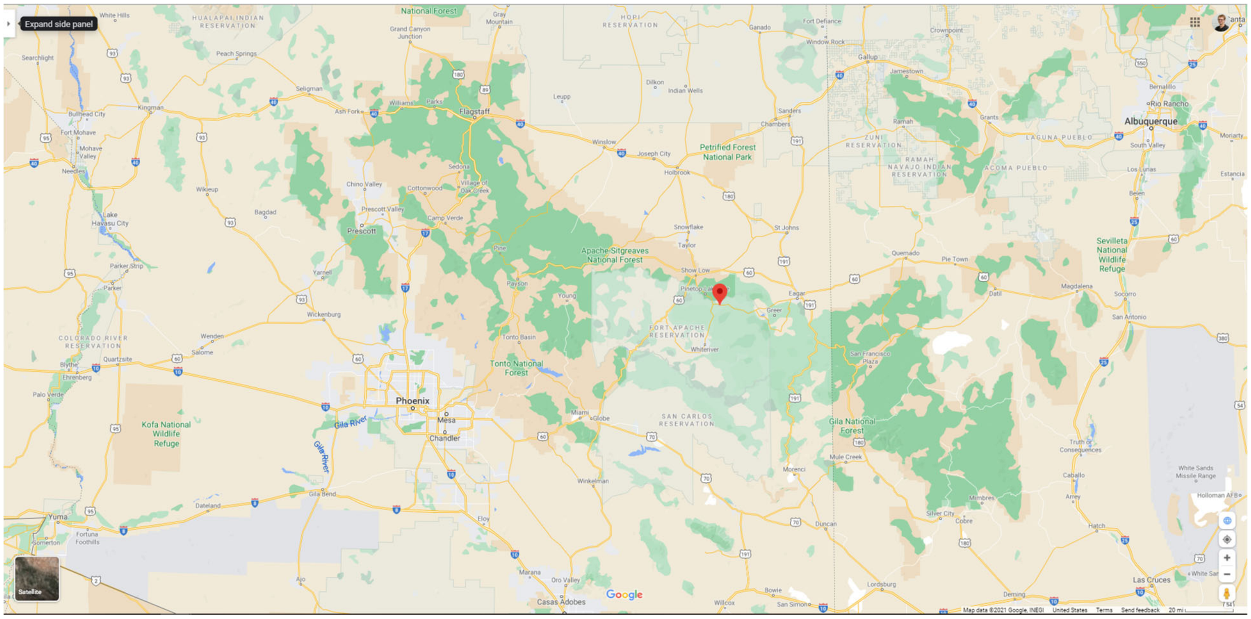

Figure 3. The location of McNary, Arizona (Google Maps 2021)

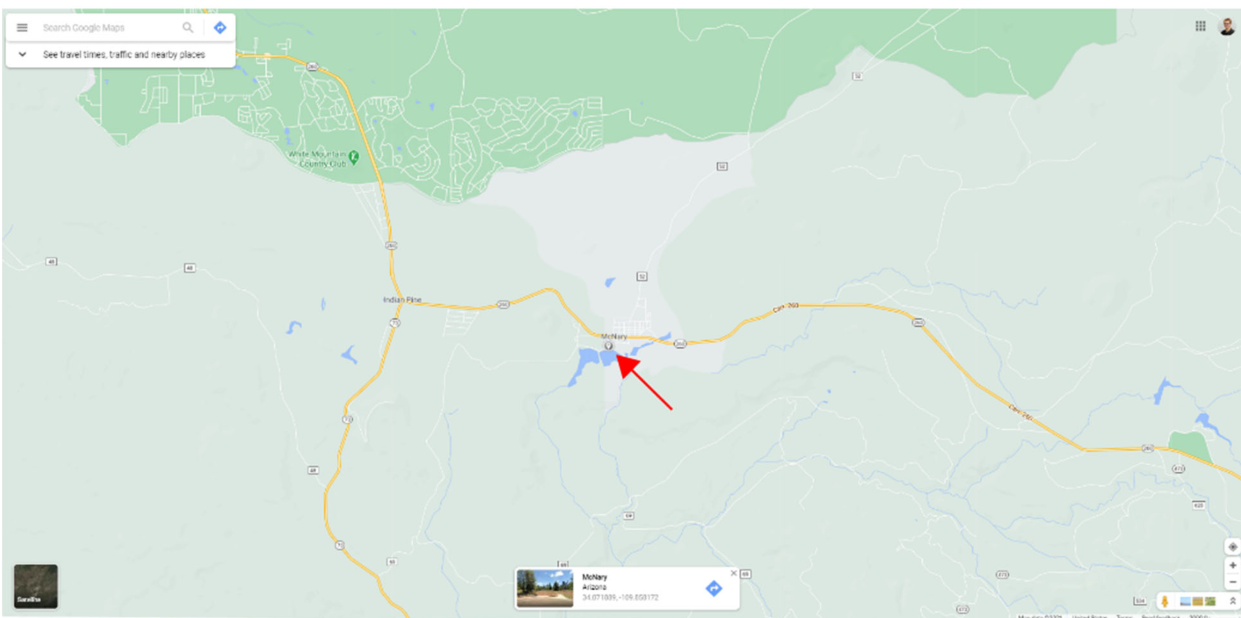

Figure 4. The approximate location of the project site at McNary (Google Maps 2021)

Towns on the reservation include Whiteriver with a population of 4,292 people, Cibecue with a population of 2,173 people, and McNary with a population of 672 people (United States Census Bureau 2021). As these areas continue to grow, so too does the demand for crops and therefore crop irrigation. The White Mountain Apache Tribe is developing small scale community gardens to provide a source of local healthy foods and also act as platforms for health and environmental education. To continue this task the White Mountain Apache Tribe wants to improve the reliable access to water for agricultural irrigation purposes. This project's goals are to determine the most feasible water conveyance and storage infrastructure systems and provide preliminary design details and cost estimation for the White Mountain Apache Tribe to utilize for their sustainable agriculture plans.

The timeline for the development and design of this project is scheduled to run from February through August 2021. This includes multiple deliverables throughout the duration of the project as listed in the previously submitted problem statement.

II. Existing Conditions

A. Geography

The project site is located in McNary, AZ and consists of a community garden. The project site elevation is approximately 7313-ft. The site sits atop a 40-ft slope from the eastern, southern, and western sides. South of the site, at the bottom of the slope, Gomez Creek has been impounded to form a series of small ponds. The nearest of these ponds is about 900-ft. away from the garden. Topographic information gathered from the USDA's National Aerial Imagery Program indicates that the water surface elevation of the existing pond directly south of the site is approximately 7270-ft. This data does not provide any information regarding topography below the surface of the water or the depth of the body of water. Topographic information shown on the attached existing conditions plan provides enough detail to be utilized for conceptual planning, but is not exact. All design alternatives will make use of elevation data; whether it be a drainage area for rainwater capture or a difference in elevation for a pumping system. Because of this, it may eventually be necessary to conduct a survey of the site and surrounding area to acquire more reliable topographic information.

B. Soil

Soil on this site primarily consists of USDA soil designation 91B, sponseller gravelly silt loam. This soil is described as a mixture of silt and gravel with patches of cobblestone. This soil is categorized as Hydrologic Soil Group C (H.S.G.: C). A soil's H.S.G. is a measure of its ability to infiltrate water; with H.S.G. A having the highest infiltration rate and H.S.G. D having the lowest infiltration rate. The infiltration rate of a soil will be important when considering rainwater capture design alternatives and water storage basins. Soil types and H.S.G. ratings for this site are shown on the attached existing conditions plan.

C. Transportation/ Roads

The town of McNary has one road going in and out of town that connects it to other surrounding towns. The road is identified as Arizona State Route 260 (AKA. AZ-260 or SR 260) and travels in an east-west direction and connects the town with the city of Eagar, AZ (to the east) and several small towns (of comparable size to McNary) to the west. McNary itself has a mix of both paved roads, mostly in the residential section of the town north of AZ-260, and unpaved roads, mostly south of AZ-260.

The chosen site is surrounded on all four sides by roads. Along the north side of the site is AZ-260, which does not have any direct access that go directly to the site. However, AZ-260 does have a turn lane onto Naco Street which borders the western, and southern sides of the site. Naco Street consists of two different sections, the first, along the west side of the site is a paved cul-de-sac which appears to have residences along both sides (Figure 6). At the end of the cul de sac circle, the road jumps the curb, and transitions into a dirt road (See figure 7) which runs along the southern side of the site, connecting the cul de sac to East Main Street. East Main street, running along the eastern side of the site, also connects into AZ-260, as well as continuing west connecting to additional secondary roads.

Figure 5. AZ-260 as seen from the entrance to Naco Street looking west into town. The project site runs along the right side of the picture (Google Maps 2016)

Figure 6. The paved cul-de- sac of Naco street, as seen from AZ-260, looking south. The project site is located to the left of the picture (Google Maps 2008)

Figure 7. The end of the cul de sac of Naco Street showing where the pavement ends and the dirt road begins (Google Maps 2008)

Figure 8. The unpaved section of Naco Street as seen from East Main Street looking west. The project site is in between Naco Street and East Main Street near the center of the picture (Google Maps 2008)

Figure 9. East Main Street as seen from AZ-260, looking south. The project site can also be seen on the right side of this picture (Google Maps 2008)

III. Design Requirements

A. Scope of Work

During the course of this project the project team will identify the design requirements, generate design alternatives, communicate with the client to seek feedback, and develop a final design, specifications, and cost estimate to meet the project goals. . The design requested is a method of obtaining and storing water. This shall allow for the development of a community garden. Additionally, the design should include any and all information on pumping, piping (transporting water from source to storage location), and local irrigation (for the garden itself) as required. This project may also briefly review potential options for further development of this site, and how the usage of water can be improved upon following the implementation of the initial design.

B. Project Objectives

The goal of this project is to help improve upon the water security for the White Mountain Apache Tribe's sustainable agricultural needs. If successful, the stakeholders, including the people of McNary should have sufficient water storage, and access to water to be able to successfully grow and utilize the project site as a community garden.

IV. Design Criteria

In order to successfully transport the required water to the community garden, the project team will need to satisfy the stakeholders needs which are listed in the design requirements. The design requirements will influence the design process and design alternatives.

A. Safety and Accessibility

The proposed designs must comply with all applicable state, federal, and tribal codes and regulations. According to the U.S Department of the Interior, as U.S citizens Native Americans are subject to federal, state and local laws. However, Native Americans on reservations are subject to federal and local (tribal) laws that apply. Due to the project being in on the White Mountain Apache Reservation, the project team will need assistance from the stakeholders to identify any tribal laws that the design team is not aware of.

B. Environmental Protection

This project must be designed to be sustainable and protect the natural ecosystem within the project area. The designs and construction must not negatively impact the water sources that we be utilized to obtain the water for the community garden. In addition, the design needs to be environmentally sustainable so that is does not impact surrounding areas. The design must also not cause any erosion, impact any wetlands, or degrade the local habitat and ecosystems. The project team also needs to research and identify the all environmental requirements and the appropriate permits that may be needed for such a project.

C. Civil Engineering Sub-Disciplines

In addition to the criteria listed above, each of the civil engineering disciplines must be considered. These sub-disciplines include structural, geotechnical, traffic, water resources, environmental, and construction engineering topics. Although any pumping alternatives may not have structural considerations a well design will require some structural evaluation to ensure the well shaft can be supported to prevent collapse. . When designing for rainwater collection, any potential structures   will need to have structural integrity and be designed to store enough water to support the agricultural operations during seasonal fluctuations. Due to the project location, there should be no impact on traffic . The project team must consider how each design alternative will impact the surrounding water resources.   The pump will have the largest impact as it will be taking water directly from the nearby pond. The rainwater collection will only reduce runoff into the nearby pond and the well will have a small impact on the groundwater. None of our designs will cause a large increase in runoff and research will be done on the area to see if we will have an impact on any endangered species. Our construction will be minimal with the rainwater collection. All three design alternatives will require equipment to dig. The groundwater collection will need to dig out a basin and a location to place the pump using an excavator. The pump water from lake alternative will require more excavation as a pipe has to be installed as well as a pump. The well alternative will require a deep well to be dug out with a drill but does not require an excavator.

V. Design Alternatives Under Consideration

A. Pumping from a Surface Water Source

The first design alternative that comes to mind when examining this site is pumping from a body of surface water located near the project site. Gomez Creek runs just south of this site. Additionally, aerial imagery indicates that this creek has already been impounded. This design alternative would consist of a pump, roughly 1,000 feet of pipe and a storage facility adjacent to the garden. Due to the garden's elevation and location within the site, the storage facility will likely need to be an above ground tank, so that the store water can use gravity to flow to the garden. A water storage basin, below ground tank, or pumping directly from the existing dam to the garden are also design alternatives . However, these options would require pumping that will require an energy source to provide power as opposed to just opening a faucet, making them less convenient for the McNary community. While this option would likely be very reliable, this option does not come without its challenges.

There is a 40-ft. difference in elevation and about 900-ft. between the existing pond and the community garden. Additionally, the pipe would travel under three unpaved roadways. More information would be needed about the vehicle traffic on these roadways to determine the magnitude of force the pipe network be subject to.

Additional to the physical constraints of this design alternative, the pond that this site would draw from is crossed by the municipal boundary between Apache County and Navajo County. While a pump would likely be placed well over 400-ft. on the Apache County side of the pond, further investigation will be needed to determine if this will complicate the permitting process. During research for this design alternative, the project team was unable to locate information regarding property boundaries. While not knowing property boundaries could affect all of the design alternatives presented in this report, it will have the greatest impact on this alternative. If this site's property does not extend to the existing pond, it is very likely that an easement will need to be acquired. Gaining approval for this could inflate the duration and cost of the project. The advantages and disadvantages of the design alternative to pump from an existing body of surface water are listed in Table 1.

Table 1: Advantages and Disadvantages of the surface water capture alternative

Advantages of Surface Water Capture	Disadvantages of Surface Water Capture
Gomez Creek is a definite source of water located close to the project site.	Pumping water from the existing pond would require a very large length of pipe.
While the water level in the existing pond may vary with season, storing water in a tank on site will allow for the storage of a reliable option.	A water line from the pond to the garden would cross 1 to 3 unpaved roadways, disrupting traffic during construction and possibly requiring stronger and more expensive materials.
There is a 40-ft. difference in elevation for a pump to overcome, which is fairly large, but less than the groundwater well alternative.	An easement may be acquired for piping to cross any properties. This can be costly and time consuming.
	Drawing water from the existing pond could require a lengthy permitting process due to the crossing of the county line.
	The water level is likely to vary seasonally.

B. Ground Water Well

Another design option is a well, either on site, or adjacent to the site, that would be utilized to access the groundwater. This design would likely require a powered pump l, as opposed to having a hand drawn well. Additionally, it would likely include an above ground storage tank to pump to. The storage tank would allow easier access to a larger volume of water than coming directly from the well and will help prevent the well from becoming overtaxed (dry for short periods of time).   It is important to note that the Arizona Department of Natural Resources lists an existing well directly to the South East of the site as shown in Figures 10 and 11. It is unknown who currently is the owner, and possess rights to the water of, this well. However, the Arizona Department of Natural Resources lists some important information regarding the specifications of this well that will help determine the feasibility of either expanding upon the use of this well, or installing a second well for community garden use only (Arizona Department of Natural Resources 2021).

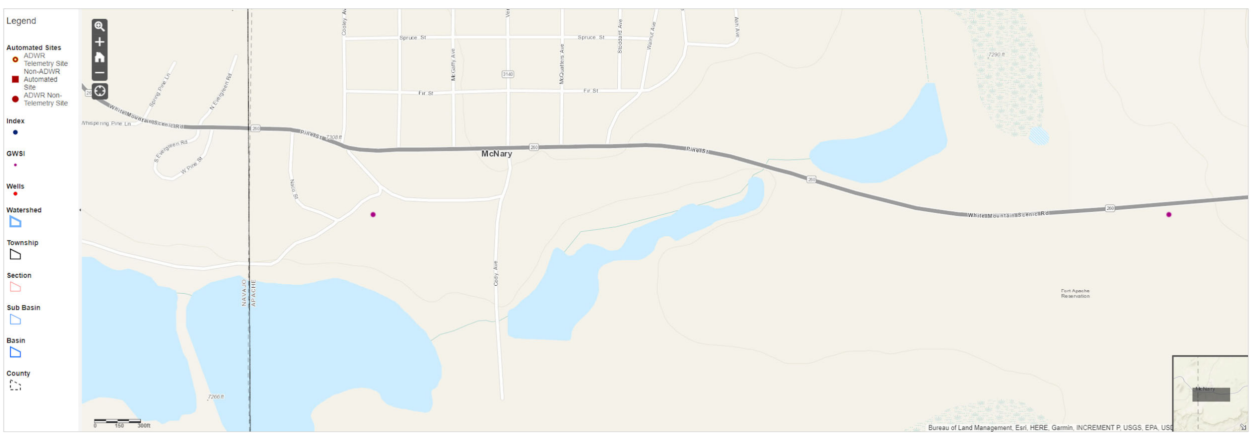

Figure 10. The two purple dots show the existing wells located in and around the town of McNary (Arizona Department of Natural Resources, 1973)

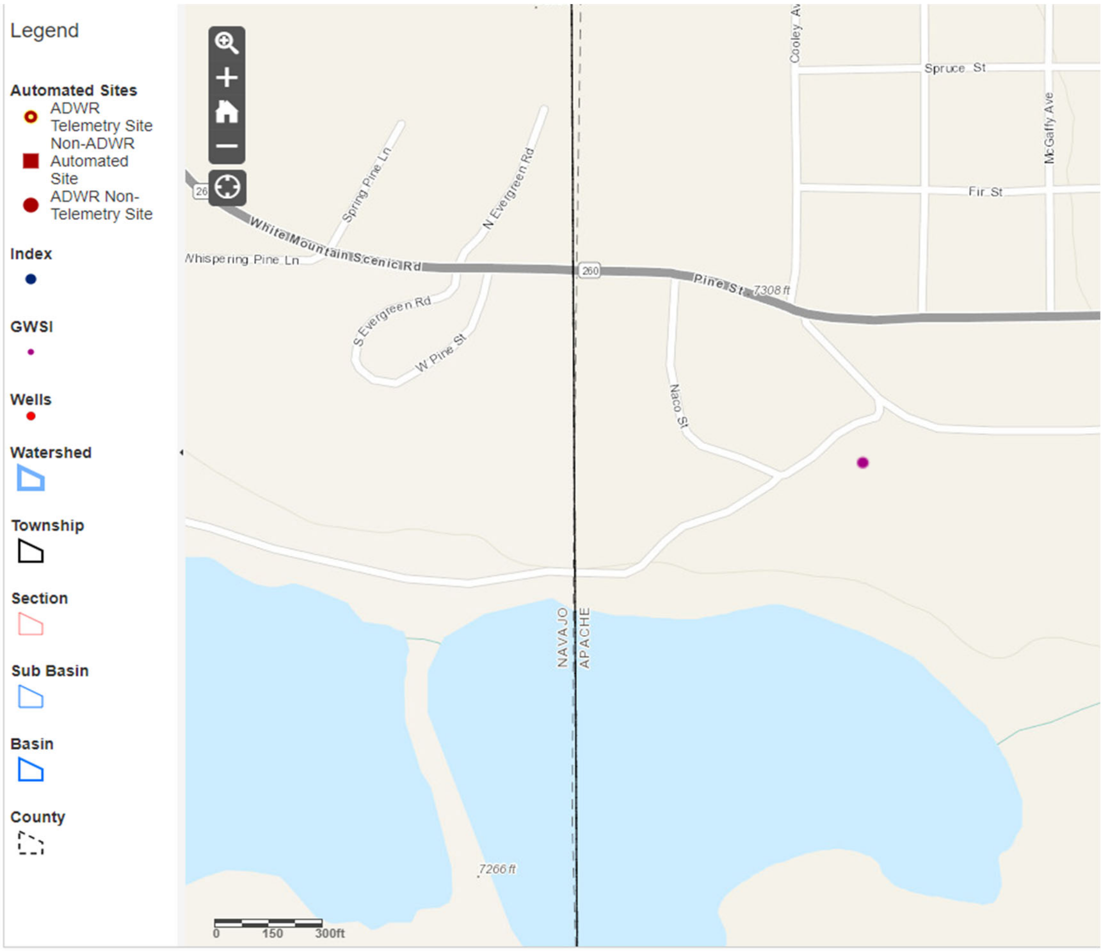

Figure 11. A zoomed in view of the location of the existing well that is located near the site of the community garden (Arizona Department of Natural Resources 1973)

The information, as found by USGS, can be seen in Figures 12 through 14. This data is listed as being taken in September 1973 and was measured with a steel tape (reliability marked as C-field checked), so some of the information may be out of date or incorrect. The important information to draw from the table is the depth of the well and the depth of the water inside of the well. Figure 12 lists the total depth of the well at 250 feet, and Figure 13 states that the water level is approximately 182 feet below the surface of the ground, which correlates to a water table elevation of 7,068 feet. No information is provided about any use of a pump in this well, or the owner of the well. Some information is provided on how and when the well was constructed in 1956. The drill method code C stands for cable tool, referring to a well drilled by the percussion or churn-drill method whereby a heavy drilling tool is raised and lowered with enough force to pulverize the rock. The rock debris is commonly removed from the hole with a bailer.

GWSI Site							
Site Type	W - WELL	Meridian	G - GILA AND SALT RIVER	Reliability	C - FIELD CHECKED		
Topo Setting	F - FLAT	Source	USGS	Quad Name	MCNARY	Map Scale	24000

Latitude, Longitude DMS							
Laiitude	34 4 20	Longitude	109 51 21	Method		Accuracy	F - 5 SECONDS

Site Elevation					
Altitude - Feet AMSL	7250	Altitude Method	M - INTERPOLATED FROM TOPOGRAPHIC MAP	Altitude Accuracy	10

Well Information							
Hole Depth	250	Well Depth	250	Depth Code	* - UNDETERMINED	Geo unit	112BLCF

Basin, County and State Information					
USGS Basin	WRB - WHITE RIVER BASIN	Sub Basin	WRB - WHITE RIVER	ADWR Basin	SRB - SALT RIVER BASIN
State	AZ - ARIZONA	County	01 - APACHE		

Site Uses		Water Uses	
Site Use 1	U - UNUSED	Water Use 1	U - UNUSED
Site Use 2		Water Use 2	
Site Use 3		Water Use 3	

Figure 12. The general information listed about the existing well directly adjacent to the project site (Arizona Department of Natural Resources, 1973)

Standard Water Levels

Date	Depth to Water ft.	Measurement Method	Meas. Code	Remark	Rem. Code	Source	Src. Code	Altitude ft amsl
9/1/1973	182	STEEL TAPE	S			USGS	U	7068

Measuring Point

Date Established	Meas. Pt. Height ft	Description
No records to display.		

Figure 13. The measured water levels inside of the existing well directly adjacent to the project site (Arizona Department of Natural Resources, 1973)

Well Completion

Completion Date	Drill Method	Drill Meth. Code	Casing Description	Case Code	Source	Source Code
1/1/1956	CABLE TOOL	C	PERFORATED OR SLOTTED	P	UNDETERMINED	*

Bore Completions

Top ft.	Bottom ft.	Diameter in.
No records to display.		

Casing Completions

Top ft.	Bottom ft.	Case Dia. in.	Case Material	Mat. Code
0		8	UNDETERMINED	*

Perforation Completions

Top ft.	Bottom ft.	Perforation Material	Perf. Material Code	Length in.	Width in.
180		UNDETERMINED	*		

Figure 14. The information provided on the construction of the existing well that is located directly adjacent to the project site (Arizona Department of Natural Resources, 1973)

The fact that there is or was (if the well got filled in) a well located in the direct vicinity of the site supports the idea that the well would be the simplest solution to obtaining water for the community garden. Additionally, if the well is still functional, or partially functional, it can be utilized in place of a new well which would have significant savings on the installation cost. As with all of the potential design alternatives there are advantages and disadvantages to this alternative, which are shown in Table 2.

Table 2: Advantages and Disadvantages of the Well Alternative

Advantages of the Well Alternative	Disadvantages of the Well Alternative
If a new well is required, it can be built directly on site, which prevents the need to cross any road surrounding the site with a pipe/ hose	If a new well is required the construction/ drilling will likely be the bulk of the cost of the well, and require the most amount of time
The existing well may be able to be utilized, dependent on the conditions/ integrity of the well significantly decreasing the cost	The pump that draws water from the well will require regular maintenance in order to maintain functionality
A well is minimally affected by seasonal changes (temperature, drought, etc.)	The pump for the well will need electricity
A well should supply a steady supply of water	There is a risk of contamination of the water (which impacts are minimal as it is not to be used for drinking)
The well will not impact the lake	The well itself requires maintenance
The well requires minimal above ground construction	If a new well is required, the site is at a higher elevation than the existing well which would require a deeper well to be built (about 250-350 feet deep)

C. Rainwater Harvesting

A third potential design alternative is collecting rainwater and storing it in a tank until use. The design would likely have a collection system in place to collect all of the rainwater for the site in a basin where it will then be pumped up and store in an aboveground water tank. The water can then be transported from the tank to be used for the community garden. The storage tank being aboveground will allow easy access and allow the use of gravity to transport the water to the garden. The water will have to be pumped up into the tank so a small pump would be needed for the rainwater harvesting design alternative.

Figure 15 shows the average monthly rainfall McNary receives, which totals to an annual rainfall of 24.3 inches per year. While this is high for Arizona, it is low on average for the U.S. in general. It can also be noted that the lowest rainfall months are April through June (0.7-1 in) with the highest coming in July and August (~4 in).

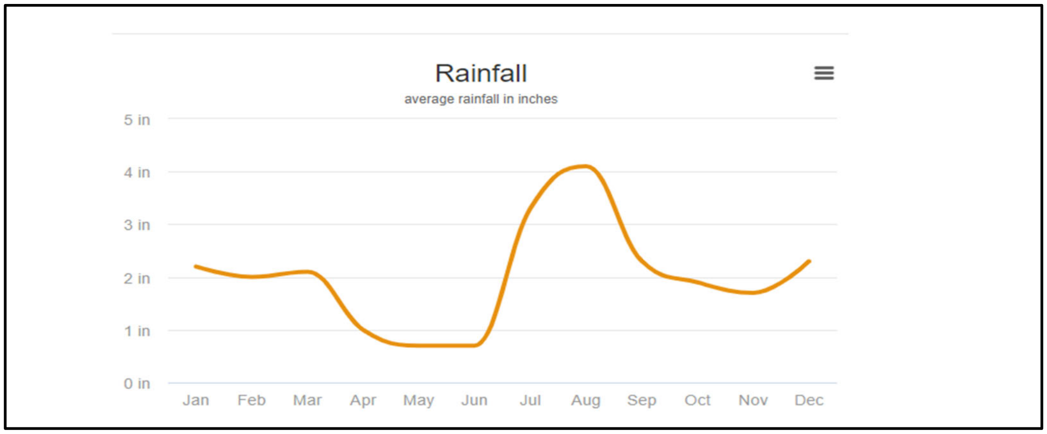

Figure 15. Average rainfall amount for McNary, Arizona by month (McNary, Arizona Climate, 2021)

Figure 16 shows the total area that can be utilized to collect rainfall from is approximately 13,000 sq. ft. This is not a large area and could result in a shortage of stored water for the community rain garden. If the collection area is increased, it will allow room for a basin at a lower elevation which will capture a much larger amount of rainwater and increase water available for the garden. The exact location of the property boundaries are not known at this time so the project site area was estimated utilizing a view from Google Earth.

Figure 16. Rainfall collection area for community garden (Google Maps, 2021)

The advantages and disadvantages of the rainwater harvesting alternative are summarized and listed in the table below.

Table 3. Advantages and Disadvantages of the Rainwater Harvesting Alternative

Advantages of Rainwater Harvesting	**Disadvantages of Rainwater Harvesting**
It will be easy to replace the aboveground storage container if needed.	Will need to install a pump as well as a basin and a storage container.
This will likely be the cheapest option as it requires the least amount of excavation/drilling.	The pump will require maintenance after installation which results in an additional cost .
This option will require the least amount of maintenance.	During low rain seasons or droughts likely won't have enough water for the garden.
Construction time will be the shortest out of the three options.	Soil type is B which will result in more infiltration and less water available for storage.
No road closures required, and no roads disturbed.	Lowest rainfall months are during peak growing seasons.
	The rainfall collection area is small and won't be able to make up for lower rainfall amounts during droughts.
	Site location is at a high point which will result in less runoff into the area and a lower amount of rainwater collection.

The rainwater harvesting alternative is the lowest cost alternative but is the least reliable option as there could be times during droughts or other seasonal variations that could result in no water being collected when it is most needed. for the community garden. This alternative could still have the risk not providing a reliable water supply for the garden and would leave the community without a sustainable garden.

VI. Recommendations

After reviewing the advantages and disadvantages of each design alternative, the project team recommends that a well may be the best design alternative to provide a reliable and sustainable source of water for the community garden. This design alternative requires less construction than pumping from the existing lake and will have less impact on the adjacent properties. Additionally, the well will have no effect on the lake whereas pumping the water from the lake would require a pump to be staged in or near the lake itself. If possible, it is recommended to research utilizing the existing well, either for the source of water, or as an existing well hole to fix and bring back into service. If this can be done it would decrease the time and cost of construction of installing new well. Most importantly, the well would produce a reliable, constant source of water with minimal variation from drought and other seasonal weather factors.

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0 100' 200'
1" = 100'

ENLARGED EXISTING CONDITIONS PLAN

DATE: MARCH 26, 2021