Design Report for

Chiricahua National Monument RV Housing Site Design

CENE 486C Engineering Design

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ELEVATION ENGINEERING

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Equations

Abbreviations

AASHTO – American Association of State Highway and Transportation Services

ABC – Aggregate Base Course

ACI- American Concrete Institute

ADA – Americans with Disabilities Act

ADEQ – Arizona Department of Environmental Quality

ADWR - Arizona Department of Water Resources

AEA- Air-Entraining Agent

FHWA - Federal Highway Administration

GPS – Global Positioning System

LL – Liquid Limit

NOAA – National Oceanic and Atmospheric Administration

NPS – National Park Services

PI – Plastic Index

PL – Plastic Limit

RV – Recreational Vehicle

USCS – Unified Soil Classification System

NRCS - Natural Resources Conservation Service

NOAA – National Oceanic and Atmospheric Administration

Acknowledgements

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Additionally, we recognize Caroline Reed for their support and for taking the time to teach us how to use GPS surveying equipment and for coordinating equipment checkouts, ensuring we had access to the tools necessary for our project.

Finally, we appreciate the encouragement from our peers, friends, and families throughout this process.

1.0 Project Introduction

1.1 Project Purpose

Chiricahua National Monument plans to develop ADA-compliant RV pads with full hookups to provide essential housing for seasonal and volunteer staff. Due to limited existing housing, this project will convert a 1.5-acre undeveloped area into a functional green living space featuring concrete RV pads and a gravel road, ensuring accessibility and compliance with Park Service and client standards. The design will incorporate drainage solutions to prevent flooding and erosion while ensuring the structures are suitable for the area's soil conditions and usage. Without these improvements, staffing challenges could arise, potentially impacting operations and the visitor experience.

1.2 Project Location

The national monument is located in the Southeast corner of Arizona, about 30 miles southeast of Willcox, as shown in Figure 1-1.

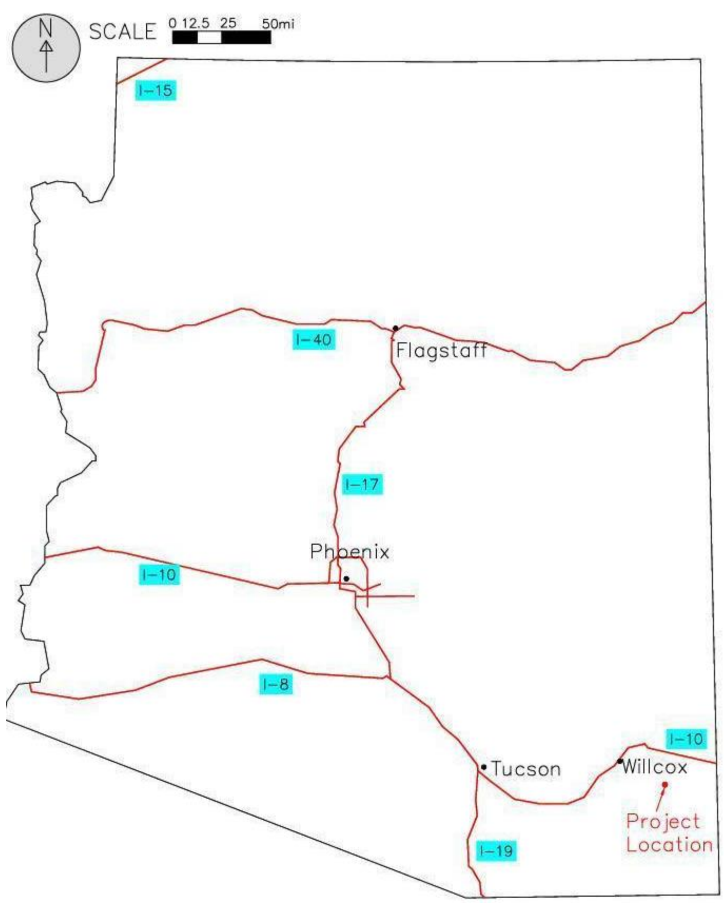

Figure 1-1 - Location Map

The project site is on the east side of Pinery Canyon Rd, a well-maintained gravel road just off Arizona State Route 181. Both the monument entrance and sign are located at the intersection of the aforementioned roads, refer to Figure 1-2.

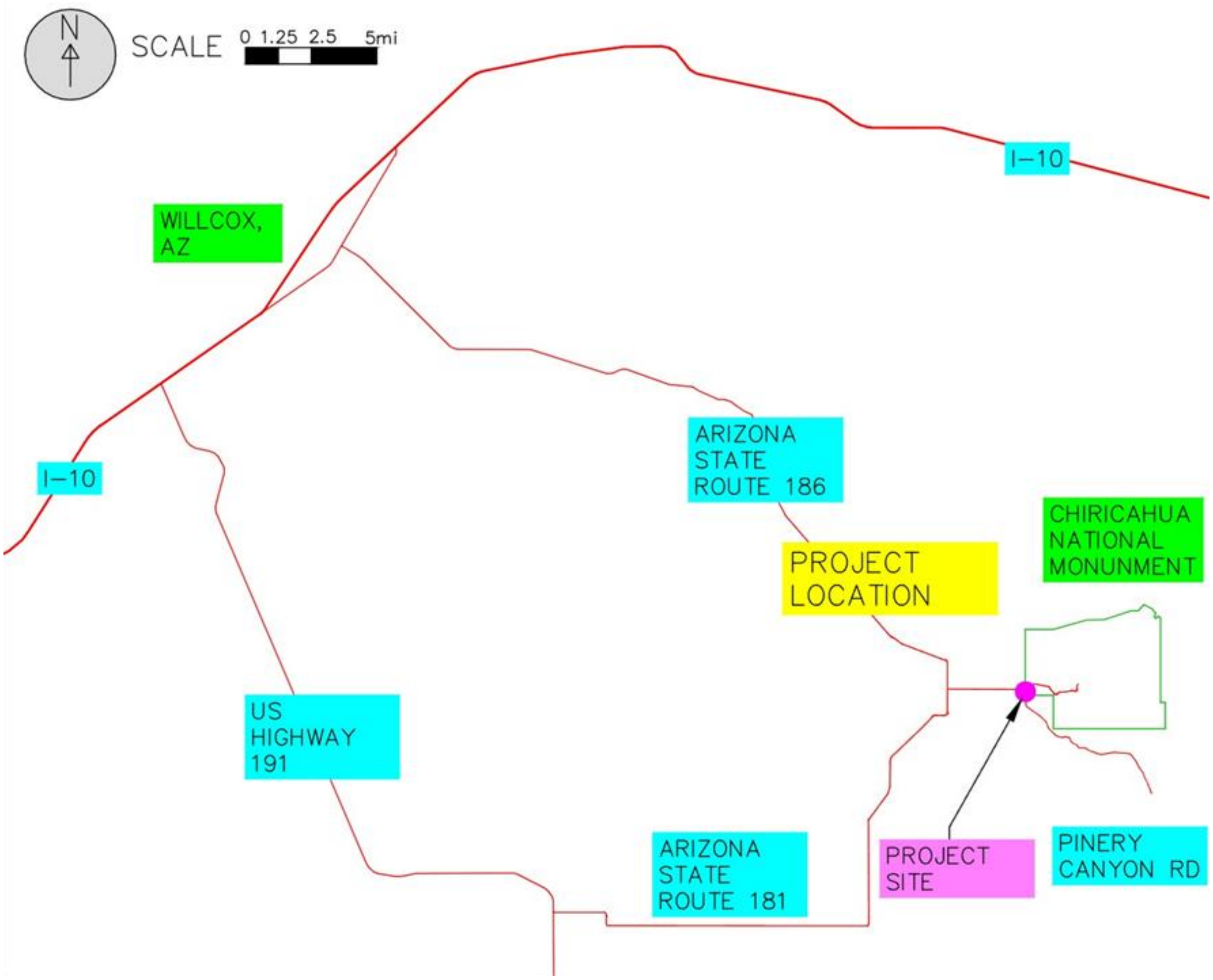

Figure 1-2 - Vicinity Map

1.3 Current Conditions

Surrounding the site to the North and the East is a shallow wash. To the west is a gravel road that is the only access point to the site. To the South of the site is more land of similar conditions to this project's site.

The site itself is a fairly barren landscape. It hosts a few medium-sized bushes, some trees both near and in the wash, and the occasional small prickly pear cactus. Also on the site are three structures. Two of the structures are on the South side of the site and are removable structures. The other structure is an NPS wellhead in the southeast side. Below a map of the existing site.

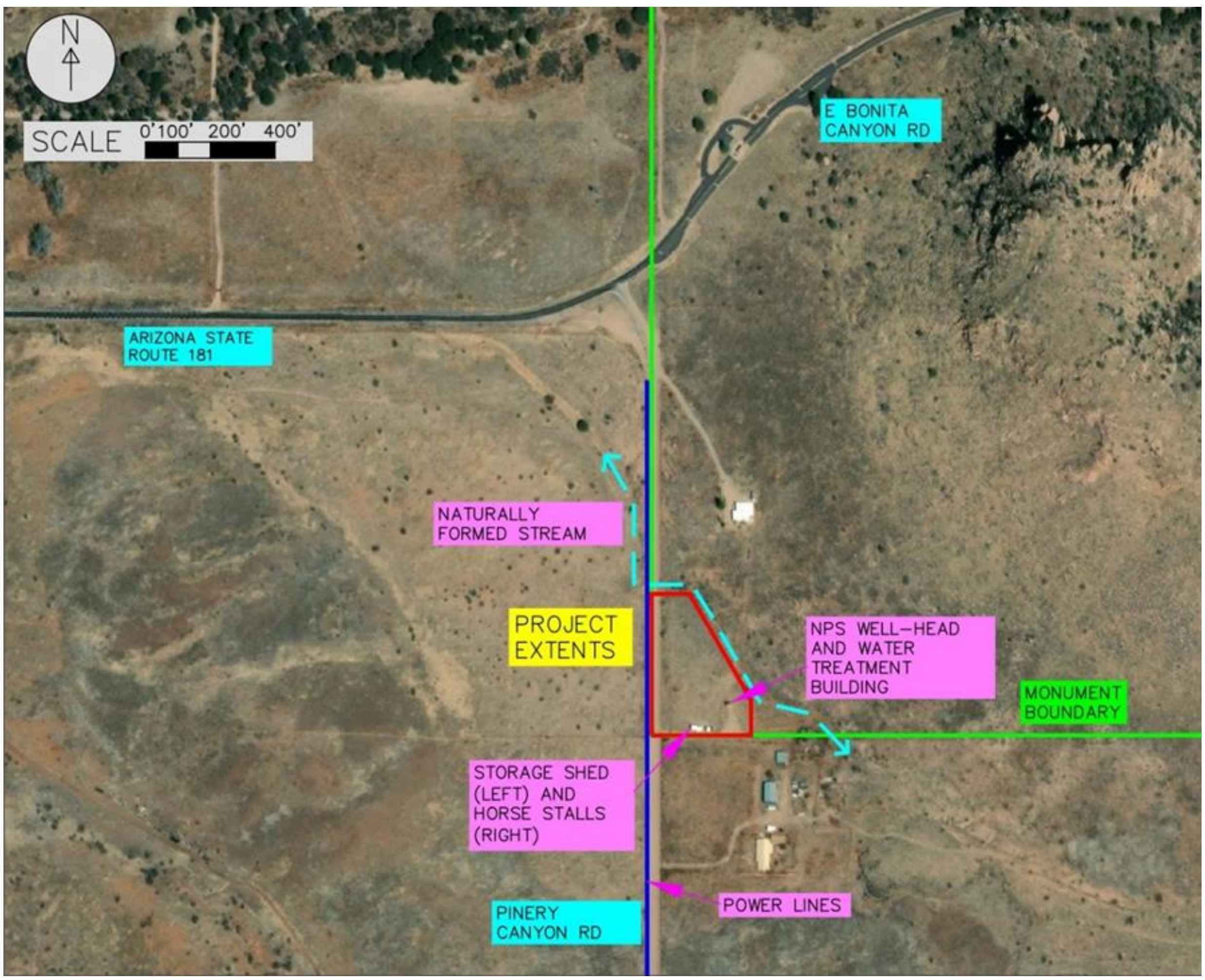

Figure 1-3 - Project Map

1.4 Area of Work

RV pads will be designed to accommodate full utility hookups, which are being planned by another team to meet client expectations and ADA accessibility standards. To ensure proper execution, various engineering factors must be addressed and incorporated before finalizing the project’s plan set.

1.4.1 Constraints and Limitations

The site's geometry presents a constraint due to the limited available space within the project’s defined borders. Accommodating multiple RV pads while allowing room for additional amenities and client requests, maintaining an aesthetically pleasing RV park, and ensuring compliance with regulatory requirements will be a challenging task.

While the site's flat, open terrain makes development easier, if present endangered plants like agave and yucca added another layer of complexity. To address this, the team conducted a site visit to map their locations and identify a way to work around them.

1.4.2 Project Objectives

Conducting a detailed survey of the project area is essential for accurately mapping the site, identifying existing land features, and determining the optimal placement of RV pads and roads with proper grading. This process plays a crucial role in ensuring the design aligns with the natural landscape, reducing potential obstacles during construction. The survey data will be imported into mapping software to generate a topographical map which will help guide the overall site design.

Water and drainage analysis is essential for managing stormwater on the site and preventing problems like flooding and erosion. A hydrologic study will analyze existing runoff patterns and determine how construction and site changes may impact water movement. This information is essential for designing the gravel roads effectively.

A hydraulic analysis is essential to evaluate the capacity of the existing stormwater management system and determine any necessary upgrades or new installations. The design must incorporate an effective drainage system that directs water away from the RV pads and roads while considering the site's soil characteristics to maintain stability. This analysis will inform modifications to existing structures to ensure they meet project requirements.

The RV pads must be designed to accommodate newer, larger RVs, requiring sufficient width and length. Additionally, slope constraints must be met to prevent water from pooling on the concrete, and leave residents comfortable in their RVs. This includes adhering to maximum slope and cross-slope limits for the pad and the driveway leading up to it. The concrete used for the pads must comply with AASHTO design standards to maintain structural integrity and prevent water accumulation.

Roadway design is another key factor, ensuring it can support the size and weight of RVs while providing easy access to each pad. The gravel roadway must be constructed with durable materials capable of withstanding frequent use. The road's cross-section must be designed to allow water to drain into parallel ditches, preventing pooling. Additionally, the subgrade beneath the road must consist of suitable soil to provide a stable foundation for both the roadway and heavy vehicles.

2.0 Field Work

2.1 General Site Conditions

The site is very flat, with a very slight downhill slope in the North direction, but overall little elevation changes across the whole site. The weather was slightly windy and cloudy, but not enough to cause any issues for the GPS surveying systems. There are no notable pooling spots or significant changes in terrain on the site, it is consistently flat ground besides a small ridge less than a foot tall, offset about 5 feet from the road. The soil is rockier than typical in the desert, but a fine dirt that is dry and compacted together well, creating a hard surface, covered in lots of dried out weeds and grass. There are a few small, removable trees and bushes scattered on the site, along with a movable structure of stalls, a movable shed, one electrical pole running power lines offset 10 feet from the road, a drinking water well and treatment pump building. The site is completely undeveloped land, except for short fencing, a well-maintained dirt road, a dirt driveway into the site and a second smaller one where the well-head is. Below is one photo standing near the Northeast boundary of the site, facing Southwest, showcasing most of the site, and another photo of the road facing North, where RVs will enter the road from. To see more photos of the site, reference Appendix A.

Figure 2-1 - Photo of Site Facing Southwest

Figure 2-2 - Photo of Road

The wash running along the north and east boundary is very natural, it has a lot of variability in geometry, more vegetation/trees than the surrounding areas, and therefore more debris in it. Approaching the culvert on the north boundary of our site, it is completely buried in debris, mostly branches and other debris, not visible or accessible. On the other side of the road, there is still a lot of debris but the culvert is visible, a basic corrugated metal pipe, about 2 feet diameter, filled with sediment leaving about 10 inches unobstructed. Below is the photo of the inside of the culvert, to see the culvert from both sides of the road reference Appendix A.

Figure 2-3 - Inside of Culvert, from West side of Pinery Canyon Rd

2.2 Soil Collection

Four soil samples were collected across the site, there was no visible difference in the soil across the site, but a small amount of variability was noticed between the samples. One was from the southeast corner of the site, one from the northwest, one towards the center of the site, and one towards the center but more on the east side near the wash. Each sample spot taken was dug approximately 3 inches deep, and 4-5 inches wide each direction, collecting well over the 2000g needed for testing from each sample. The soil was very dry, rocky, and compacted. Some samples had more rocks than others, some were more compacted and harder to break up the soil than others, some appeared to have softer, finer dirt than others, but as said, they were mostly the same. The soil was so compacted, the back of a hammer had to be used to break it up, before collecting it with the trowel. The soil was collected in gallon size Ziploc plastic bags, which were placed in a bucket or grocery bag in case the plastic bag got damaged and leaked. Larger rocks were taken out during collection, but there were lots of smaller rocks that had to be kept in the sample to be used in sieving and taken out for proctor compaction. See below for the specific soil sample locations, or reference Appendix A for more photos.

Figure 2-4 - Soil Sample Location Map

2.3 Survey Data Collection

Using a GPS base station and rover, we took 750 survey points on and around our 1.5-acre site. This included boundary points of the entire site, a grid of points within the site, cross sections along the entire road west of the site within the north and south boundary of our site, cross sections along the entire wash within the north and south boundary of our site, and borders around both removable and non-removable structures, like bushes, trees, the well-head, stalls, and electrical pole on the site. Below is a photo of the GPS setup on site, reference Appendices A for more site photos. With this survey data, a topographic map was made using Autodesk Civil 3D 2025, as described in section 3.1 and can be viewed in Appendix B.

Figure 2-5: Photo of GPS setup; Facing East

3.0 Testing/Analysis Performed

3.1 Site Data Analysis

All GPS data collected from the site was then exported into Autodesk Civil 3D 2025 to create a visual representation of the site, a topographic map. The elevation data points were used by the software to generate contour maps to represent the elevation changes across the site. As previously mentioned, all unique features such as vegetation, infrastructure, and larger rocks in the site were correctly labeled in order to accurately represent them in the topographic map. This data was used in section 4.0 when deciding how existing features affected design aspects. Topographic map is presented below.

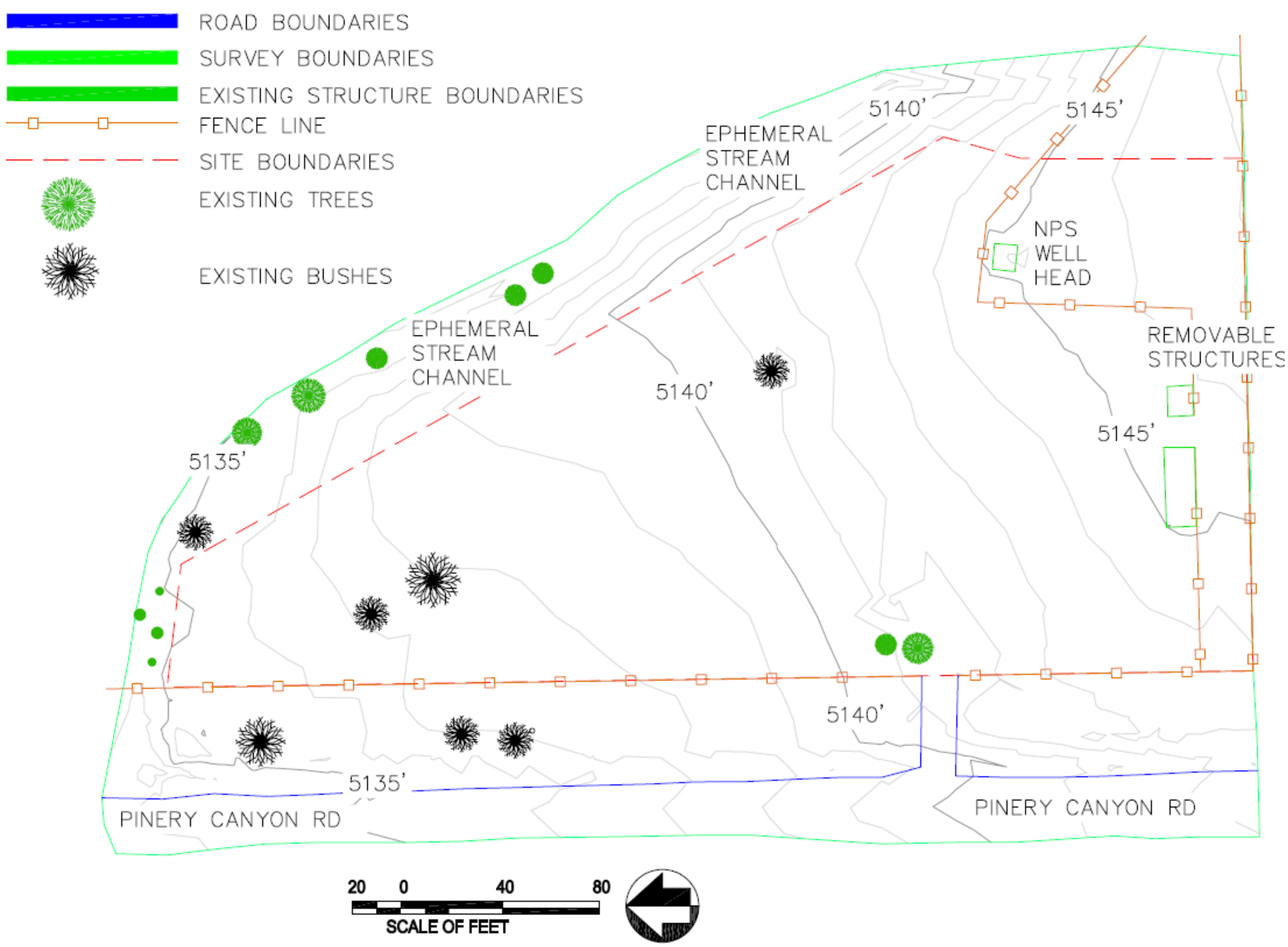

Figure 3-1: Topo Map

This site has approximately a 10-foot decline in elevation from the South to North boundary, which is approximately a 2% slope. From East to West across the site, there is typically only a 1-2 foot difference in elevation. The wash stays generally the same elevation though, not experiencing as much of this slope. Besides the cross sections for the wash and road, and a small steep incline in terrain on the land near the road which was recorded, there were no special changes in terrain like pooling that needed to be recorded.

Elevation and topographic data was crucial to analyze the natural water flow paths and possible water pooling areas. Such features were considered and utilized for further hydrological analysis to ensure a proper drainage system. Additionally, elevation data facilitated roadway alignment and to identify where grading and earthwork was necessary for slope requirements. Overall, the placement and location of all features of the final design were dependent on the existing elevation data.

3.2 Geotechnical Testing

Prior to any soil testing, the soil samples needed to be fully dry. For this to happen the lab oven had to be turned on, set to the right temperature of about 230°F, and on for 24 hours prior to their use as recommended by the lab manager. Once the oven was heated up, the samples collected were labeled and deposited into the oven to let dry 24-48 hours.

Starting with the sieve particle distribution test, ASTM D6913 was referenced which requested for sieves #4, #10, #20, #40, #60, #100, #140, #200, and the bottom pan to determine the proportion of silt, sand, and clay present in the sample and therefore the overall site. These proportions were used to determine the classification of the soil which provides characteristics about the soil behavior in load and drainage situations. The results were crucial to understanding the soil suitability for the proposed design.

Figure 3-2: Photo of Sieves

Due to the percentage of fine particles present in the soil, an Atterberg limit test had to be performed in order to determine the liquid limit and plastic limit of the samples. ASTM 4318 was referenced for the procedure of the test. For the plastic limit, the moisture content of soil finer than the #40 sieve was modified until the sample rolled cracked with a diameter of an eighth of an inch. The sample was collected and dried for limit calculations.

Figure 3-3: Rolled Soil Sample for Plasticity Test

The liquid limit was determined in a similar way with the help of the casagrande device. By altering the moisture content of the soil sample that collapsed with different amounts of blows were collected and the data was graphed to interpolate the limit. Lastly, both limits were used in the calculation of the plasticity index.

Figure 3-4: Soil Sample in Casagrande Cup for Liquid Limit Test

Furthermore, a modified compaction test was performed to determine the optimal moisture and the maximum dry density of the compacted soil on site. ASTM 698-12 was referenced for the procedure of the test. Soil was compacted into layers into a mold with a known volume using the modified hammer. The compacted sample was extruded, and a small portion is kept to collect a moisture content. This process was repeated with added moisture on each sample until enough data for a compaction curve was obtained. The test results are crucial to ensure proper soil stability on site. This test acted as a guide for site preparation for the proposed roadways and RV pads. For a photo of a low-moisture compaction sample, reference appendix C.

Figure 3-5: Moisturized Soil Sample after Compaction Test

3.3 Geotechnical Analysis

3.3.1 Sieve Particle Distribution

The recorded mass of each sieve was used to calculate the percentage retained on each sieve was calculated with the equation below

Equation 3-1: Percent Retained on Individual Sieve

$$R_n = \frac{W_n}{W_{ts}} \times 100$$

Where:

R_n= Percent Retained on individual Sieve

W_n= Mass of individual Sieve (g)

W_{ts}= Mass of Total Sample (g)

The results were used for percentage passing calculations with the equation below

Equation 3-2: Percent Finer

$$Percent\ Finer = 100 - \sum_{i=1}^{i=n} R_n$$

Where:

R_n= Percent Retained on individual Sieve

Full tables with lab data are presented in Appendix D.1.

The particle size distribution of the samples is presented below

Table 3-1: Particle Size Distribution Results

	Sample #1	Sample #2	Sample #3	Sample #4
Sieve	Percent Passing	Percent Passing	Percent Passing	Percent Passing
Sieve No. 4	91.59%	95.21%	87.91%	91.96%
Sieve No. 10	82.37%	78.32%	76.13%	78.93%
Sieve No. 20	67.15%	61.48%	59.42%	58.17%
Sieve No. 40	52.68%	47.58%	44.91%	40.06%
Sieve No. 60	41.23%	36.52%	32.79%	25.69%
Sieve No. 100	29.97%	25.62%	21.27%	15.33%
Sieve No. 140	21.82%	17.54%	14.18%	9.20%
Sieve No. 200	15.42%	11.69%	8.98%	5.36%

Additionally, the particle distribution curves are presented below.

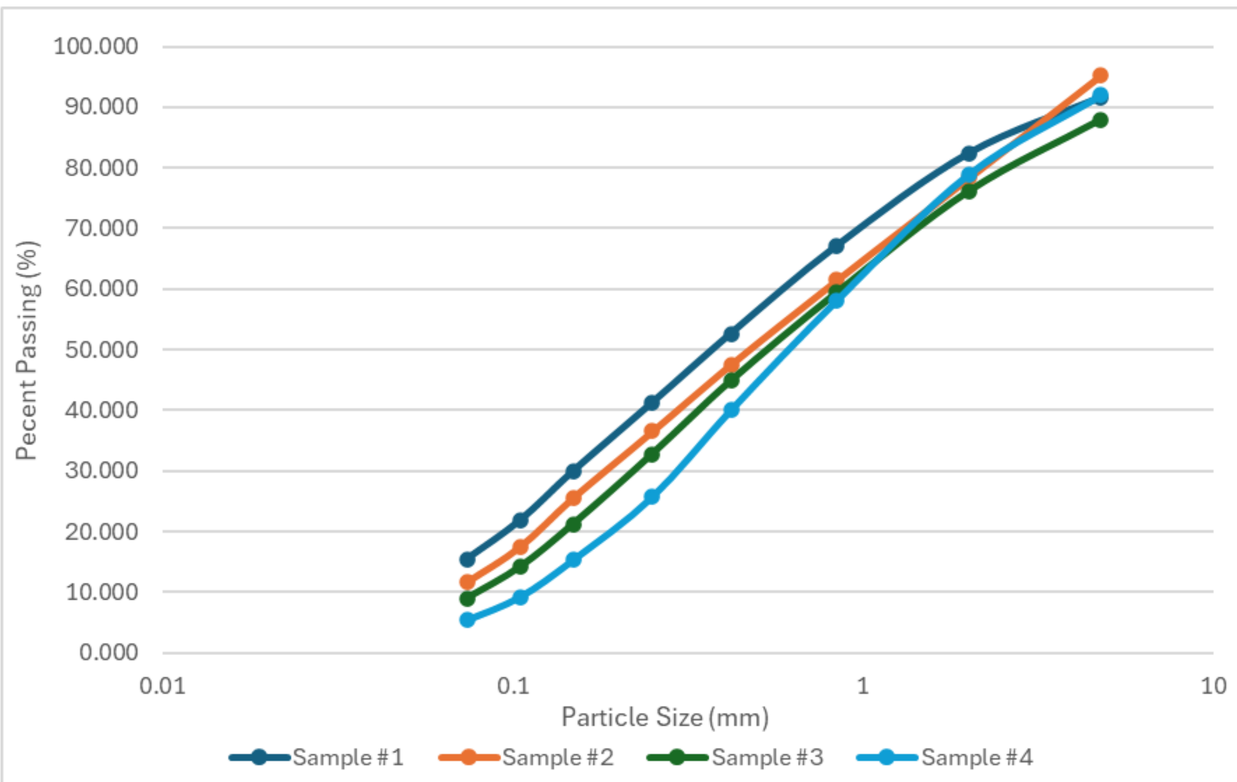

Figure 3-6: Particle Size Distribution Curves

3.3.2 Atterberg Limits Test

The plastic limit of each sample is a moisture content reported with no percentage mark calculated with the equation below. The liquid limit is the moisture content (%) that soil transitions from a plastic state to a liquid state, found using the Atterberg's test process with the Casagrande Cup.

Equation 3-3: Plastic Limit

$$PL = \frac{M_m - M_d}{M_c - M_c} \times 100$$

Where:

PL= Plastic Limit (unitless)

M_m= Mass of can and Moist Sample (g)

M_d= Mass of can and Dry Sample (g)

M_c= Mass of can (g)

The liquid limit was determined by plotting the number of blows recorded during the test then interpolated to 25 blows which represents the liquid limit. Once both the plastic limit and the liquid limit are determined, the plastic index is calculated with the equation below.

Equation 3-4: Plastic Index

$$PI = LL - PL$$

Where:

PI= Plastic Index (unitless)

LL= Liquid Limit (unitless)

PL= Plastic Limit (unitless)

The Atterberg limits and plastic limits of all samples are presented below

Table 3-2: Atterberg Limits Results

Results	Sample #1	Sample #2	Sample #3	Sample #4
Liquid Limit	22.19	23.80	24.19	26.82
Plastic Limit	18.77	21.42	22.66	25.24
Plastic Index	3.41	2.38	1.53	1.57

Full data tables are presented in Appendix D.2. Results from the sieve particle distribution analysis and the Atterberg limits test were utilized to determine the soil classification of our site. The USCS soil classification system was used to determine soil class, the soil properties were compared to a set criteria to come to a final conclusion. Based on USCS soil sample classification, sample #1 are classified as SC, clayey sands, while the rest of the samples, samples #2, #3, and #4, are classified as SP-SC, a combination of poorly graded sands and clayey sands. These results lead to the assumption of the site gradually changing soil classification as the wash is approached from the south. Based on the classification, the present soil is capable of higher load-bearing capacity compared to pure clay and it is able to undergo volume changes due to its moisture properties. Classification table presented in Appendix D.4

3.3.3 Proctor Compaction Test

All recorded data was used for the following calculations. The moist unit weight was initially calculated using the equation below.

Equation 3-5: Moist Unit Weight

$$\gamma_{moist} = \frac{W_2 - W_1}{V}$$

Where:

γ_{moist}= Moist Unit Weight (g/cm^3)

W_2= Mass of Mold and Moist Soil (g)

W_1= Mass of Mold (g)

V= Volume of Mold (cm^3)

Then the dry unit weight was calculated with the following equation.

Equation 3-6: Dry Unit Weight

$$\gamma_d = \frac{\gamma_{moist}}{1 + \frac{\omega}{100}}$$

Where:

γ_d= Dry Unit Weight (g/cm^3)

γ_{moist}= Moist Unit Weight (g/cm^3)

ω = Moisture Content

Lastly, the required dry unit weight was determined using the max unit weight determined from the curves.

Equation 3-7: Required Dry Unit Weight

$$C_R = \frac{\gamma_d}{\gamma_{d,max}} * 100$$

Where:

C_R= Required Dry Unit Weight (g/cm^3)

γ_d= Dry Unit Weight (g/cm^3)

$\gamma_{d,max}$= Max Dry Unit Weight (g/cm^3)

The calculations were completed to get the max dry density for each sample, along with the moisture content to get that density. The data showed us that the soil on the south part of the site is a little weaker, the sample in the center and in the center near the wash, are all almost the same. The soil on the north part of the site was the strongest, but overall the soil is fairly similar, staying within the range of 1.88g/cm^3 to 2.15g/cm^3 for all of their max dry densities. Even the compaction at 3% moisture resulted in at least 1.60g/cm^3 which is equivalent to about 100lb/ft^3.

The proctor compaction test results are displayed below.

Table 3-3: : Proctor Compaction Results

	Sample 1	Sample 2	Sample 3	Sample 4
max dry density (g/cm^3)	1.884	2.00	1.98	2.15
optimal moisture content (%)	11.76	10.86	12.26	12.11

Compaction curves present below

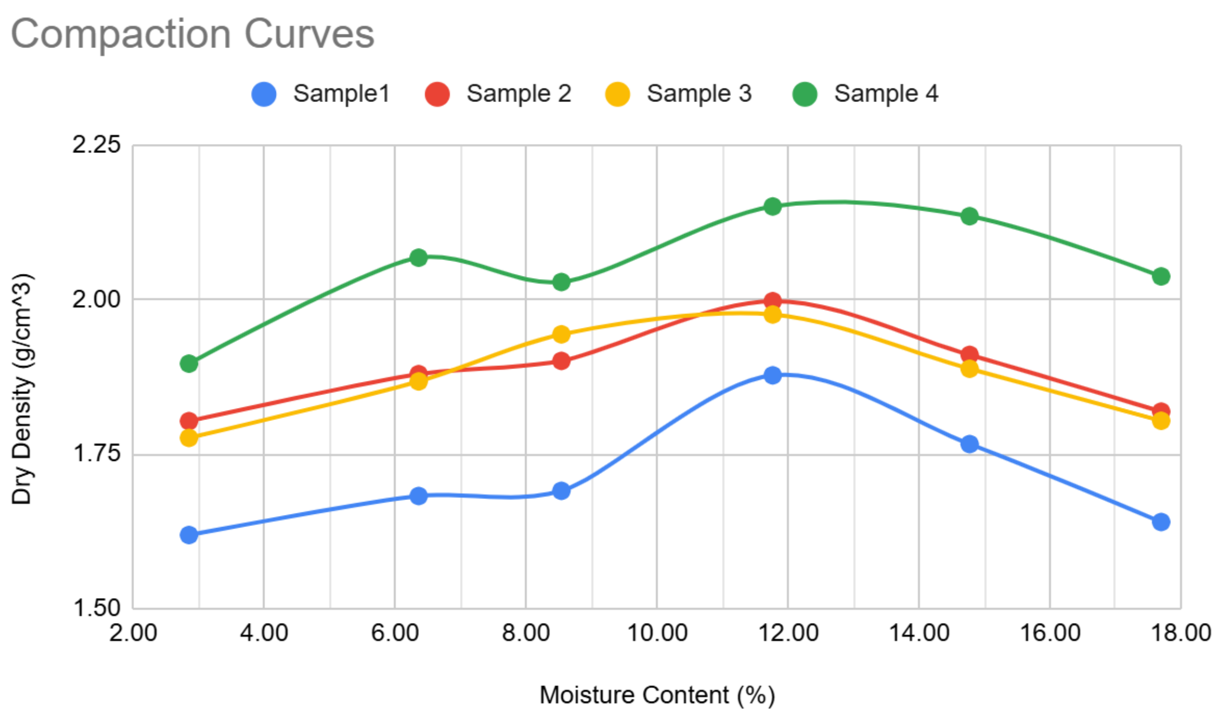

Figure 3-7: Compaction Curves for Soil Samples

This data helps show the soil's properties, allowing us to ensure it can handle the weight of concrete and large RVs driving over and parking on it. It also helps to determine if any soil compaction is needed before placing concrete and gives the approximate ideal moisture content to do so. Full tables with data are presented in Appendix D.3. A photo of the compaction samples

3.4 Hydrological Analysis

To delineate the watershed, USGS StreamStats were used to generate the area that would include the site. The software outputs various types of data such as basin characteristics, peak flows, and flood probability, however, only the basin characteristics were utilized for the project. The delineated watershed encompasses a total area of 0.41 square miles (262 acres) and has a mean basin elevation of 5,384.48 feet. The delineated watershed is presented below with the site boundary highlighted green. Lastly, on purple would be the longest flow path being 6869 feet long. Full USGS StreamStats results are presented in Appendix E.1

Figure 3-8: Watershed Delineation

All parameters and analysis methods were based on the *Cochise County Floodplains Regulation Manual*. The county has a preference on using *PC-HYDRO* which was developed by Pima County. The version used for the analysis was PC-HYDRO 7.4, being the most current version available. PC-HYDRO is applicable for urban and non-urban watersheds less than or equal to 10 square miles, have a time concentration of less than 180 minutes, and are not controlled by flood-controlled reservoirs or basins [15]. All of which are met by this project site. The guide states that a 50-year and 100-year with 1-hour rainfall event is commonly reported for design standards. Table 3-4 shows all the assumptions and parameters used as input in the software.

Table 3-4: Hydro Analysis Parameters

Parameter	Value
Soil Type	Type B & C & D
Cover Type	Herbaceous
Cover Density	9%
Impervious Area	0%
Watershed Area	0.41mi²/ 262.4 acres
Longest Watercourse	6869 ft

The soil type was based on *NRCS-SCS Soil Types* and *Hydrologic Soil Group Classification*. The report claims for the area to have a 25% type B, 55% type C, and a final 20% of unclassified soil which was assumed as type D. The cover type and density were determined from the streamstats report which states an average presence of 9% herbaceous cover through the watershed. Herbaceous cover fits the site the best based on vegetation presence and elevation. The impervious area was set to 0 due to the site being completely undeveloped before the project. Additionally the same report stated a total watershed area of 0.41 square miles. The longest watercourse was measured as 6869 feet based on the flow defined in the streamstats report and google maps. Lastly, historical rainfall data was extracted from the *NOAA* to represent the average rainfall on-site. The software calculated a 50-year storm event peak discharge of 1124.9 cubic feet per second and a 100-year storm event peak discharge of 1347.7 cubic feet per second.

The results of the 50-year and 100-year storm events of the hydrological analysis are presented in the table below. The peak discharge values were compared to the channel capacity calculated using a simple Manning's equation. All relevant results were tabulated into Table 3-5 presented below.

Table 3-5: Hydrological Analysis Results

	50-year	100-year	Units
Weighted Runoff Coef. (Wc)	0.43	0.47	Unitless
Time of Concentration	14.8	13.6	min
Rainfall Intensity (i)	6.84	7.85	in/hr
Runoff Supply Rate (q)	2.97	3.66	in/hr
Peak Discharge	784.6	968.8	cfs

Full report presented in Appendix E.3.

The channel capacity was calculated through a simple Manning 's equation due to the size of the channel. An open channel calculator made by professionals on engineering.com was utilized to determine the capacity of the channel by inputting geometry from the survey. Their newest version of the calculator was used and this was last updated in 2020. The geometry used was from the further west side of the channel which has a bigger area and better represents the geometry of the rest of the channel included in the watershed. This website develops a variety of calculation tools to simplify complex calculations into inputs and outputs. The equation used is presented below.

Equation 3-8: Manning's Equation

$$Q = \left(\frac{1.49}{n}\right) AR^{\frac{2}{3}}\sqrt{S}$$

Where:

Q= Flow Rate (ft^3/s)

n= Manning's Roughness Coefficient (Unitless)

A= Area of Cross Section (ft^2)

R= Hydraulic Radius (ft)

S= Channel Slope (ft/ft)

The calculated capacity was about 550 cubic feet per second which is not enough to contain the calculated flow. Even with the unaccounted culvert it would not be possible for the channel to handle the calculated peak flows. Additionally, with a calculated velocity of 7.5 ft/s the channel would experience erosion due to the high velocity of the flow. Therefore, in addition to the originally planned clean-up of the wash, the team recommends the implementation of riprap to reduce the velocity of the flow and a possible expansion of the channel to handle not only the pre-development peak flows but the post development ones as well. This task falls outside the original scope of the project and is left as a recommendation.

Software output is presented in Appendix E.5.

4.0 Preliminary Designs

For this project, a number of design options were examined and assessed using a decision matrix that took into account sustainable design options, capacity, amenities, aesthetics, and extension possibilities. Numerous strategies were investigated, such as various site plans, road designs, drainage systems, and green infrastructure. Each option aimed to strike a balance between sustainability, usability, and low environmental impact. The rough sketches of the proposed designs are also in Appendix F for more detail.

Figure 4-1 which details alternative one's design. This alternative focused on a smooth loop around the site for RVs to drive on. The design had one entry on the north side of the site which would lead to a one-way road that would loop around south, east, and then back north. It located all amenities in the middle of the loop as a common area for all spots. This alternative did not leave space for future expansion and had conflicts with the location of the septic tank and some pads.

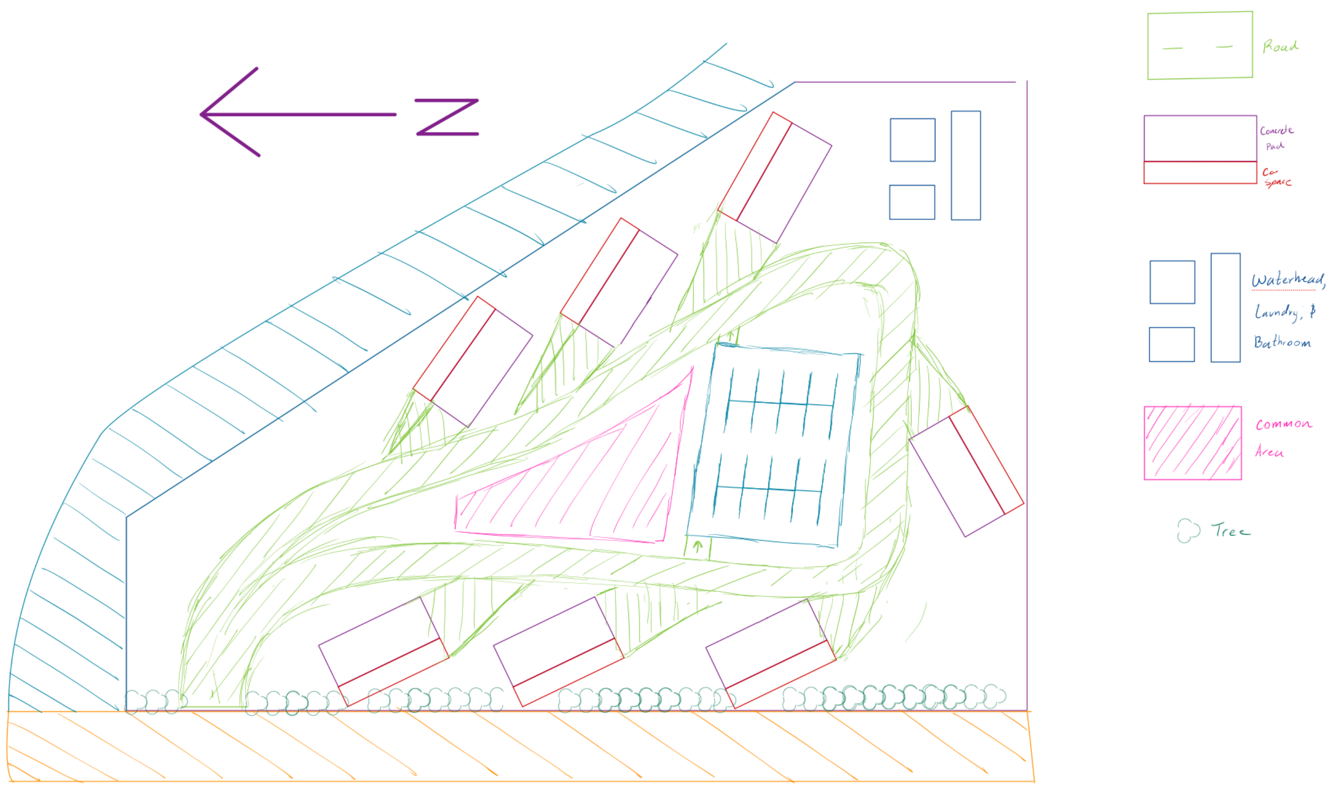

Figure 4-1: Alternative 1

Figure 4-2 which details alternative two's design. This alternative features a half loop with entry points on north and south of the site. On the outside of the loop are four RV pads spread across the site. Within the loop are two extra RV pads and a common area that features a bathroom area, a gazebo, and multiple picnic tables. Also in the south east corner of the site is a parking lot for personal vehicles. This design's primary flaw came with the RV pads within the loop as placing them there isn't practical. Additionally, the pads being perpendicular to the main road isn't convenient and is difficult to navigate.

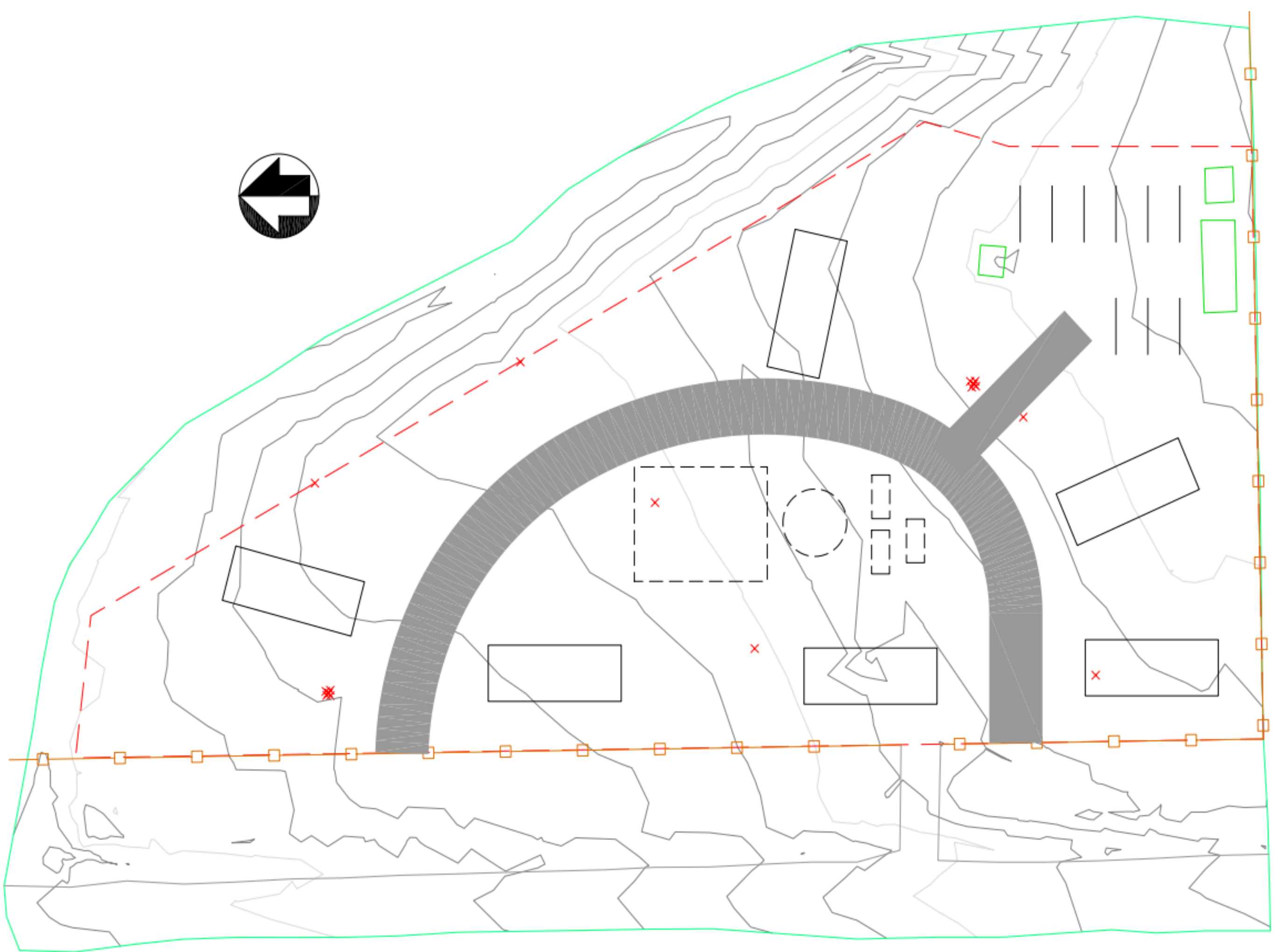

Figure 4-2: Alternative 2

Figure 4-3 which details alternative three's design. Alternative three was designed to balance site expansion with efficient use of space. It included minor adjustments to the roadways and RV pad layout to allow for future growth while maintaining accessibility. Drainage and green property features were incorporated without significantly altering the natural landscape. However, this alternative prioritized practicality and expansion over aesthetics or amenities.

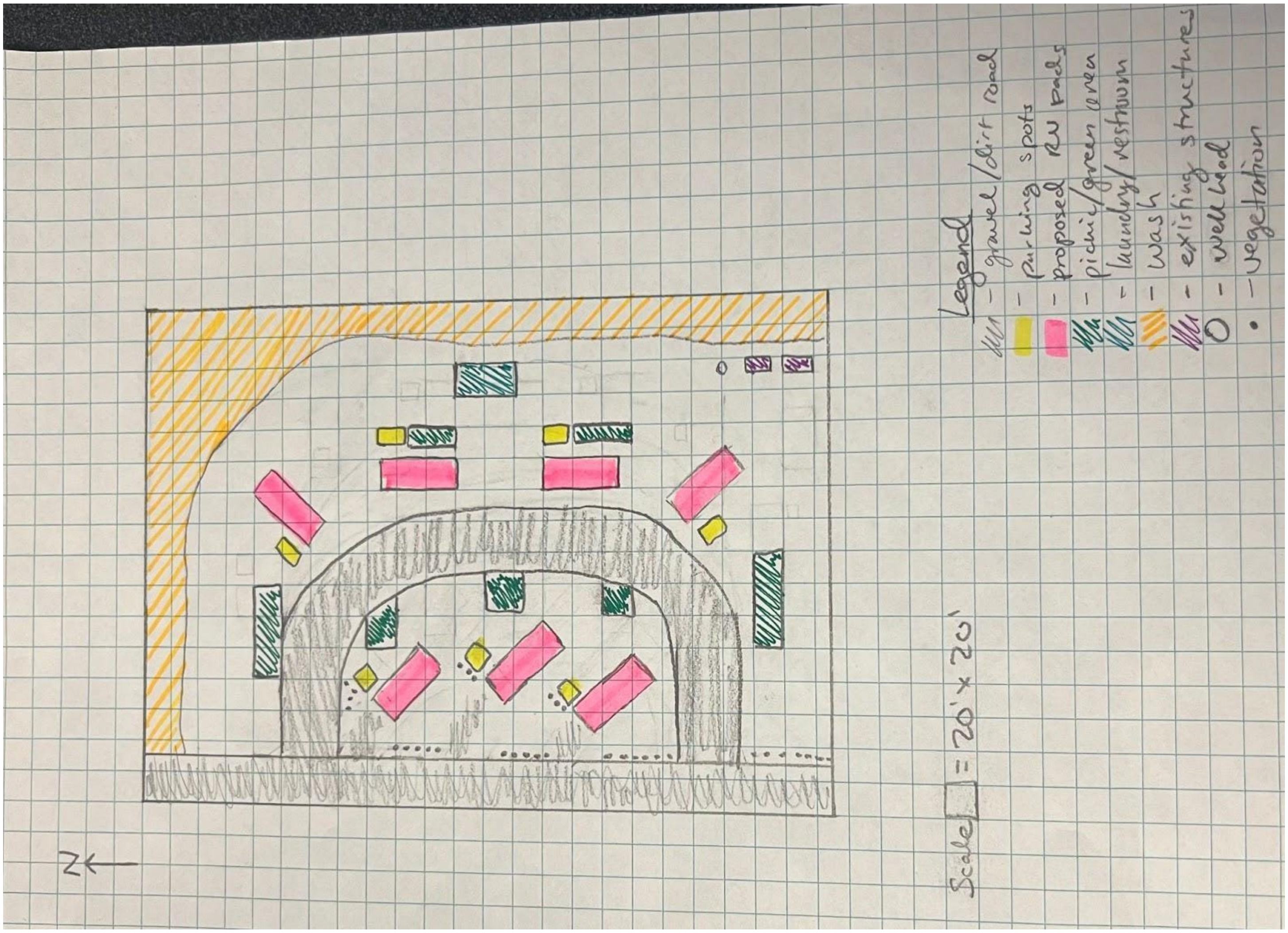

Figure 4-3: Alternative 3

Figure 4-4 which details alternative four's design. Alternative four focused on long-term expansion potential. Its redesigned layout created space for additional RV pads or future infrastructure. Roadway modifications were also made to support easier expansion. However, this alternative placed less emphasis on landscaping and aesthetics.

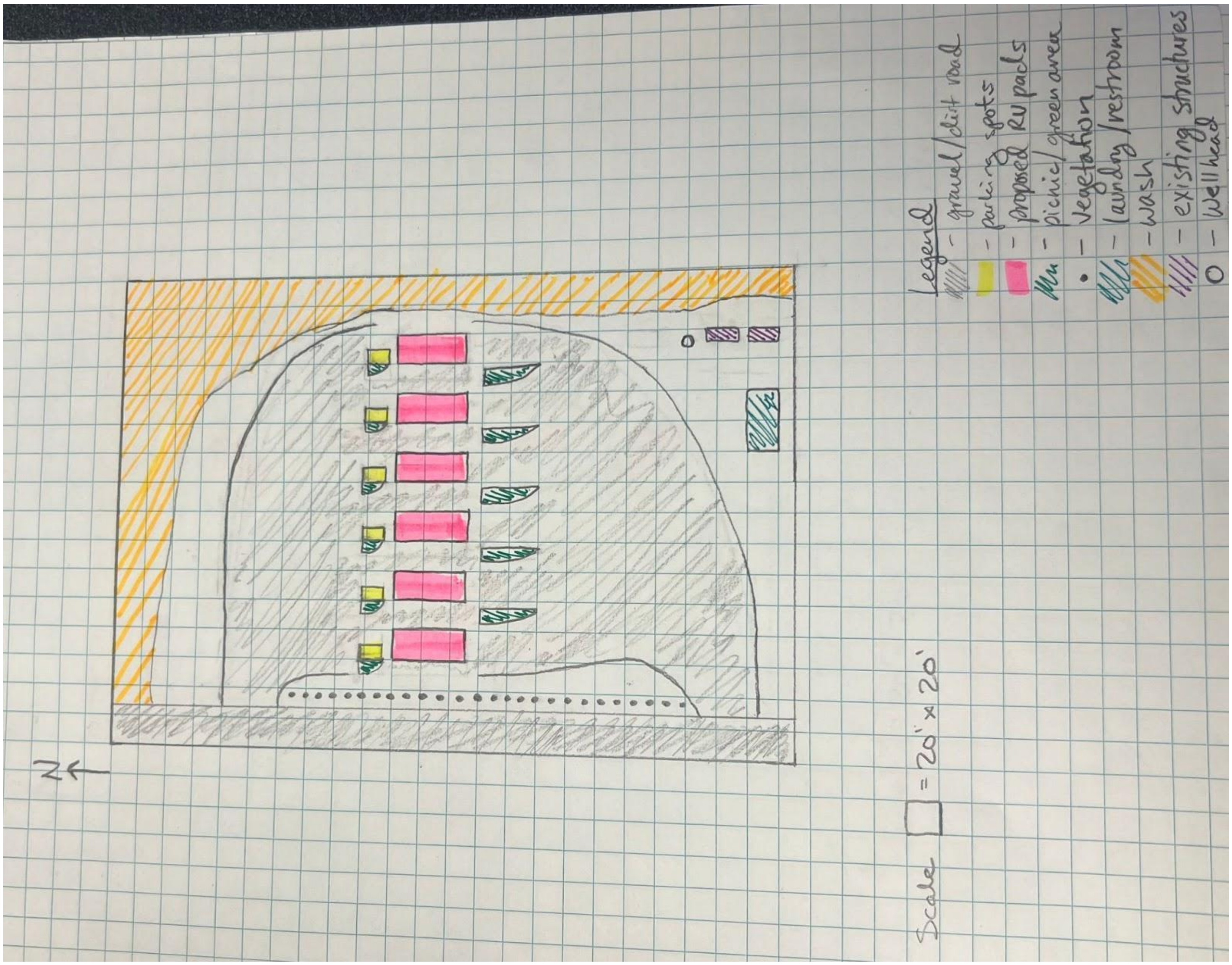

Figure 4-4: Alternative 4

Figure 4-5 which details alternative five's design. Alternative five was a loop design, focused on achieving a high capacity while also fulfilling all other needs of the client. Users will enter from the south entrance, looping to exit from the north entrance, and backing into their spots. The loop road is designed to be as wide of a turn as possible, while also fitting pads along the East side of it before the wash. The pads are evenly spaced out to fit six on the East side of the road, one south of it, and one more was fit in near the exit. South of that pad is a parking lot, allowing users to store their personal vehicles and/or UTV's without taking up space by their pad. South of the parking lot is the majority of the amenities, with two gazebos, a grill/cooking/seating area by them in the small square drawn, and a bathroom in the large square drawn. Finally a space for a bathroom was made next to the road in the common area, and space for a laundry room was saved next to the road near the well housing, with plans for their design to be developed later.

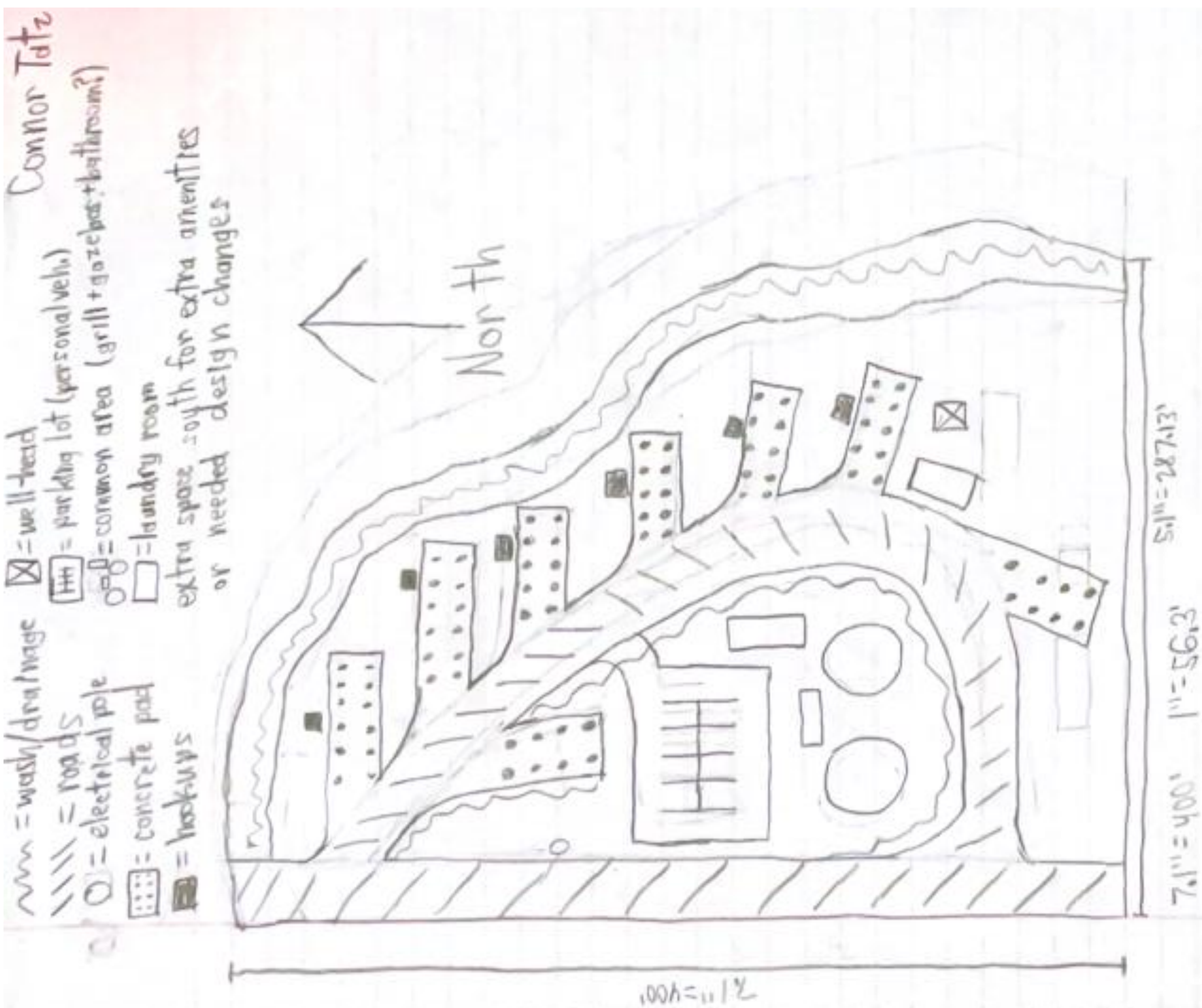

Figure 4-5: Alternative 5

To evaluate the different design options for this project, a decision matrix was used to break everything down in a clear and structured way. This approach helped us compare each design objectively based on the factors that mattered most to the project and the client. The most important category was capacity, which looked at how many RV pads each design could support while still leaving enough space for maneuverability and accessibility. Since this was the core function of the site, the team gave it the highest weight at 40% of the score. The team next looked at amenities which made up 25% of the score. This included things like space for communal restrooms, picnic areas, and other features that would make the space more comfortable and user-friendly. The team also factored in expansion potential, worth 20%, to see how easily more RV pads could be added in the future if needed. Finally, aesthetics was given a weight of 15% because the team and client wanted the site to be visually appealing even if it wasn't a top priority.

For scoring, a one to five scale was used for each category. A score of one meant the design did not meet expectations. Two showed it had a mix of strengths and weaknesses. A three meant the design met expectations and performed well overall. A four also had mixed qualities but leaned more positive, showing above-average performance with only small issues. A five meant the design went above and beyond expectations, with strong features and functionality in that category. Each raw score was then multiplied by the category's weight to get a weighted score. Once the scores were tallied, a total score was calculated for each design. This allowed the team to clearly see which option best met the project's key criteria, guiding them toward a well-informed and balanced decision. The final design was chosen because it provided the best balance of space, usability, and room for future growth. The decision matrix used can be viewed below in Table 4-1.

Table 4-1: Decision Matrix

Criteria	Weight (%)	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Aesthetics	15	0.6	0.6	0.6	0.3	0.45
Amenities	25	0.75	0.75	0.5	0.5	0.75
Capacity	40	1.2	1.2	1.2	1.2	1.6
Expansion Potential	20	0.4	0.4	0.6	0.8	0.4
	Total	2.95	2.95	2.9	2.8	3.2

Following the decision matrix evaluation, alternative five was chosen as the final design for the project due to its ability to maximize capacity, provide essential facilities, and allow for future expansion.

The layout guarantees that the location can support the necessary quantity of RV pads while preserving usability and accessibility. The roadway plan has been adjusted to guarantee smooth traffic flow, and site improvements have been made to improve operation without needlessly disturbing the land. A detailed CAD drawing of alternative five can be viewed below.

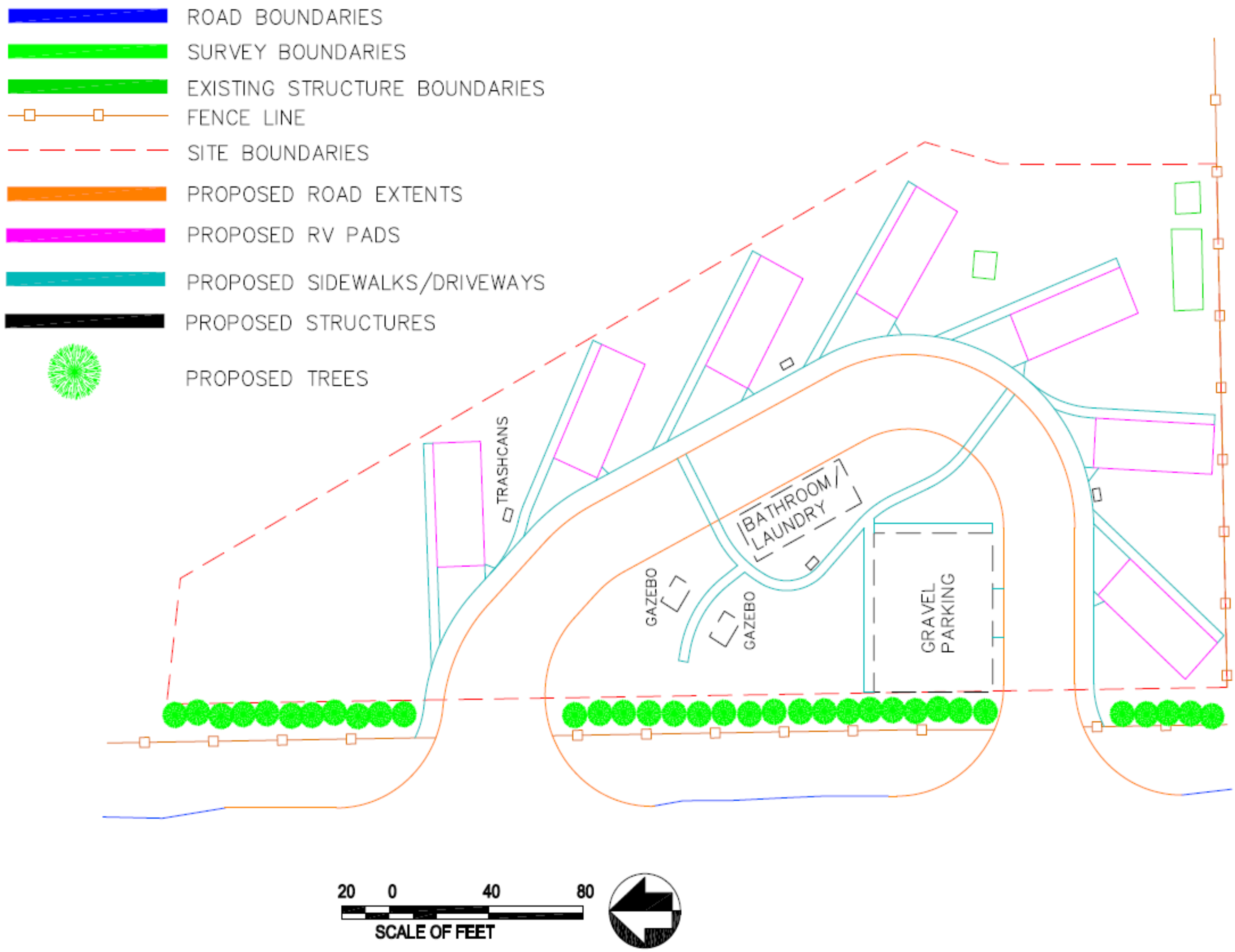

Figure 4-6: Final Alternative

To enhance drainage, restore proper water flow, and prevent flooding, the existing culvert will be cleared of debris and silt buildup. Grading adjustments will help direct runoff efficiently while minimizing erosion. The roadways will be constructed with compacted gravel and the RV pads will be constructed with reinforced concrete to create a durable and low-maintenance surface. While adding additional landscaping, the design also prioritizes preserving the existing plants to improve the site's beauty. Compacted gravel and reinforced concrete will be used in the construction of the RV pads to create a sturdy, low-maintenance surface. In order to improve the site's appearance, the design also incorporates new landscaping while preserving as much of the existing vegetation as feasible. These improvements create a well-planned, functional, and adaptable housing site for park staff and volunteers [18]. The final design can also be viewed in Appendix F.6

5.0 Final Design Recommendations

With the final alternative chosen, some final minor adjustments were made to the design. The first adjustment was to the general shape of the road. The main turn to the south end's radius was expanded to better accommodate the RV's movement through the site. As this changed the alignment, the RV pad placements were also adjusted accordingly and the amount of pads on the East side of the site changed from 5 to 4 pads. Although this change reduced the total number of pads from 8 to 7, it allowed them to better fit on the site and provided more space to each designated spot.

As was requested by the client, a sidewalk was introduced parallel to the road, allowing ADA access to all the pads. Additionally, the gazebo shapes were changed from circular to rectangular in order to accommodate solar panels on the roofs, allowing for some on-site power generation. Once all of these changes were made, details regarding the road plan and profile could be finalized.

5.1 Grading and Cut/Fill

The grading was done by assuring an ADA compliant sidewalk system which connected to accessible RV pads on top of the existing surface. Those set elevations were then used as a guideline for the remaining features in the design. Once all elevations were determined, consistent grading from the feature to the existing surface was implemented. Utilizing the final proposed grading for the site and the existing one, cut fill calculations were computed by *Civil3D* by comparing the surfaces' elevations. The final earthwork came to a total of 90.68 cubic yards of cut work and 1315.54 cubic yards of fill work, bringing an overall net of 1225.49 cubic yards. The final proposed grading is presented on the next page.

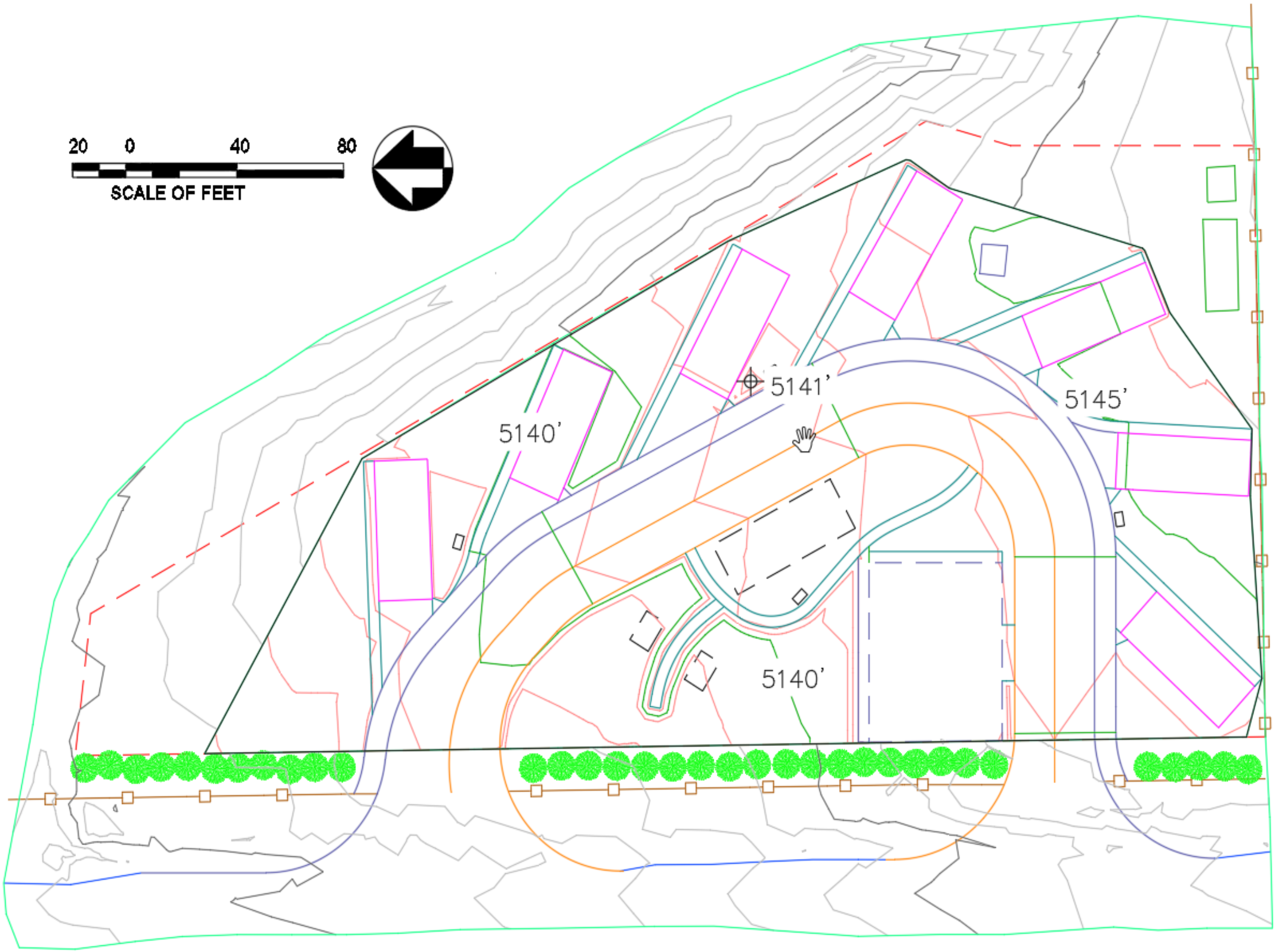

Figure 5-1: Proposed Site Grade

5.2 Roadway Design

The main alignment for the roadway was created in such a way that it would be able to accommodate the bigger turn radii of RVs. The standard turning radius for RVs is about 40’ and as such, radii of 55’ and 60’ were used in the alignment. Additionally, the entrance and exit to the roadway have curves with a radius of 45’. An overview of the roadway with details on the alignment can be seen below.

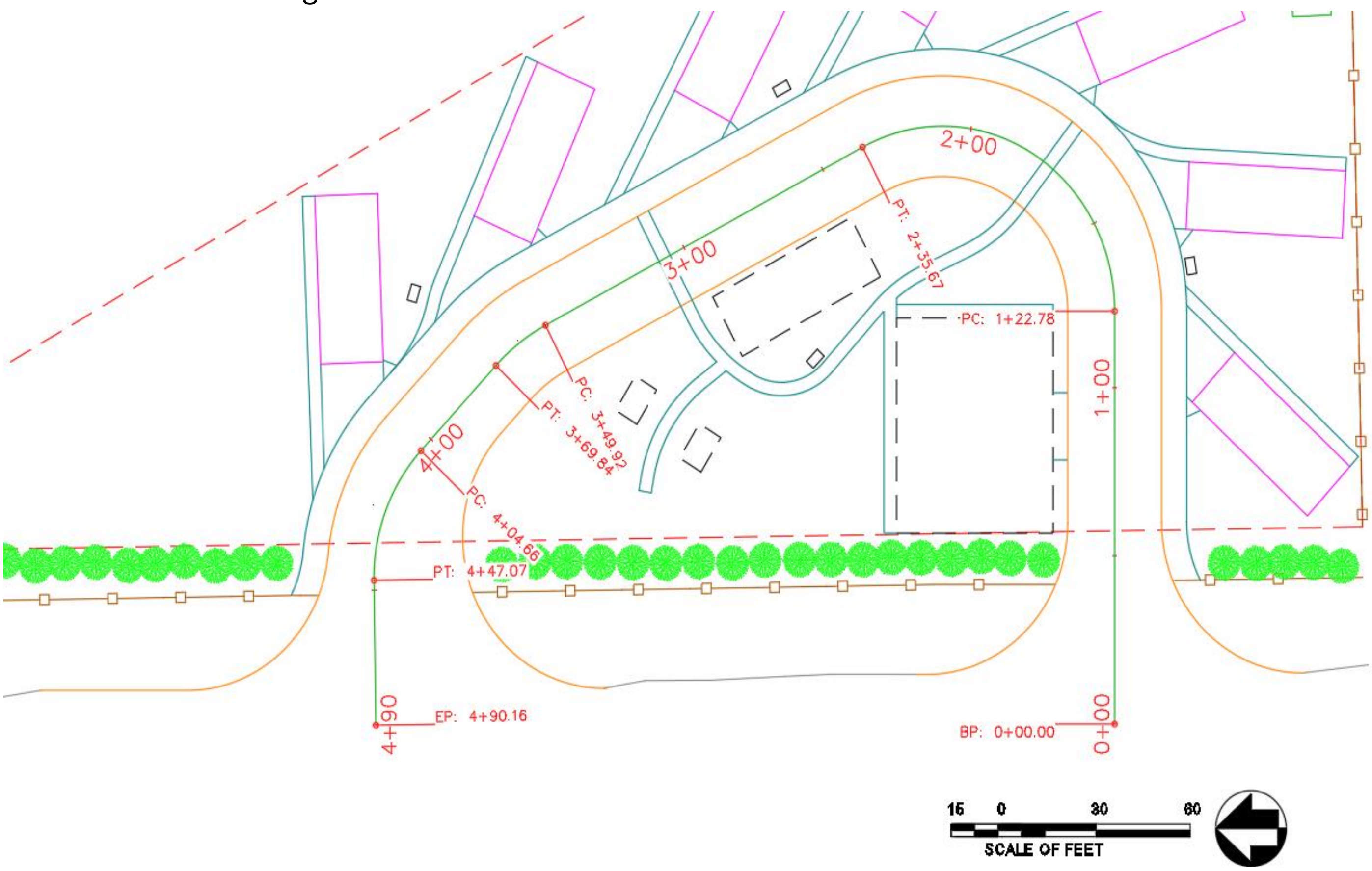

Figure 5-2: Proposed Road Plan

With the alignment created, the roadway itself was then made. A roadway width of 30’ was chosen to be acceptable as it allowed RVs to comfortably make all turns through the site and also any reverse movements onto the pads. A turning movement test was carried out on Civil3D which showed that all movements on and through the site were possible and comfortable. Additionally, it was decided that a road thickness of 5.5” would be used. This was determined using the FHWA Gravel Road Construction & Maintenance Guide, Appendix A, Table 3.

Parallel to the road is an 8’ wide AB binder sidewalk. This sidewalk would provide an ADA accessible walkway both between all the RV pads and also to any amenities on the site. It was determined that the sidewalk would be 5.5” thick at any portions in which RV’s would drive over the sidewalk to enter the pads and 4” thick elsewhere. A typical roadway cross section can be seen below.

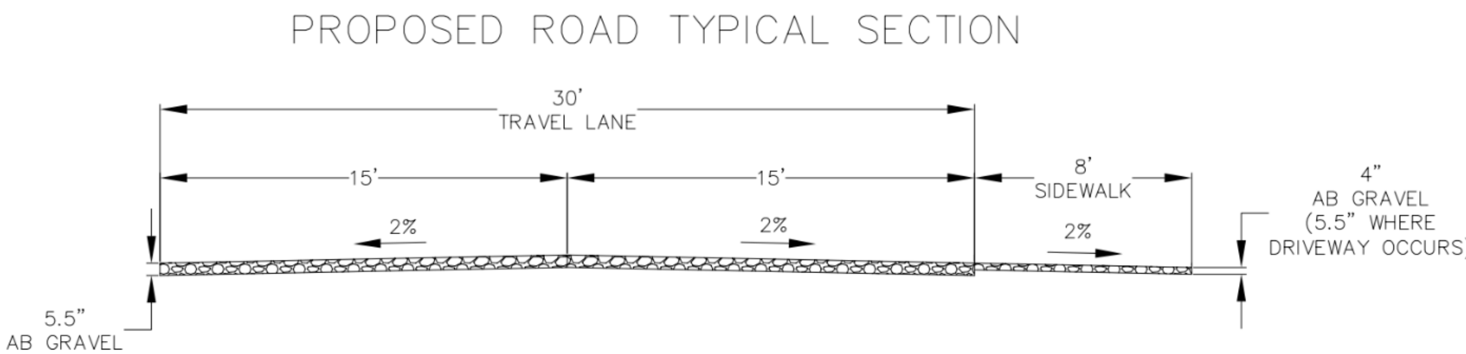

Figure 5-3: Road Cross Section

Following the creation of the roadway path, all the amenities and pad locations were slightly tweaked in order to better fit on the site. These new locations were then called out in relation to the roadway alignment both for construction purposes and clarification purposes. The roadway plan view which contains all these callouts can be seen in Appendix I.3.

To ensure that RVs could make the turns into every driveway, Autodesk Vehicle Tracking was used. The design vehicle of a bus was used. This bus had a length of 45’ and a turning radius of about 41’. Although the park is meant to be designed for RVs, the RV within the program only had a 30’ length which is less than what the pads themselves are designed for. By using a bus as the design vehicle within the program, it ensures that larger RVs will also be able to make it onto every pad with no issues. Additionally, as all the pads on the East side of the site were designed to be the same, only 2 of those 4 pads were checked, that being the one on the most northeast and the pad just south of the previous pad. Seen in the next page are the results of the turning movement check for pads 1 and 7, which were the most problematic pads. The full turning movement results can be seen in Appendix I.4.

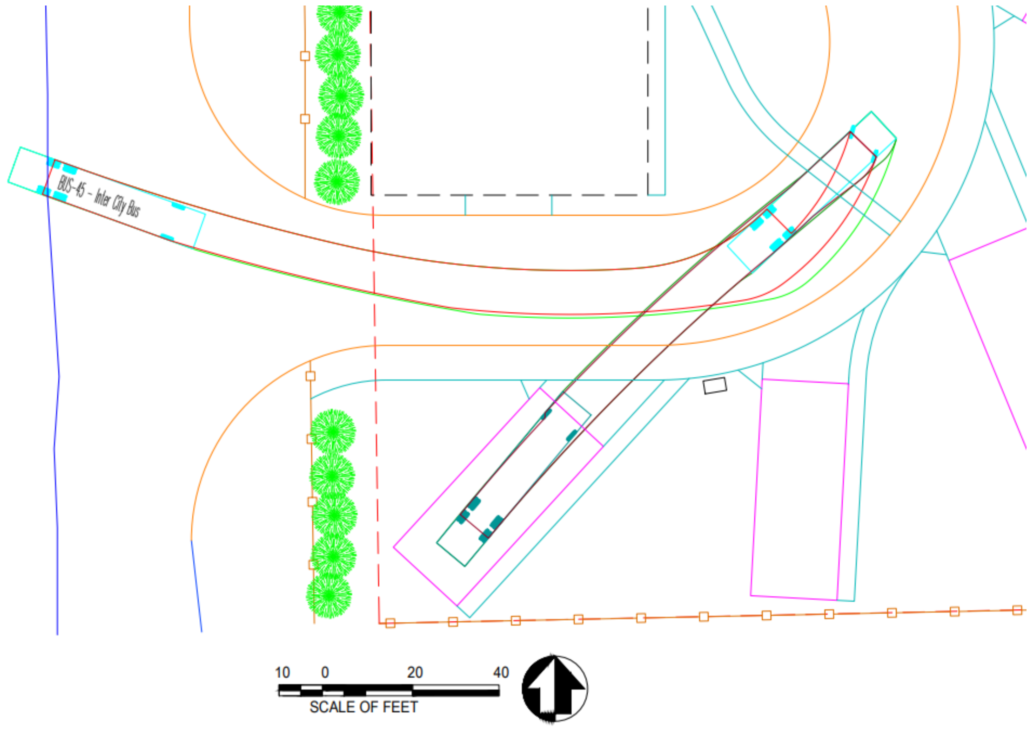

Figure 5-4: Pad 1 Turning Movement

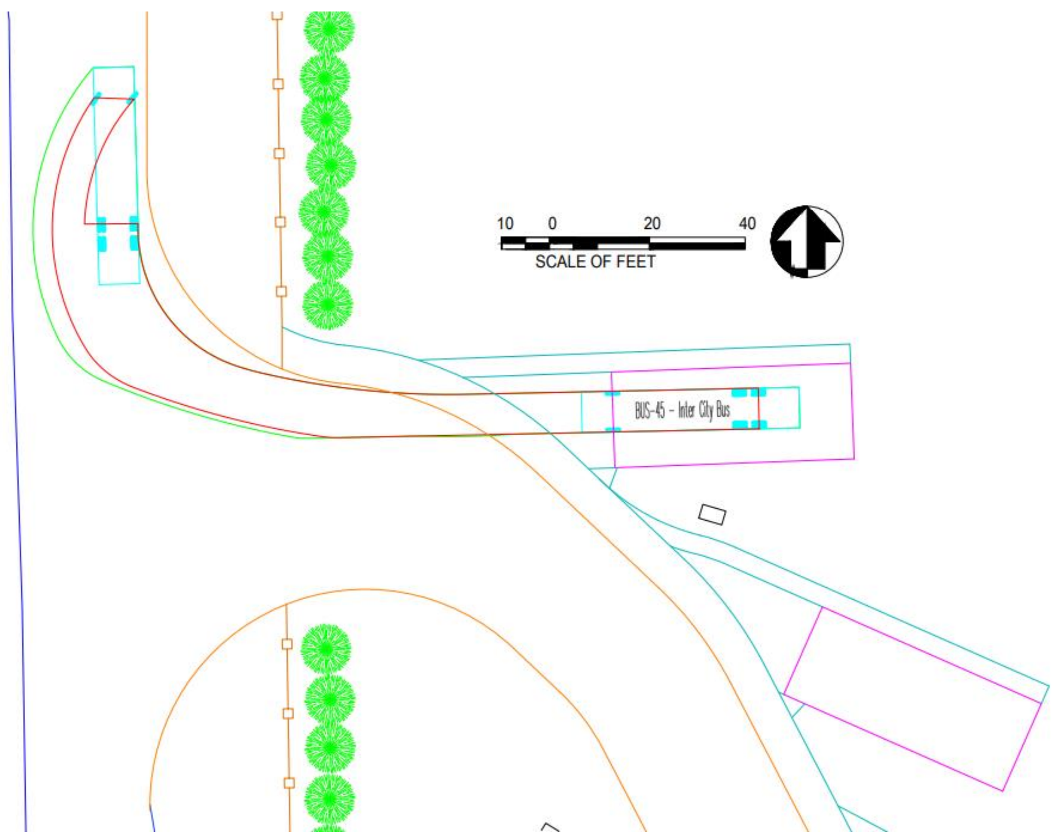

Figure 5-5: Pad 7 Turning Movement Check

Finally, a profile view of the alignment was created. This was done to ensure that all sections of the road were less than 2% in grade. As the sidewalk is parallel to the roadway, the roadway needs to be ADA compliant as well, meaning that it can have a max of 2% grading. The final profile view for the roadway can be found below.

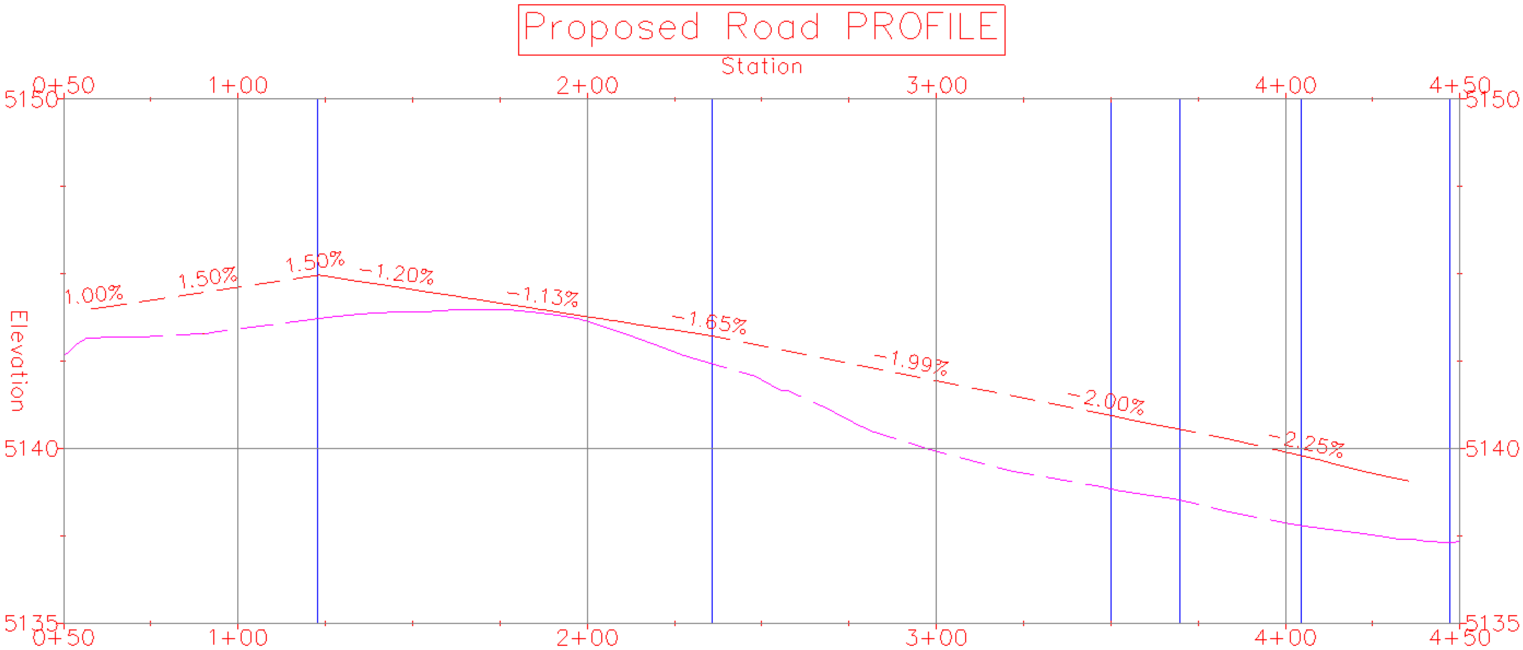

Figure 5-6: Road Profile

5.3 RV Pads & Concrete

The RV pads are the only part of the project explicitly designed using concrete. This achieves both stability and longevity for NPS and the pad's users. The pads are 50 feet long, excluding their driveways, and 20 feet wide. These dimensions were determined to be capable of comfortably accommodating RV's of all sizes. They also follow the recommendation from the NPS Campground Design document (see references). Each pad has electric and water utility hookups on the drivers side, and an AB binder sidewalk connects to every pad on the passenger side, giving access to the common area and other parts of the site. Below is a photo of the top view of the RV pads.

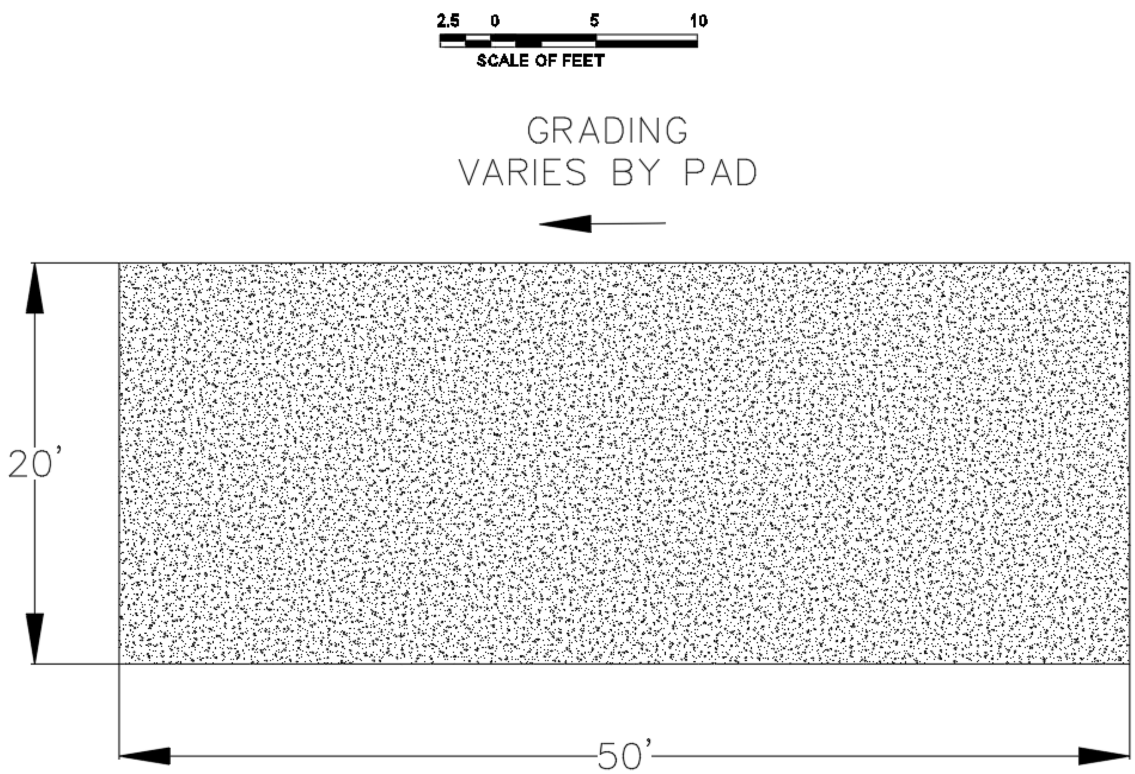

Figure 5-7: RV Pad Top-View Profile

Grading requirements for the RV Pads through NPS standards have also been met. The pad cross sections were designed with a less than 2% longitudinal slope, less than 1% cross slope, and a 0.5% crown on the cross slope. This was done to ensure that the pad was to be as flat as possible while still draining water. The pad was designed to be 9" thick vertically on the edges, which is 9.5" down the center due to the crown). This is well over the NPS minimum requirement of 4" concrete since it is quite a large slab to help ensure stability and longevity of the pad. There is also 10" of aggregate under the concrete to prevent shifts in the soil from affecting the slab.

The concrete that the pads will be made of is MAG AA, 1” machine with AEA mix, rated for 4000psi. 4000psi is the standard concrete density used when accommodating larger vehicles such as semis. The concrete mix is a magnesium-based aggregate mix. This type of mix is general-purpose and commonly used in construction projects. As a class AA concrete, it has high strength and durability requirements that allow it to be used for things like bridge decks, slabs, reinforced piles, shaft foundations. 1” machine refers to the 1-inch maximum coarse aggregate size, and that the aggregate is machine-processed for better uniformity, improving bonding and ensuring it meets specifications. For the project site, this should be a 5-7% entrainment to handle the sometimes below-freezing weather of Chiricahua National Monument. The site exposure category under ACI 318-19 is F1, meaning it is exposed to freezing/thawing cycles and has limited exposure to moisture. This concrete follows NPS Structural Engineering Standards (see references) section for concrete, following ACI-360R-10 for slab-on-grade design, and being classified for exposure using ACI 318-19 table 19.3.1.1 (see references). Below is a photo of the side profile view of the RV Pad. To see the full detail sheet of the RV pads, reference Appendix I.6.

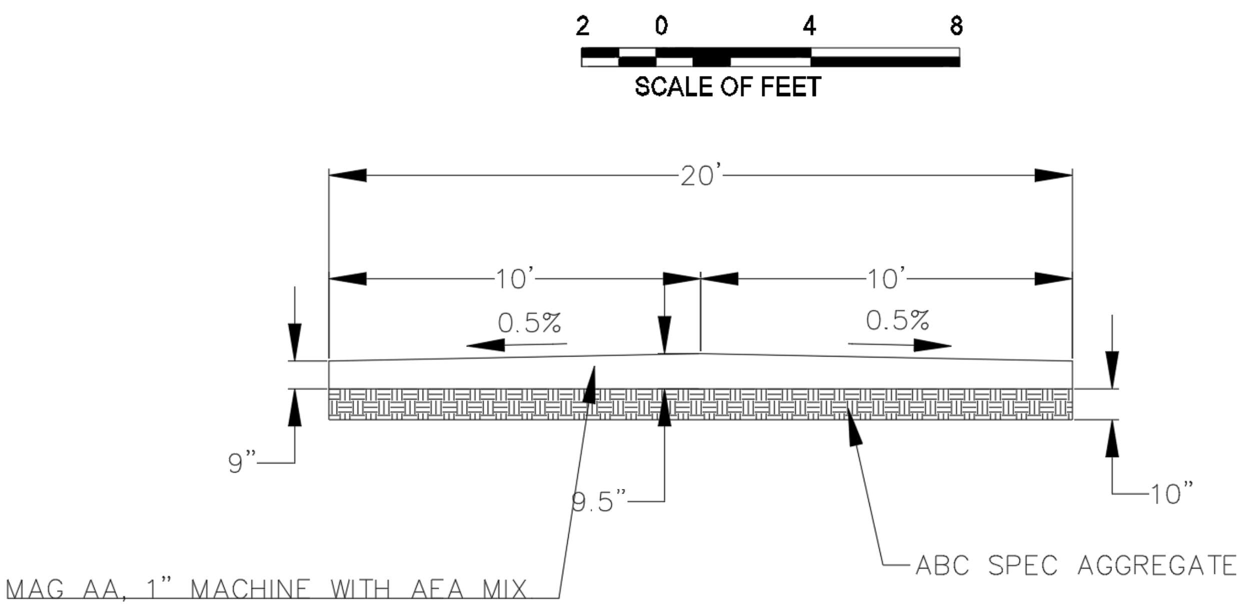

Figure 5-8: RV Pad Side-View Profile

Following ACI 360R-10, the minimum amount of rebar is As=0.18%, but they recommend As=0.50% for larger slabs that do not have contraction joints and experience varying weather/temperatures. With no joints and extreme temperature variations at Chiricahua, As=0.50% has been designed for. ASTM A-615 grade 60 rebar has been selected, as required by NPS Structural Engineering Standards. #4 rebar has been selected, a very commonly used size of rebar for slabs, with a diameter of half an inch. Using a 1 foot cross section, an estimated max live load, calculated dead load, factored load equation, and an assumed moment equation (real equation would vary and be very complex because the varying soil properties under the pad that act as thousands of springs with various k-values), a required steel area was calculated, and found to be slightly less than the minimum steel area requirement of 0.18%. This makes sense as RVs are not a heavy load for the size of the slab when compared to other uses of a slab that large. To see the full sheet of calculations, reference Appendix J. The minimum edge clearance of rebar is 1.5 times area (0.2in^2 for #4 rebar) or 1.5 inches. To be safe with a larger slab, this is designed with a 3 inch edge clearance on the sides, and as required for on-ground slabs has a 3 inch edge clearance on the bottom too. However, it is only a 2 inch edge clearance on top as this was the minimum requirement, allows better placement of mats, and helps more with hot/freeze cycles being closer to the top of the concrete. Since this is a 9 inch slab, it is not required but recommended to have two mats, and this made more sense to design for when trying to get an area of 0.50%. The steel minimum requirement was found to be 10.8in^2 across the 20 foot side and 27.2in^2 across the 50 foot side, resulting in 27 #4 rebar spaced evenly across 19.5 feet on the 20 foot side for each mat, and 68 #4 rebar spaced evenly across 49.5 feet on the 50 foot side for each mat, resulting in approximately 9 inches of spacing between each rebar, which is under the max spacing restriction of 18 inches from ACI 318-19. For the first mat, on the 20 foot side with the more critical, longer rebar, it was placed at an ideal height of 3.25 inches at center point from the bottom (bottom edge of rebar sits 3 inches above bottom of concrete), and on the 50 foot side it was placed at a height of 3.75 inches at center point from the bottom, leaving the two directions of rebar touching each other top edge to bottom edge. In the 2nd mat, the 20 foot side is still on the bottom of the mat, with the rebar centerpoint being 6.25” off the ground, 2.75” from the top. The 50 foot side rebar centerpoint is 6.75” off the ground, 2.25” from the top, having the two directions of rebar once again touching edge to edge. This is shown in the two rebar cross sections in the next page. For the full detail sheet, reference Appendix I.6.

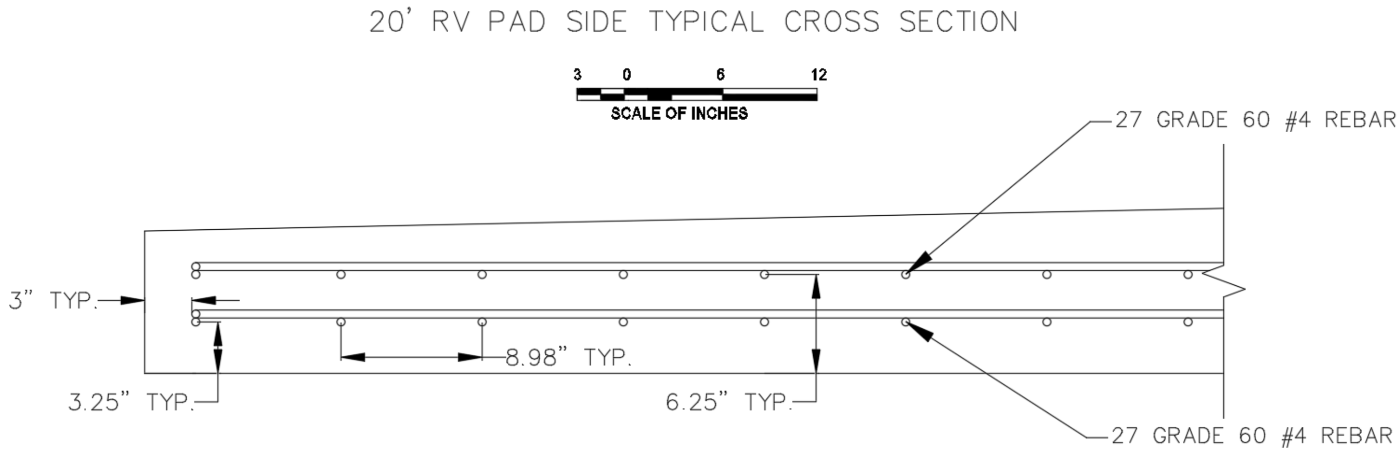

Figure 5-9: RV Pad Rebar 20 Foot Side Partial Cross Section

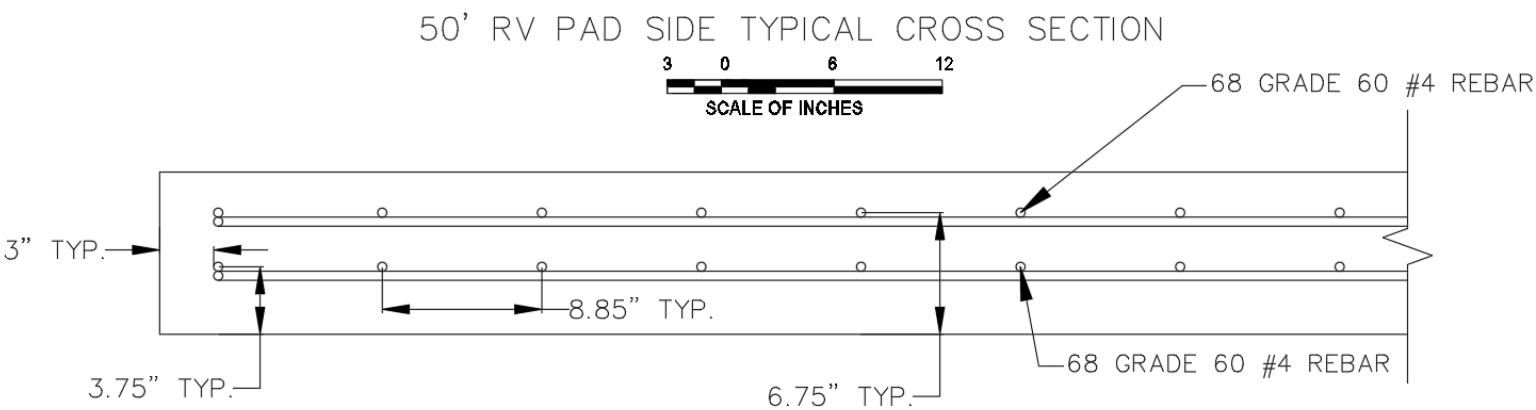

Figure 5-10: RV Pad Rebar 50 Foot Side Partial Cross Section

5.4 Site Amenities and Improvements

The site has one primary common area on the inside of the loop with multiple amenities present. With the intended users of seasonal employees and volunteers staying anywhere from a weekend to several months, users must have the amenities to not just stay, but be able to live on the site. The site was made to be ADA compliant so it is accessible to anyone, utilizing AB binder for the road, sidewalks, and all other amenities. This was done for a sturdy, compliant surface. Additionally, all walkways were designed for less than a 2% slope. Users are provided with 20 x 50 foot concrete pads with full utility hookups on the drivers side of the pads. Each spot has at least 20 feet of open space between it and the next pad. Sidewalks run from the passenger side of each parking spot, before running along the outside of the loop to two marked road crossings. These crossings connect to each other inside the common area and also provide access to the amenities present there.

Within the inside of the loop, users are provided a covered parking lot on the south side. This allows them to store extra vehicles like UTVs, extra personal vehicles, or just save space at their parking spur by parking their vehicle at the lot. Northeast of the parking lot is a recommended but not designed 50 x 20-foot building that would house a laundry room, along with bathrooms that include showers. It is also recommended within the NPS campground design guide that there are “showers, laundry, and other key features”. North of this are two movable square gazebo structures, each 12x8 feet and containing two eight-foot-long benches. These two gazebos also have some open space around them to be used as desired by the users or the client. Four animal/bear-proof trash cans will also be placed around the site to prevent littering on the national monument and keep animals from gaining interest in the site.

Being a green property, solar will be used as the shade structure for the parking lot, and placed on the roofs of the laundry/bathroom building, the gazebos, and the well house. This amount of solar results in a total output of 71.4kW, reducing electricity consumption of the site and saving monthly costs over time. To protect users of the site from the dust of those using the Pinery Canyon Rd while also providing a privacy screen, a tree line will be put in place along the road. 34 young Desert Willow Trees will be placed, with a max buffer space of 10 feet between the center of each. This allows 5 feet of space to grow on each side for each tree. Desert Willow Trees commonly grow to 20+ feet tall and 10+ feet wide. This will help to vegetate the site more, provide a good privacy screen, and provide protection from dust.

Special amber-hue low lighting has been used across site to preserve the night sky as advised in the campground design guide. For pathways, LUVO 17w PC Amber led bollard lights with louvers will be installed approximately every 10 feet. These are short light poles used on sidewalks to light the path, but screen the light downward away from the sky. At the entrance of each gazebo, laundry room, bathrooms, and scattered around the parking lot will be HEZE 40w PC Amber led full cutoff wall pack. These provide stronger amber lighting in key areas, but still point the lighting downwards. They will be attached to walls of buildings or the solar structural poles in the parking lot. These lights can function without power access too, with the light poles having 147,000 hours of light, and the wall lights having 213,000 hours of light.

5.5 Post-Development Hydrological Analysis

Once the final design was completed, a post-development hydrological analysis was performed to determine how the design changed the hydrology of the site and to ensure it did not increase the peak flow. The parameters used are presented below.

Table 5-1: Post-Development Hydro Parameter

Parameter	Value
Soil Type	Type B
Cover Type	Herbaceous
Cover Density	9%
Impervious Area	0%
Watershed Area	0.41mi²/ 262.4 acres
Longest Watercourse	6869 ft

The main changes compared to the previous analysis would be site characteristics. Due to the new soil brought into the site, the soil type is B now which implies a moderately low runoff potential. The overall vegetation cover would stay the same. Lastly, due to the concrete and structures recommended in the design, the impervious area was changed into a 20% coverage. The 50-year and 100-year storm events were calculated and presented below.

Table 5-2: Post-Development Hydro Analysis

	50-year	100-year	Units
Weighted Runoff Coef. (Wc)	0.54	0.57	Unitless
Time of Concentration	13.2	12.3	min
Rainfall Intensity (i)	7.2	8.23	in/hr
Runoff Supply Rate (q)	3.87	4.65	in/hr
Peak Discharge	1024.5	1230	cfs

Overall, the design reduces the peak discharge expected from the site, bringing as improvement on the hydrology of the site. Full report present in Appendix E4.

6.0 Cost of Implementing the Design

A thorough cost analysis has been conducted for the project, covering all site additions, quantities, and associated costs. The total project cost includes expenses for site amenities, solar panels, concrete work, roads, sidewalks, and earthwork. These expenses are divided into three main categories: material costs, construction costs, and lifecycle costs. Although a thorough life cycle cost study was not completed, standard percentage rates applied to the initial costs of each component were used to estimate annual maintenance expenses. These percentages represent the normal maintenance requirements for each type of infrastructure.

6.1 Cost of Construction

The construction cost was estimated factoring in labor, materials, installation, and equipment rental. While site amenities and solar panels come at a relatively lower cost, earthwork demands more resources due to the use of heavy machinery and the high cost of importing suitable soil. Concrete work represents the most significant expense, with over $215,000 allocated to RV pads themselves. Road and sidewalk construction followed, totaling more than $260,000. A summary of these costs are shown in the table below, with detailed figures available in Appendix K.1

The construction cost analysis was developed using a combination of research tools, industry references, and practical experience. Unit costs for materials such as concrete were drawn from company-provided cost sheets based on recent project data. Solar panel estimates were calculated using the NREL PVWatts Calculator to determine system size and performance. Vegetation selection and pricing were based on research into regionally appropriate, drought-tolerant plants and verified through online nursery and supplier databases. General pricing for items such as lighting fixtures, site furnishings, and aggregate materials was gathered from manufacturer websites and standard construction supply vendors. Where appropriate, labor and installation costs were estimated based on past project experience and regional cost averages. All assumptions and supporting sources are cited in the project references [21-34]. Table 6-1 shows a summary of the cost of construction presented in the next page.

Table 6-1: Summarized Cost of Construction

Cost of Construction	
Category	**Cost**
Site Amenities	$83,845
Green Improvements	$105,162
Concrete	$231,978
Roads/Sidewalk	$262,630
Earthwork	$45,057
Equipment	$39,000
Project Total	**$767,673**

6.2 Estimated Annual Operations & Maintenance (O&M) Costs

While a full lifecycle cost analysis was not completed, annual maintenance costs were estimated using standard percentage rates applied to the initial construction costs of key site components. These rates were selected based on both publicly available data and consultation with an industry professional experienced in site maintenance budgeting. For example, a rate of 1.7% was applied to site amenities such as picnic tables and lighting, while solar panels were estimated at 1.5% due to their minimal maintenance requirements. Concrete elements, including RV pads and building foundations, were assigned a rate of 2.0%. Sidewalks, which experience frequent use and exposure to weather, were estimated at 5.25%. Earthwork was given a rate of 4.2%, accounting for ongoing needs such as grading and erosion control. These estimates provide a realistic basis for anticipating long-term maintenance costs and support informed planning for future site upkeep [35]. Table 6-2 below summarizes these estimated O&M costs.

Table 6-2: Estimated O&M Costs

Estimated O&M Costs	
Category	**Cost**
Site Amenities	$1,425
Green Improvements	$1,577
Concrete	$4,640
Roads/Sidewalk	$13,788
Earthwork	$1,892
Project Total	**$23,323**

7.0 Impacts Analysis

This analysis applies the Triple Bottom Line framework looking at economic, environmental, and social impacts to evaluate the proposed development near Chiricahua National Monument. The project aims to provide housing for seasonal volunteers and staff. By assessing the final design through all three lenses, we can better understand how the development supports sustainable growth, enhances visitor and community experiences, and responsibly manages natural and economic resources.

7.1 Economic Impacts

The development of this project will have a great impact on the economic side of it. Mainly, the overall revenue of the monument will be increased due to job creation and reduction in housing costs, which may allow the monument to be recognized as a National Park, boosting tourism and the local economy. The presence of tourists has many implications for them, they will not only affect the project area but the local economy as well. Willcox will most likely see a bit more traffic and volume of tourists due to its proximity to the monument boosting local businesses, services, and attractions. As the client mentioned, the monument staff is aiming for the Chiricahua National Monument to be recognized as a National Park, the initial success of this project could lead to more support and funding for expanding and upgrading infrastructure in the area such as roads, signage, and utilities. Solar panels will be installed on all structures, including a shaded parking area, reducing the O&M costs of the site.

Potential negative impacts are that business could only come in seasons, leading to seasons where there are no visitors or revenue getting made. Off-seasons would lead to underutilized facilities and job insecurity for those employees hired for this facility. Additionally, due to the undeveloped area surrounding the project, local roads might need to be upgraded to satisfy the new users. Lastly, the overall cost of the project is a negative impact to the client and the monument due to the low funding national monuments receive in general.

7.2 Environmental Impacts

Sustainability and environmental impact were key considerations throughout the RV park design, given its location within the boundaries of Chiricahua National Monument. The design aimed to minimize ecological disruption while still meeting ADA accessibility requirements and supporting long-term residential use. Although concrete was necessary for the RV parking spurs, more sustainable materials, such as gravel with an AB binder, were used for the loop road and sidewalks to reduce environmental impact while maintaining ADA compliance. Site grading was some cut which will be reused on the site, and mostly fill, but a natural aggregate is used for the fill. The drainage design follows natural flow patterns: areas east of the loop road drain into the existing wash, while areas to the west flow into a roadside ditch that also connects to the wash.

Preservation of native vegetation was prioritized where possible. The existing treeline along the road was maintained to help offset the impact of vegetation removal in developed areas. While the laundry and restroom facility requires a concrete foundation, all other structures, such as gazebos and benches, are designed to be temporary and removable. Low-impact amber lighting with shielding was specified to protect the night sky, and bear-proof trash receptacles were included to reduce litter and deter wildlife interaction.

The solar panels also benefit the project environmentally, offsetting electricity use and promoting renewable energy. Areas of the site not designated for development will remain undisturbed to preserve the natural landscape.

While some environmental impact is unavoidable due to the use of concrete and gravel, the design integrates multiple strategies—such as solar energy, low-impact lighting, and native vegetation preservation—to reduce and offset those effects wherever possible.

7.3 Social Impacts

This project is expected to help improve the overall experience for visitors and seasonal staff at the monument. A key benefit of this project is that it offers on site housing for volunteers, which directly supports monument operations and encourages longer term involvement. Additionally, the development makes productive use of currently unused land, transforming it into a functional and welcoming space. All major amenities such as bathroom and laundry facilities, as well as parking, are centrally located, making them easily accessible from all parts of the site. This thoughtful layout improves comfort, convenience, and movement throughout the area. Overall, the project creates a more organized and enjoyable environment for everyone who works or volunteers at the monument.

Although the project offers many benefits, there are a few social concerns to consider. If the channel and culvert remain untouched, there is some flooding risk from a rare major storm event. If the site becomes too popular, there may be a risk of overcrowding. A high number of visitors could lead to long wait times for shared amenities like bathrooms and laundry, reducing the overall quality of the experience. Overuse of the space might also create more noise, litter, and wear on the facilities, which could affect both visitors and staff. In addition, the construction process itself may temporarily disrupt the surrounding environment. Noise, traffic, and limited access during this phase could negatively impact current residents and wildlife in the area. Proper planning and management will be needed to reduce these effects.

8.0 Summary of Engineering Work

The project timeline outlined in the proposed Gantt chart, which can be viewed in Appendix L.1, served as a general framework for the timeline of the project. For the most part, the work progressed according to the original plan. However, one portion of the geotechnical investigation required an unexpected laboratory test that had not been included in the initial schedule. This adjustment resulted in additional hours being logged beyond the original estimate.

Another phase of the project, the final site development section, also demanded more time than anticipated. While the team's limited experience with hydrological modeling contributed to the extended timeline, the primary challenge involved multiple iterations of grading for the RV pads. These revisions were essential to achieve a balanced cut-and-fill approach, ensure ADA compliance, and maintain proper drainage across the site. Additional time was invested in refining these elements to uphold the quality and functionality of the overall design.

In contrast, time was saved during the preliminary design phase. Strong communication within the team and effective collaboration with the client allowed for faster consensus on design alternatives and overall direction. This efficiency helped offset some of the additional hours spent in earlier phases and contributed to maintaining project momentum.

To accurately reflect these adjustments, a revised Gantt chart was developed and is included in Appendix L.2. This updated version incorporates the added testing, extended hydrological analysis timeline, and the time savings from the design phase. It offers a more accurate representation of the project's progression and highlights the team's ability to adapt to evolving project demands. Importantly, none of these adjustments affected the overall project start or end dates, and all key milestones were still met on time.

9.0 Summary of Engineering Cost

The total hours invested in the project were almost the same as the ones presented in the proposal, however, the distribution of hours varied significantly. First, the site visit was smoother and quicker than expected due to the pre-visit research and training the team had with the GPS surveying equipment. The geotechnical analysis had a significant amount of additional time spent on it due to the addition of the Atterberg's limits test, which was not originally planned. A major time saver in the project was during the preliminary site development due to the clear communication between the team and the client while developing the decision matrix, alternatives, and final alternative. On the other hand, the biggest time addition to the project was in the final site design due to multiple iterations of the site grading and RV pad designs. Lastly, both the writing of the deliverables and management hours were overestimated in the proposal. The total hours invested in the project by the team ended up being 5 hour less than the proposed total. The table displaying the hour comparison is presented below.

Table 9-1: Proposed v. Actual Hour Log Table

	Proposed					Actual					Diff
Task	SENG	ENG	EIT	EI	Total	SENG	ENG	EIT	EI	Total	
Task 1: Site Visit	2	8	30	20	60	4	12	19	14	49	-11
Task 2: Geotechnical Analysis	2	12	18	6	38	3	12	23	13	51	13
Task 3: Survey Data Analysis	2	3	10	6	21	1	2	5	3	11	-10
Task 4: Hydrologic Analysis	6	17	26	16	65	8	14	26	17	65	0
Task 5: Preliminary Design Development	4	23	35	21	83	5	15	25	17	62	-21
Task 6: Final Site Design	4	35	48	11	98	6	36	62	28	132	34
Task 7: Develop Construction Cost Estimate	2	2	8	2	14	2	5	15	8	30	16
Task 8: Construction Plan Set	7	10	18	13	48	4	11	25	14	54	6
Task 9: Project Impacts	2	6	0	0	8	1	4	8	14	27	19
Task 10: Project Deliverables	13	29	30	18	90	6	16	22	18	62	-28
Task 11: Project Management	20	50	20	45	135	20	40	20	32	112	-23
TOTAL	64	195	243	158	660	60	167	250	178	655	-5

A detailed table displaying all subtasks is present in Appendix M

Before beginning the project, a proposed summary of engineering cost was created. This featured the supplies & equipment, along with travel costs associated with completing a site visit and analyzing the data found. It also included personnel cost, using an estimated rate and proposed hours of each position. Since this proposal, the costs for supplies and equipment and travel have not changed, as the site visit was already being planned with accurate cost values during the proposal phase. The actual hours from the proposed were four less for senior engineer, 28 less for engineer, but 7 hours more for Engineer in training, and 20 more for the engineering intern. Despite only a 5-hour reduction in hours from the proposed to actual, the higher-paid positions having reduced hours has reduced the total cost of engineering services by $4,165. The proposed vs actual costs can be seen in the table below.

Table 9-2: Summary of Engineering Cost

	Classification	ProposedHours	Rate	ProposedCost	Actual Hours	Actual Cost
1.0 Personnel	Senior Engineer	64	$280	$ 17,920	60	16800
	Engineer	195	$195	$ 38,025	167	32565
	Engineering in Training	243	$145	$ 35,235	250	36250
	Engineer Intern	158	$70	$ 11,060	178	12460
	Total Personnel			**$ 102,240**		**$98,075**
2.0 Travel	**Classification**	**Quantity**	**Rate**	**ProposedCost**		**Actual Cost**
	Large AWD vehicle	3 days	$52.8/day	$ 158		$ 158
	Mileage	750 miles	$0.31/mile	$ 233		$ 233
	Hotel	2 days	$145/day/person	$ 1,160		$ 1,160
	Per Diem	3 days	$54/day/person	$ 648		$ 648
	Total Travel			**$ 2,199**		**$ 2,199**
3.0 Supplies & Equipment	**Classification**	**Quantity**	**Rate**	**ProposedCost**		**Actual Cost**
	Nikon/Topcon 3D Total Station	3 days	$35/day	$ 105		$ 105
	Tripod	3 days	$10/day	$ 30		$ 30
	GPS Rover (includes accessories)	3 days	$50/day	$ 150		$ 150
	4 Reflective Vests	3 days	$5/day	$ 15		$ 15
	Soil Storage Ziplocs	12 units	$1/unit	$ 12		$ 12
	Compaction Lab access/testing	2 days	$100/day	$ 200		$ 200
	Computer Lab Access	10 days	$100/day	$ 1,000		$ 1,000
	Sieve Lab access/testing	2 days	$100/day	$ 200		$ 200
	Total Supplies			**$ 1,712**		**$ 1,712**
4.0 Total Cost of Engineering Services				**$ 106,151**		**$ 101,986**

10.0 Conclusion:

This project turns an undeveloped site within Chiricahua National Monument into a fully-developed ADA-compliant RV park capable of short or long-term use by seasonal and volunteer NPS employees. A site visit, GPS surveying, and geotechnical analysis were completed so that an AutoCAD topographic map, site design map, grading with cut and fill, and hydrological analysis for the site could be completed. As deliverables were completed, the various features of the site were detailed specifically to work for this project and to meet requirements.

The site utilizes a 30-foot-wide loop road, made of 5.5” AB binder and designed to handle the turning radius of the largest RVs. On the South and East side of this road are 7 back-in 50x20 foot concrete RV Pads with full utility hookups. These pads are 9 inches of MAG AA concrete with air-entraining agent rated for 4000psi, 69 total #4 rebar per pad, and 10 inches of aggregate below that. ABC binder Sidewalks run from the side of each pad through the common area inside the loop road. This common area features a covered parking lot, two gazebos with benches, and some extra space for other activities for residents to utilize. We recommend construction of a laundry and bathroom structure here too. To reduce the environmental impact of the site on the national monument and promote sustainability, a few measures were made. Bear-proof trash cans were placed around the site to prevent littering, concrete was only used on the pads with AB binder being used for ADA compliance elsewhere, a treeline was made both to reduce dust from the road and make up for the natural brush the site design will destroy, and solar panels were placed on every roof available on the site, which is the gazebos, the pumphouse, and the covered parking lot. This is approximately a total of $767,673 to design the site. Construction time will be determined by NPS as the client has stated they must go through extra regulations and procedures to start construction.

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