NORTHERN ARIZONA UNIVERSITY
College of Engineering, Informatics,
and Applied Sciences
Civil Engineering, Construction Management, and
Environmental Engineering Department

Letter of Transmittal

TO: Rich Goepfrich, Jr. National Park Service Manager
FROM: Desmin Fontaine, Dylan Edens, Julia Trivers
DATE: Wednesday, November 18, 2020
SUBJECT: Final Report – Saguaro National Park Parking Lot Assessment/Design

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Dear Mr. Goepfrich,

The project final report is attached, titled Saguaro National Park Parking Lot Assessment and Design: Final Report. The purpose of the report is the completion of a final report, phasing out deliverables based on the progress our team made throughout the semester. Please let us know if you have any comments or concerns.

The final design consists of two delineated gravel and asphalt lots for Saguaro National Park to decide on the final design. For the asphalt design the final estimated cost of construction was $62,400.00 and for the gravel lot the estimated cost of construction was $26,937.00.

Best,
Saguaro Systems Engineering
Civil & Environmental Engineering, NAU
jpt79@nau.edu

11/17/2020

Saguaro National Park Parking Lot Assessment and Design: Final Report

Fall 2020 – CENE 486C- Section 1

To Richard Goepfrich, Saguaro National Park
Facility Manager

Written By:

Saguaro Systems Engineering

Members:

Desmin Fontaine, Dylan Edens, and Julia Trivers

NORTHERN ARIZONA UNIVERSITY
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List of Abbreviations

Abbreviation	Definition
AASHTO	American Association of State Highway Transportation Officials
ADA	Americans with Disabilities Act
ADOT	Arizona Department of Transportation
ASTM	American Society for Testing and Materials
AZ	Arizona
CCC	Civilian Conservation Corps
CFS	Cubic Feet per Second
DWG	AutoCAD Drawing Database
EIT	Engineer
GI	Grading Instructor
GIS	Geographic Information System
GPS	Global Positioning System
LOB	Left Overbank
NAU	Northern Arizona University
NPS	National Park Services
NRCS	National Resource Conservation Service
PE	Project Engineer
ROB	Right Overbank
TA	Technical Advisor
US	United States
USCS	Unified Soil Classification System
USDA	United States Department of Agriculture
USGS	United States Geological Survey

Acknowledgement

We wish to express our sincere gratitude to our grading instructor Dr. Jeffrey Heiderscheidt of Northern Arizona University for guidance and support through this project. A sincere thanks to Nate Reisner, District Development Engineer of Arizona Department of Transportation, for technical guidance and support through this project. We wish to express a special thanks to our client, Rich Goepfrich, Facility Manager of Saguaro National Park, for guiding and believing in undergraduate students to aid in the development of Saguaro National Park. This research was funded by course tuition and fees for CENE 486 Senior Design for the year of Spring 2019-Fall 2020 at Northern Arizona University.

1.0 Project Introduction

1.1 Project Information

The project is located in the southern part of Arizona, in Saguaro National Park located in the Tucson Mountain District seen in *Figure 1-1*. The project location, the Cam-boh Picnic Area (32°19'9.98"N, 111° 9'57.97"W), is located on the west side of Saguaro National Park 12.5 miles north-west of Tucson, Arizona (*Figure 1-2*), just south of Picture Rock Road *(Figure 1-3).*

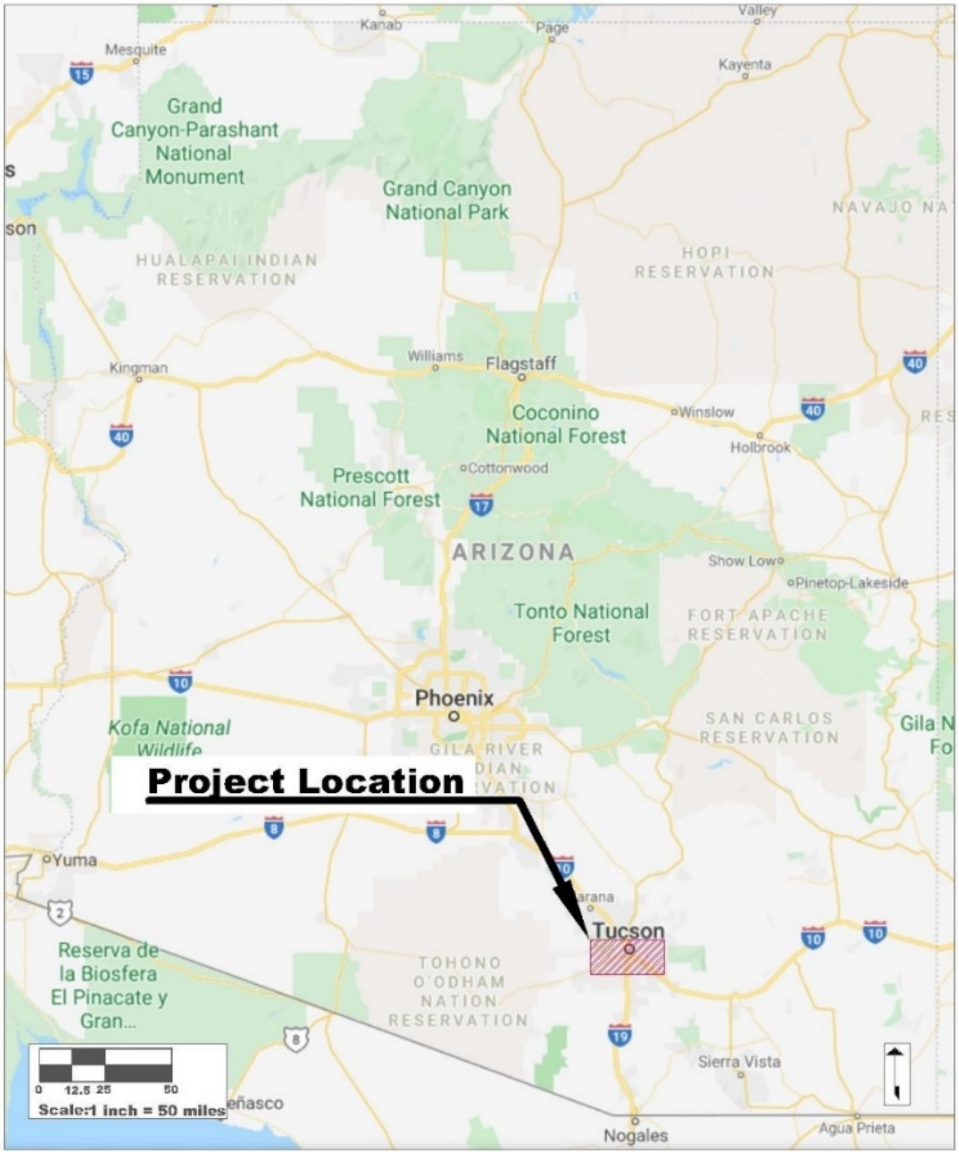


Figure 1- 1 Project Location in Arizona

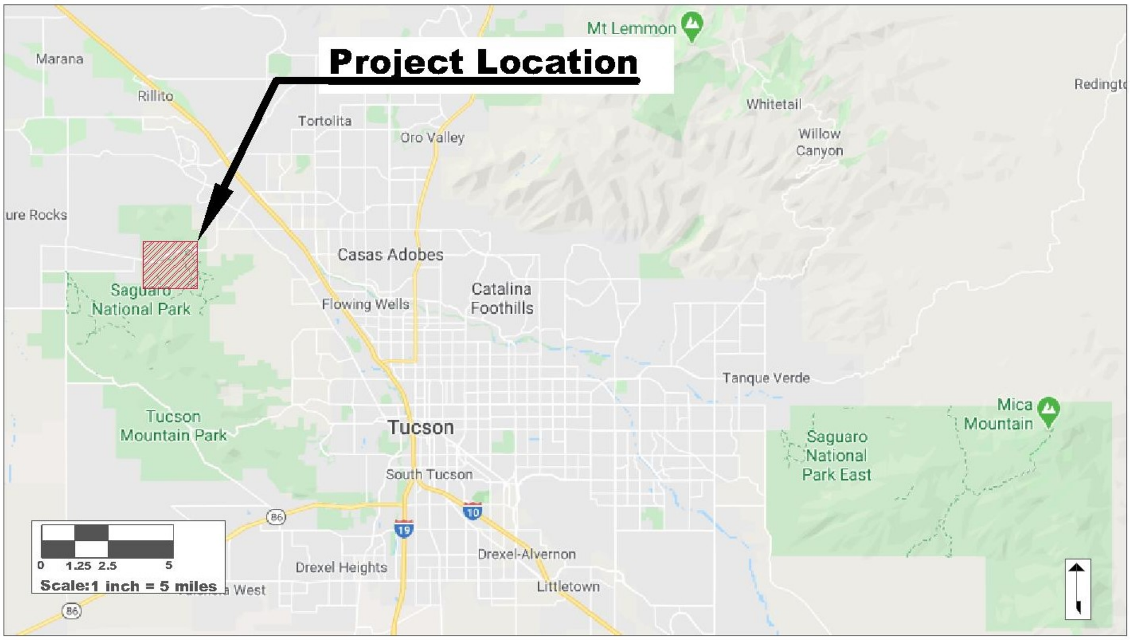


Figure 1- 2 Project Vicinity Map

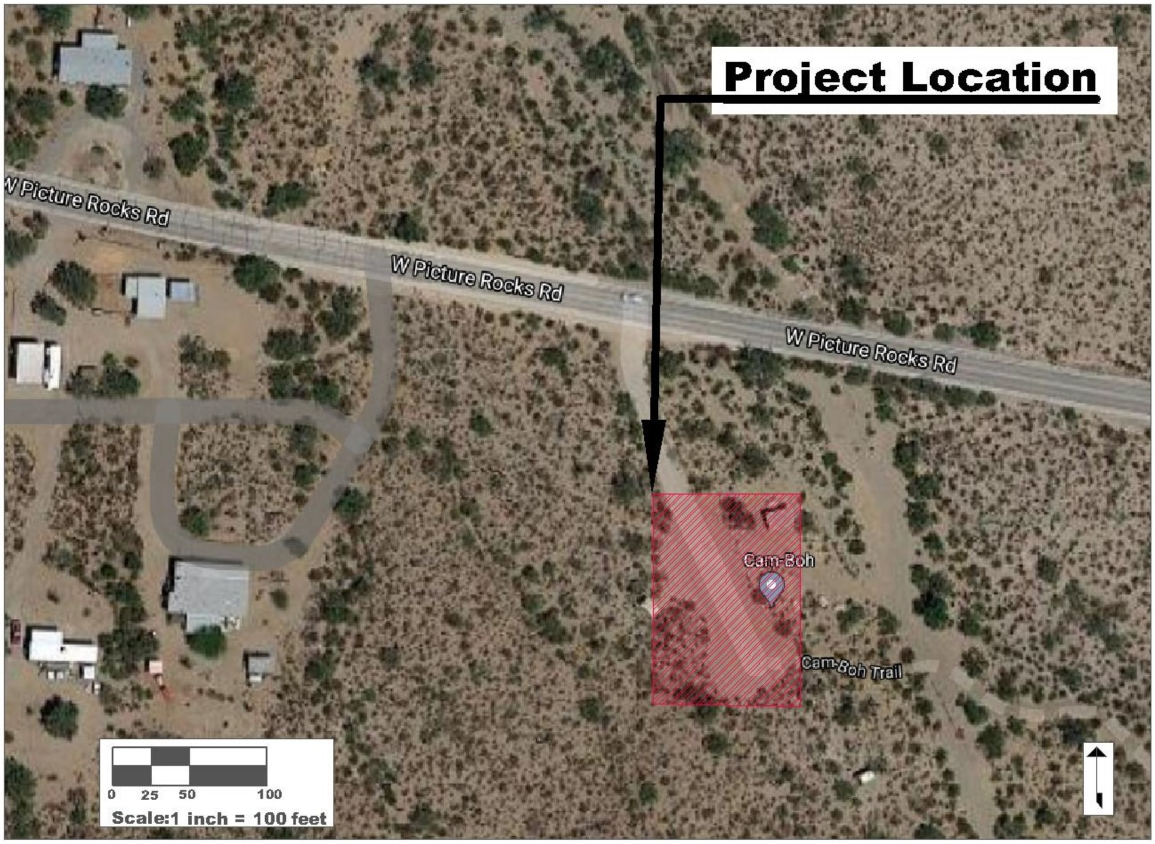


Figure 1- 3 View of Project Site

1.2 Existing Conditions

The available land encompasses approximately 4.5 square acres. The site is between a small development of residential homes and a natural wash that is approximately 160 feet to the west of the park's entrance displayed in *Figure 1-3*. The site's associated trail is the Cam-boh Trail – which runs parallel to Picture Rock Road from Cam-boh Picnic Area and is a major connection between the east and west parts of the Tucson Mountain District providing several loop opportunities for mountain bikers, hikers, and equestrian riders. [1]

The current dirt parking lot footprint is inadequate in size for horse trailers and for the many visitors. In the picnic area there is a comfort station, a shade shelter, multiple picnic tables, and a few trail heads that lead into the interior of the park. Boulders were placed along the gravel lot to create a boundary for the parking lot. The vegetation surrounding the Cam-boh picnic area consists of two biotic communities: desert scrub and desert grassland. These biotic communities are consistent throughout the Sonoran Desert encompassing the surrounding regions of the park.

1.3 Constraints/Limitations

There were a number of potential challenges including: location, weather conditions, and current restrictions due to COVID-19. The site was a potential challenge for the project team because it is 251 miles south of Northern Arizona University and the number of trips to the site was limited due to university limitations. The project team planned to conduct the visual site survey, geotechnical soil collection, and the site survey all in one site visit, but no site visits occurred. The project team was anticipating university approval to travel on the requested date, so the schedule was adjusted to keep the project on track and reflect the delay in the schedule. This change in ability to travel restricted the project team to create assumptions from previous projects and gathered information.

All new land developments cause changes to the stormwater and land characteristics so there was a need of criteria to follow. The constraints of the design project included: the available space for the existing parking lot design, protection and removal of native plants, possess adequate drainage, parking spaces available for horse trailers/trucks, and ADA compliance. Due to the complexity and time constraint, a full redesign of the comfort station and existing structures was excluded from the scope. This limited the available area for the design of the parking lot, so the project team had to design around the existing structures.

An identified challenge involved with this project was the relocation of existing protected vegetation and species. The existing footprint was not an adequate size for the design, so vegetation including ironwood tree and saguaro cactus will be removed and relocated per NPS regulations. The National Park Service is an agency in the Department of the Interior and the National Park Service administers the Cam-boh Picnic Area. To remove native plants from National Park Service land, the contractor is required to fill out an Application for Arizona Protected Native Plants and Wood Removal, obtained from Arizona Department of Agriculture and then the protected plant can be relocated. This was noted in the vegetative relocation plan in the plan set.

1.4 Project Objective

The purpose of the project included designing a parking lot in Saguaro National Park in the Cam-boh Picnic Area that will be adequate for trail visitors, including visitors with horse trailers, trucks, and other vehicles. In order for the trail to serve its intended purpose for the users and increased visitation, a new lot was designed to suit the client's needs.

There was a need for the design and implementation of a parking lot to provide a safe area for visitors to the park, as well ensure the natural desert is preserved by preventing parking in undesired areas. The client requested a revision to the current site because of limited parking area for vehicles and trucks due to visitors parking on the shoulder of the road, limited Americans with Disabilities Act (ADA) accessibility parking, and lack of clear signage.

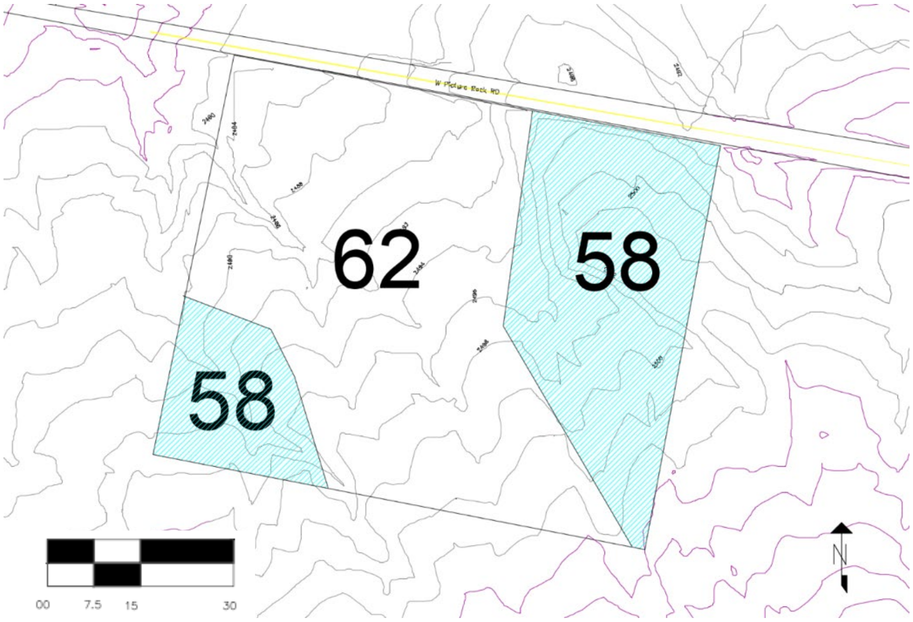
The client requested the team to create two delineated designs with corresponding construction plan sets for the redesigned parking lot with one asphalt design, and another separate gravel design.

2.0 Existing Site Due Diligence

The goal of due diligence was to locate any preexisting data, which helped aid in the design and assessment of the parking lot. This aided the project team because of the cancelation of the site visit. Doing this step helped the project team determine an estimated basis of the existing site conditions of geotechnical properties, general topography, previous survey maps and the visitation statistics for Saguaro National Park.

From a USGS 7.5 topographic map of the Avra Quadrangle in Pima County, Arizona, found in *Appendix A*, it presented natural features of the surrounding area. It located and named mountains, valleys, plains, rivers, and vegetation and identified connecting roads and county boundaries. It was concluded from this map that the site sits approximately at 2500 feet in elevation and there is a noticeable wash to the east of the Picnic Area.

From an existing geotechnical report provided from the National Resource Conservation Service (NRCS), the team estimated that the geotechnical soil on site is sandy clay loam. Because this data is from 2019, the project team intended to complete a geotechnical analysis of collected soil. Below in *Figure 2-1* is the soil map report from NRCS along with the soil map report legend in *Figure 2-2*.



Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
58	Pantano-Granolite complex, 5 to 25 percent slopes	1.9	39.7%
62	Pinaleno very cobbly sandy loam, 1 to 8 percent slopes	2.9	60.3%
Totals for Area of Interest		**4.8**	**100.0%**

Figure 2- 1 NRCS Soil Map Report.

3.0 Field Work

3.1 Site Investigation

The purpose of the site investigation was to travel to the site in Tucson, Arizona, and take a visual survey of the land to determine the vegetation and general existing conditions in the area for the teams parking lot design. Because of university travel restrictions, traveling to the site was not completed. A visual inspection of the site was completed using Google Maps, to determine where vegetation is located and to show the different limitations that will affect design. It was determined that there were many immovable structures located in the internal boundary of the existing project footprint, which created a constraint for designing the layout of the parking lot. Protected species of ironwood, palo verde, and short and tall saguaro cactus was noted to be relocated were found in to be in the project area. Any of the species that are located in the boundary of the proposed site layout will be moved to the exterior boundary of the project, or in the designated vegetation areas located on the team's construction plan set. Included in the construction plan set is a sheet comparing the existing protected species location and the proposed location during construction. The identified protected species will need to be surveyed prior to verify the exact location and to conserve and relocate before construction begins.

3.2 Surveying

Surveying was anticipated to be completed, but it was not accomplished due to university restrictions. During the initial site visit, the team was going to visit the site and use GPS technology and survey the existing footprint of the proposed site. This would help create a topographic map of the job footprint. Even though a site visit was not conducted, the team found an existing USGS topographic map of the Avra Quadrangle. This helped the team estimate the topography of the surrounding watershed and an estimated elevation. The topographic map of the area is presented in *Appendix A*. In addition to the USGS 7.5-minute topographic map, the project team was provided a 2-foot contour DWG file of Saguaro West from Pima County GIS Division that will be explained in Section 2-4 Survey Data Analysis.

3.3 Soil Sampling

Once on site, the team planned on taking 5 soil samples from 5 different trial pits with a shovel, ranging between 1 to 5 feet underneath the earth's surface at each corner of the project site as shown in *Figure 3-1*. Due to COVID-19 an initial site visit was not completed; no samples were taken at the project site and no lab tests were conducted on any soil samples. Instead, approximate soil properties were estimated and are explained in 4.0 Geotechnical Analysis.

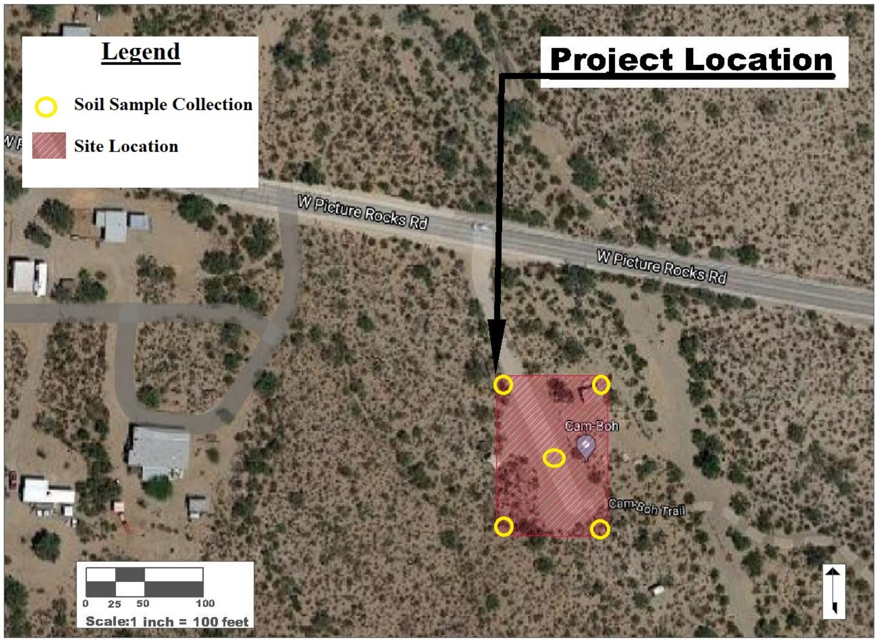


Figure 3- 1: Site Soil Sampling Plan

4.0 Geotechnical Analysis

The geotechnical information provided in this report is based on properties found at other Tucson-area projects, since the team was unable to perform a site visit due to COVID-19 travel restrictions. The team instead utilized all resources to determine the most accurate assumption of what the soil at the site represents. Saguaro National Park is located in Pima County which uses the 1986 AASHTO Guide for the Design of Pavement Structures as the primary guidance for new pavement designs. Therefore, the basis of this geotechnical investigation will be using AASHTO design standards based off of geotechnical analysis, subgrade considerations, and pavement design in accordance with the Pima County Roadway Development and Street Standards Manual shown in *Appendix M and N*. A published soil survey of Pima County Arizona (AZ669) was used to estimate the soil that pertains around the Pima County Area. *Appendix R- Boring Log of Union Office Complex in Mesa, Arizona* was used in conjunction with the Unified States Department of Agriculture (USDA) texture classification triangle in aiding our team to estimate the soil at our site to be sandy clay loam.

Sandy clay loam consists of 20-35% clay, less than 28% silt, and more than 45% sand shown in *Appendix L- USDA Soil Textural Triangle*. *Appendix S- Tabulation of Boring Log data in Mesa, Arizona* shows the percent passing the #200 sieve to be 39% for a depth of 14 feet. Assuming the soil at the project site is sandy clay loam; the soil was classified by the AASHTO classification system, then determined to be A-6, as shown in *Appendix M* with the assumption of sandy clay loam classification. The soil has at least 39% of fines passing through the #200 sieve with a maximum liquid limit of 26 and a minimum plasticity index of 8. The Group Index was then estimated to be GI- 0, A-6. The soil was then classified using the USCS classification system which was found to be a sandy-gravelly clay mixture (CL, SC). 80% of the grain size can be estimated to have passed the #4 sieve leading us to assume that the sandy clay loam located at the project site will have a fair to poor rating as a subgrade.

Table 4-1: Typical CBR and Modulus of Elasticity Values for Various Materials shown below illustrates typical CBR, R-value, and Resilient Modulus values that are representative of soil at the site for sandy clay loam. It was estimated for the soil at the project site to have a CBR of 10, an R-value of 20, and a Resilient Modulus of 10,000 psi from *Table 4-1*.

Table 4- 1: Typical CBR and Modulus of Elasticity Values for Various Material

Material (USCS given where appropriate)	CBR	R-Value	Elastic or Resilient Modulus (psi)
Diamond	-	-	170,000,000
Steel	-	-	30,000,000
Aluminum	-	-	10,000,000
Wood	-	-	1 - 2,000,000
Crushed Stone (GW, GP, GM)	20 to 100	30 to 50	20,000 - 40,000
Sandy Soils (SW, SP, SM, SC)	5 to 40	7 to 40	7,000 - 30,000
Silty Soils (ML, MH)	3 to 15	5 to 25	5,000 - 15,000
Clay Soils (CL, CH)	3 to 10	5 to 20	5,000 - 15,000
Organic Soils (OH, OL, PT)	1 to 5	Less than 7	Less than 5,000

The Arizona Department of transportation (ADOT) pavement design manual has adopted the 1986 AASHTO design standards for guidance on pavement design. The ADOT Pavement Design Manual specifies in Section 1.7.1 Subgrade Tabulations,

> "Soils that are excessively expansive should receive special consideration. Generally, expansive soils have high plasticity indices, high percentage passing the #200 sieve, low R-values, and are A-6 and A-7 soils according to the AASHTO Soil Classification System. One solution may be to cover these soils with a sufficient depth of selected material to overcome the detrimental effects of expansion. Expansion may often be reduced by tight control of the compaction water content. In some cases, it may be more economical to treat expansive soils by stabilizing with suitable admixture, such as lime or cement, to over excavate and replace the material, or to encase a substantial thickness in a waterproof membrane to stabilize the water content. Also, widening and deepening the cut ditches and providing the shoulder slopes with a membrane may help to stabilize the roadway section." [3]

The team determined that excavation is going to be needed at the site to replace the unsatisfactory soil with a subbase that meets the 1986 AASHTO Guide for the Design of Pavement Structures Standards. After careful consideration of all pertinent geotechnical information assumed for sandy clay loam; the team expects the soil left at the site after excavation will make a fair to good aggregate base subgrade for the proposed parking lot after being reconditioned and compacted to an optimum compaction rate of 95%. The soil left after excavation meets all regulations specified in the 1986 AASHTO Design Standards for Guidance on Pavement Design.

5.0 Survey Data Analysis

In preparation for the survey data analysis, a 7.5-minute topographic map was collected for a reference. This topographic map allows for the survey data analysis to be cross referenced with the known topography. This topographic map can be seen in *Appendix A*. The team was able to proceed in the surveying investigation of the project site because survey information in the form of a topographic DWG file consisting of southwest area of Saguaro National Park was provided to the team by the GIS Coordinator of Pima County. This topographic map was altered due to the file size and to adequately locate the project site. This file consisted of lines outlining 2-foot contour intervals that were used to find the Cam-Boh Picnic Area. This DWG file was a key item in understanding hydraulic topography and delineation of the parking lot. An image of the given topography map can be found below in *Appendix P*.

6.0 Hydrology and Hydraulics Analysis

6.1 Watershed and Stormwater Runoff Analysis

The preliminary work for the hydrology and hydraulics analysis applied here heavily relies upon the survey data analysis and this was completed included collecting a topographic map to conduct a watershed delineation. The hand estimated watershed delineation was then be compared using a software program called StreamStats. Preliminary work was completed to estimate the peak-flow statistics along with the contributing watershed area for the site. The StreamStats report can be found in *Appendix C and Appendix D*. StreamStats application was a useful tool for the project team to delineate the drainage basin for the selected Cam-boh Picnic Area site. This program determines drainage basin boundaries by use of digital elevation data obtained from the USGS 3D Elevation Program. Once the existing entrance to the parking lot was selected, the program determined that the contributing watershed area was 0.9 square miles. [4] This area was verified by delineating the watershed by hand on the 7.5-minute topographic map of Avra Quadrangle. But because of the uncertainty of hydraulic infrastructure located on the site, the project team utilized the project area of 4.5 acres as the contributing sub-basin watershed area in the further hydrology and hydraulics analysis. This watershed, outlined in black, along with the sub-basin point of concentration, depicted with a blue circle, can be seen below in *Figure 6-1: Sub-Basin Contributing Watershed*.

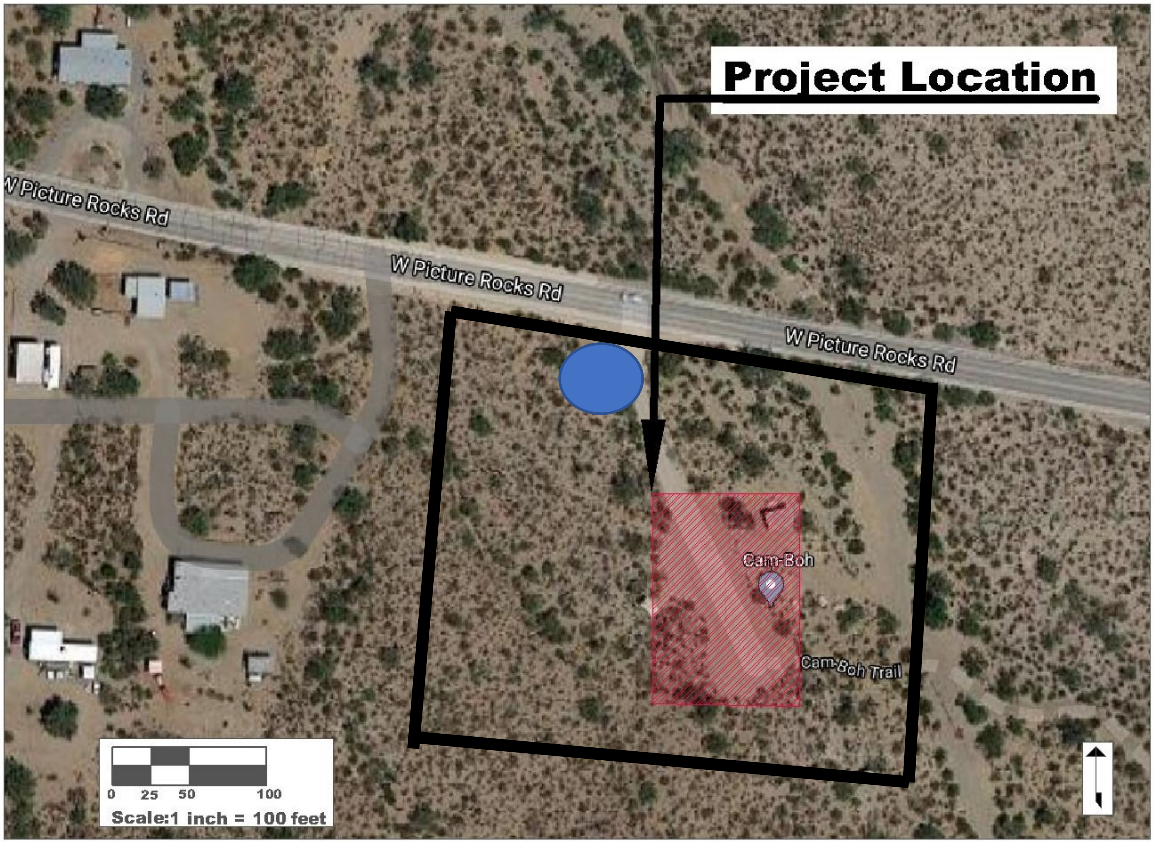


Figure 6- 1: Sub-Basin Contributing Watershed

When undeveloped land becomes developed, there is a decrease in runoff travel time and the infiltration rate is slower than if it occurred on a natural, non-developed surface. This has the ability to create negative effects to the surrounding area which can include: an increase in erosion, flooding, surface velocities, and the ability for pollution to be transferred. The intended implementation of infrastructure cannot create more health or environmental issues than the current site. By analyzing the current site compared to the proposed site, the project team explored if the addition of increased impervious surface is possible and if further infrastructure needs to be in place. To complete this analysis, the project team gathered state and local guidelines for the hydrology analysis and impervious surfaces design. The Design Standards for Stormwater Detention and Retention for Pima County was utilized as a manual to provide design standards and policy direction for detention and retention systems are explored in Pima County. [5]

The Pima County Stormwater Standards states that in order to calculate the time required for a storm runoff to flow from the most hydraulically remote point in an area to the point of concentration, the user is required to utilize the county's PC-HYDRO computer software. This program calculates flood peak events of varying frequencies that are used in the analysis and design of drainage systems of less than 10 square miles in unincorporated Pima County. The project site meets that criteria. The program utilizes a semi-empirical method in which a peak discharge for a chosen storm frequency is calculated as a product of inputting a run-off coefficient, rainfall intensity, and drainage area. This method is similar to the Rational Method but avoids one of the drawbacks of the Rational Equation by incorporating a runoff to rainfall ratio that increases with increased rainfall. In addition, this procedure calculates rainfall intensity by computing the watershed time of concentration by using an empirical formula that relates time of concentration to the physical characteristics of the watershed and the rainfall intensity. [6]

The Pima County Hydrology PC-HYDRO calculations are subject to the following assumptions which were appropriate for this project. Rainfall is uniformly distributed over the entire watershed, rainfall occurs at a uniform intensity for a storm duration at least equal to the time of concentration, peak rate of runoff is proportional to rainfall intensity of rainfall depth averaged over a time period equal to the time of concentration, the return period of the runoff event is the same as the return period of the precipitation event, and channel storage processes or diffusion are negligible. [6]

6.2 Existing and Proposed Infrastructure Analysis

Because the project team was unable to complete a site visit, the existing infrastructure was limited to a satellite image and AutoCAD file. The AutoCAD file provided to team from Pima County only consisted of a 2-foot interval contour map. As seen in *Appendix A*, the existing infrastructure at the site consisted of primarily a wash located to the east of the existing parking lot which travels from Wasson Peak, 17213 feet south of the site, to W. Picture Rocks Road. Because of no site visit, the team was constrained to the satellite image as well as client provided information. The existing condition of the site was evaluated for the stormwater runoff at the site for various storm events. The proposed infrastructure analysis conducted comprised of analyzing the change between the stormwater runoff from the pre-existing condition to the proposed conditions for each of the design alternatives.

To complete the analysis in PC-HYDRO, the project site was determined to be in a non-critical balanced basin presented in *Appendix E – Critical Basins within Unincorporated Pima County*. Because of this conclusion, the PC-HYDRO Guide states that “new development located within a Balanced Basin must provide sufficient detention to reduce the post developed 2-, 10-, and 100-year peak discharge rates to the predeveloped rates.” [6] The project team followed Pima County standards that ensures the development does not increase the flow from either a 2-, 10-, or 100-year storm. Because NPS aims to decrease the alteration to the natural world, the client requested that the project team utilize the existing wash and to calculate the comparison of pre-development to post-development with the worst storm event of a 100-year storm event.

The project team began with utilizing Pima County’s PC-HYDRO program to calculate the time of concentration and flow that occurs in the existing conditions at the project site. The watershed information of watershed, watershed type, length of longest watercourse, length to center of gravity, and corresponding basin factors with length increments were inputted. The watershed area on site of 4.5 acres was identified and previously stated. The length of the longest watercourse of 1439 feet was achieved by tracing the flow of the east wash from the concentration point to the upstream-most reach in the project site boundary of 4.5 acres. The watershed shape is nearly symmetrical, so the length of the longest watercourse to the center of gravity of 719.5 feet was approximated by divided the length of the longest watercourse by 2. The length of the longest water course was divided into four segments and the length, channel slope of 0.024 ft/ft, and basin factor (found in *Appendix K*) was inputted. The watershed was chosen to be undeveloped – foothills. Next the project team inputted the vegetation and soil information of vegetative cover density, vegetative cover type, and impervious cover. The vegetative cover density of 90%, the vegetative cover type of desert brush, and impervious cover of 5% were estimated from the provided aerial site photo. Next the project team chose the project site to be the site of interest for the rainfall data input. PC-HYDRO uses by default the 90% Upper Confidence Limits of the intensity duration frequency curves published in NOAA Atlas 14. Next the soil type of type C and curve number was chosen and inputted. The project team estimated from the assumed geotechnical testing that the site soil is classified as Type C as described in *Appendix G*. The curve number of 90 was determined from the chart provided in the PC-HYDRO Manual provided in *Appendix H*.

From these inputs the team was able to produce the runoff data for the existing site conditions produced below in *Table 6-1 Pre-Development Conditions.*

Table 6- 1: Pre-Development Conditions

Pre-Development Conditions			
Storm Interval	2-Year Storm	10-Year Storm	100-Year Storm
Weighted Runoff Coefficient (Cw)	0.37	0.51	0.64
Tc (min)	14.8	10.1	7.4
Rainfall Intensity (i) at Tc (in/hr)	2.57	4.83	8.44
Runoff Supply Rate (q) @ Tc (in/hr)	0.95	2.49	5.41
Peak Discharge (CFS)	4.7	12.3	26.7

The process detailed above for PC-HYDRO existing conditions was repeated for the post-development condition of a gravel lot design. The inputs for the watershed information, soil type, and rainfall data were the same for the gravel post-development conditions, but the vegetation/soil information was altered to reflect the increased impervious conditions. The vegetative cover density was reduced to 85% and the impervious cover was increased to 10%. The vegetative cover type was not altered. From these inputs the team was able to produce the runoff data for the post-development site conditions of a gravel lot produced below in *Table 6-2 Post-Development Conditions (Gravel Lot).*

Table 6- 2: Post-Development Conditions (Gravel Lot)

Post-Development Conditions (Gravel Lot)			
Storm Interval	2-Year Storm	10-Year Storm	100-Year Storm
Weighted Runoff Coefficient (Cw)	0.37	0.51	0.63
Tc (min)	14.9	10.2	7.5
Rainfall Intensity (i) at Tc (in/hr)	2.57	4.81	8.41
Runoff Supply Rate (q) @ Tc (in/hr)	0.94	2.43	5.3
Peak Discharge (CFS)	4.6	12	26.2

The process detailed above for PC-HYDRO existing conditions was repeated for the post-development condition of an asphalt lot design. The inputs for the watershed information, soil type, and rainfall data were the same for the asphalt post-development conditions, but the vegetation/soil information was altered to reflect the increased impervious conditions. The vegetative cover density was reduced to 85% and the impervious cover was increased to 20%. The vegetative cover type was not altered. From these inputs the team was able to produce the runoff data for the post-development site conditions of a gravel lot produced below in *Table 6-3 Post-Development Conditions (Asphalt Lot).*

Table 6- 3: Post-Development Conditions (Asphalt Lot)

Post-Development Conditions (Asphalt Lot)			
Storm Interval	2-Year Storm	10-Year Storm	100-Year Storm
Weighted Runoff Coefficient (Cw)	0.42	0.55	0.67
Tc (min)	13.9	9.8	7.3
Rainfall Intensity (i) at Tc (in/hr)	2.65	4.89	8.5
Runoff Supply Rate (q) @ Tc (in/hr)	1.13	2.7	5.66
Peak Discharge (CFS)	5.6	13.4	28

To examine the existing volume of the basin, the project team began with conducting a cross-section analysis on the provided topographic map of one cross-section because the client informed the team that the channel is uniform throughout the site. A thalweg, a line that connects the lowest points along the length of the channel, was drawn along the channel's length. Next, important data points of left overbank (LOB), right overbank (ROB), and thalweg were noted. In order to gather the cross-section data, the project team used the stationing interval method that consisted of establishing a 5-foot interval for each station and then noting the elevation of each of the 5-foot stations. Below in *Figure 6-2* is a cross-section view of the channel of interest in the hydrology analysis and the inputted cross-section data can be found in *Appendix I.*

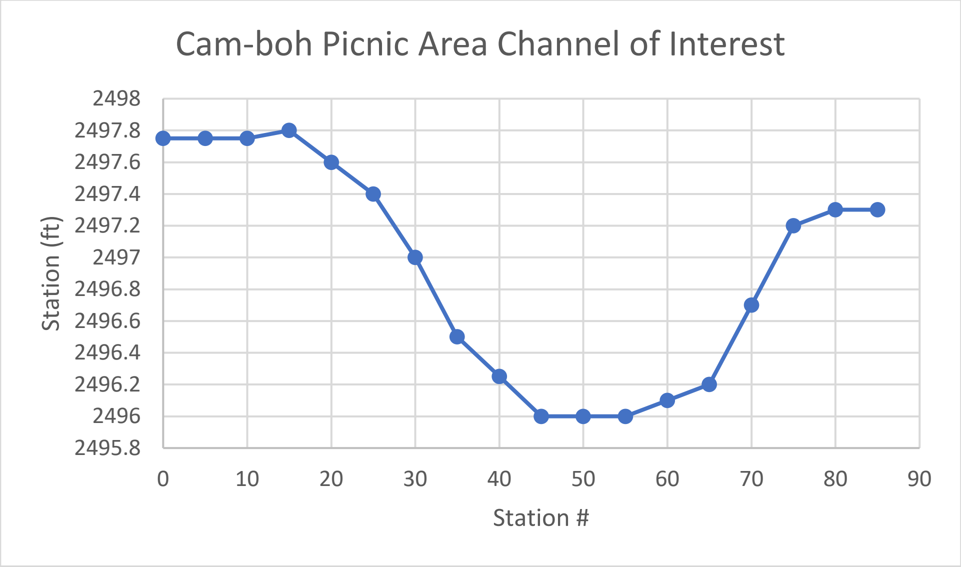


Figure 6- 2: Cam-boh Picnic Area Channel of Interest Cross-Section

Once the cross-section data was established and recorded, the project team utilized NRCS Cross Section Analyzer to determine the if the flow produced from the change in impervious surfaces will be able to be transported in the existing channel. This utilized spreadsheet allows the user to describe a cross-section of a channel by entering ground elevations and stations. The cross-section data was inputted along with the corresponding n-value for the LOB, thalweg, and ROB. Because the project team was not able to take a visual site survey of the existing channel, the project team was able to estimate from the topographic DWG file and Google Maps that the profile slope and n values of the LOB, thalweg, and ROB was 0.04, 0.08, 0.04 from the Table of Manning's n for Channel produced in *Appendix J*. This spreadsheet employs macros of programmed commands that are activated when the user selects one of the two buttons in the spreadsheet. After the channel information was inputted into the sheet, a ratings table was produced with hydraulic parameters. The project team selected analyze single condition and inputted the flow calculated from the PC-HYDRO for the existing site conditions of a 2, 10, and 100-year storm event. Below in *Figure 6-3* is the pre-development existing cross-section of the channel for the 100-year storm.

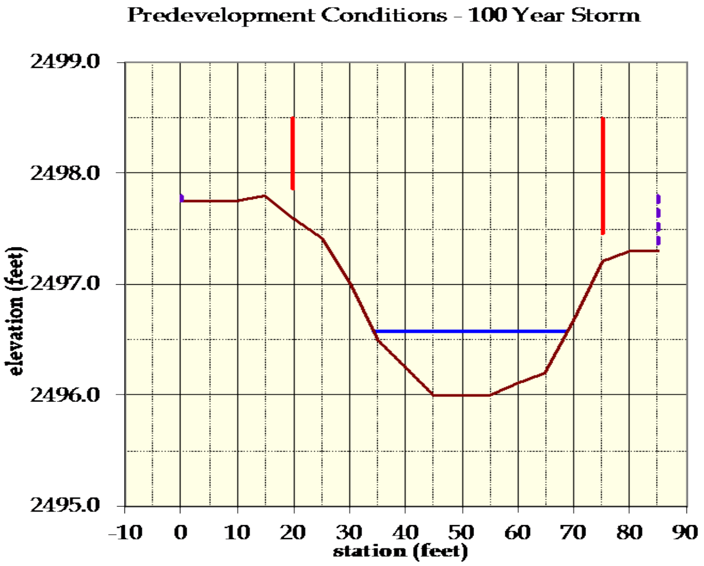


Figure 6- 3: Pre-Existing Cross-Section Conditions of Channel

This process was repeated for the two post-development conditions of gravel and asphalt parking lot design. Below in *Figure 6-4* is a comparison of the two post-development conditions and it is apparent that the change of impervious surface, either gravel or asphalt will increase the volume of water in the wash, but the total volume of water can be carried in the existing wash and not rerouted. As presented in *Table 6-1*, *6-2*, *6-3*, for the 100-year storm there is only a different in flow of 2 CFS throughout. In order to keep the flow consistent with pre-development conditions, there will be erosion control devices implemented in the project site and further explored in the final design.

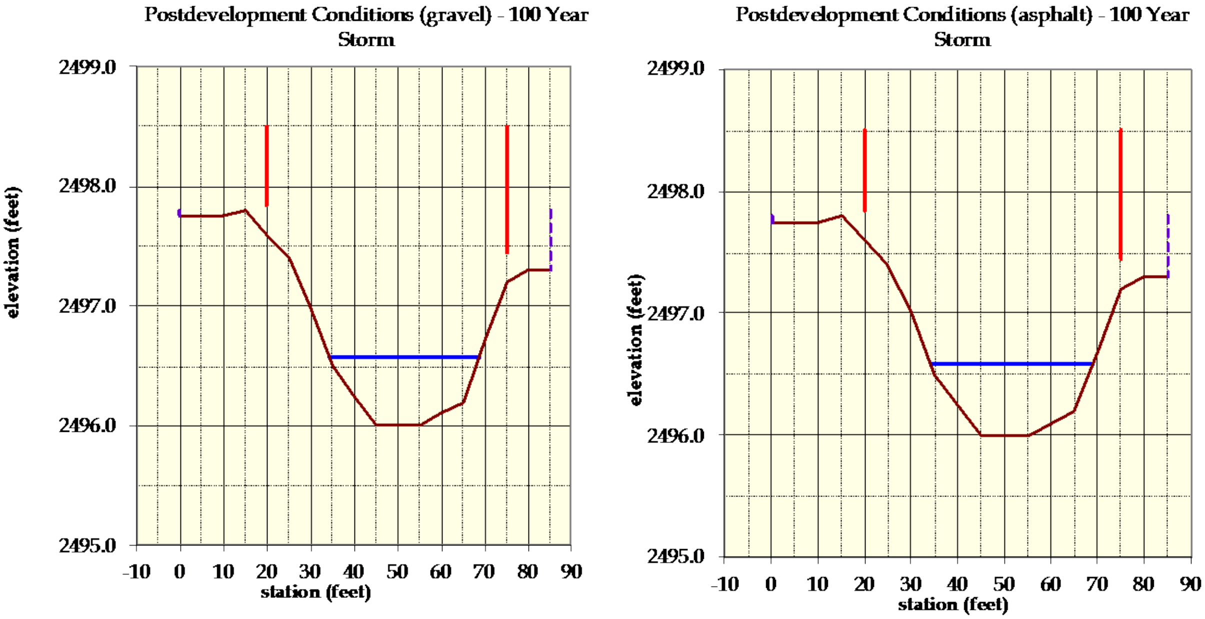


Figure 6- 4: Comparison of Asphalt and Gravel Lot Cross-Section Conditions

As explained above, there was a slight increase in flow from the pre-existing conditions to the gravel and asphalt design and Pima County requires that this change in flow has to be analyzed, slowed down, and considered in the design. The project team designed an erosion plan that consists of riprap running along the east wash until the entrance of the parking lot. Reduction of runoff to pre-development levels was accomplished with adjusted slopes of the pavement design and implementation of riprap to slow the flow. The implementation of riprap can be found below in *Figure 6-5*.

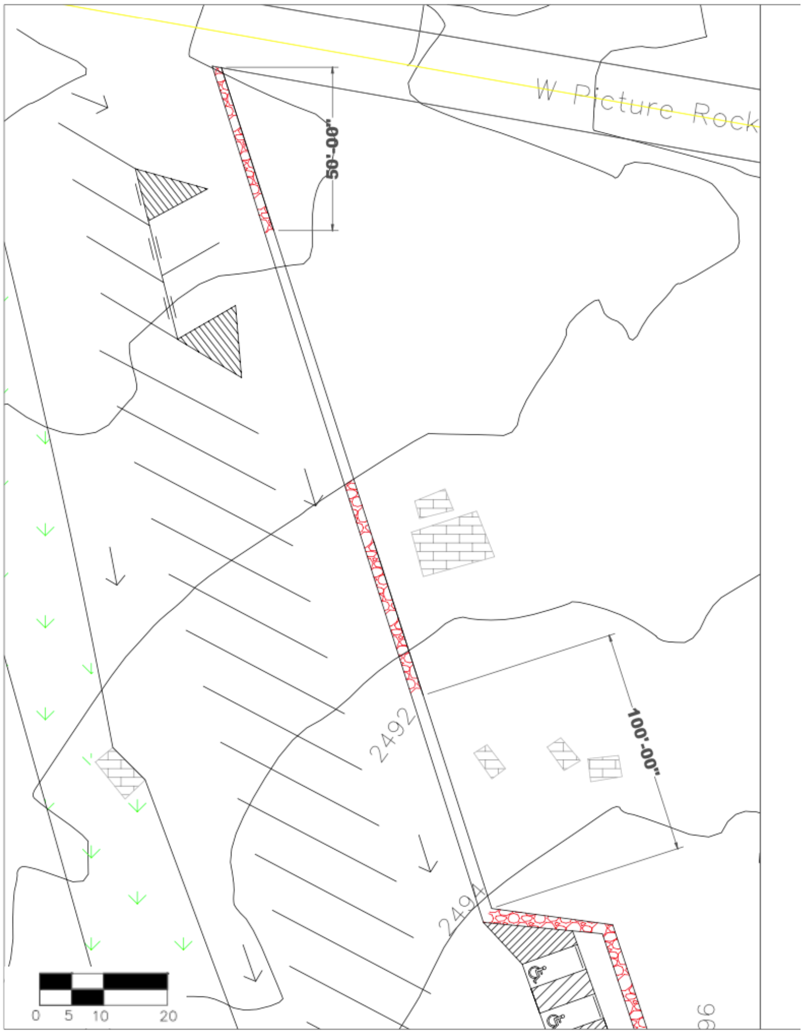


Figure 6- 5: Implementation of Riprap Control

7.0 Traffic and Visitation Analysis

In 2019, Saguaro National Park had the largest number of visitors for the first time in the park's history. The 91,716 acres preserve saw 1,026,226 visitors in 2019, up from 950,000 in the previous year. [7] During the peak season in the winter months, the client estimated that Cam-boh Trail accounts for approximately 20-25 vehicles per day. The project team estimated to design the parking lot to account for 15-20 vehicles at one given time to adjust for an increase in visitors and this visitation count was an aid in designing the overall size of the redesigned parking lot.

8.0 Alternatives Pursued

The client requested the team to create delineated designs with corresponding construction plan sets for the redesigned parking lot with one asphalt design, and another separate gravel design. In order to do so, the project team designed the two alternatives per Pima County, NPS, and ADA Standards. According to the Organic Act of 1916, "All NPS parks shall be designed to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations. Designs shall be harmonious with park resources, esthetically pleasing, functional, cost-effective, and welcoming as possible to all segments of the populations." [8] Though one of the main objectives was to increase the available parking spaces, an important constraint that limited a large increase in size was the existing structures and the impact to the environment. Both delineated lots were delineated the same and the differences of surface material will be described below.

8.1 Lot Size Determination

8.1.1 Overall Lot Dimension and Flow

The client requested that the entrance to the parking lot remain in the same location, so the project team began the design at the current entrance along Picture Rock Road. As mentioned above, the project team was not requested to redesign the existing picnic tables, vault toilets, ramada or the stone monument currently on site, or the entrance to the trail, so the design was constrained to being designed around those items. The constrained area available can be seen below in *Figure 8-1.* The project team determined 24 parking stalls would achieve the objective of increased number of parking stalls while minimizing the environmental impact. To accommodate the 24 total parking spots of 5 passenger vehicles, 15 pull through equestrian truck and trailer, and 3 ADA parking stalls, the overall dimensions of the lot was designed to be 443'-03" in length and 169'-09" in width. For a small parking area of less than 30 parking spots, it was designed to have a circular pattern that includes a loop that prevents vehicles from becoming trapped when all spaces are full.

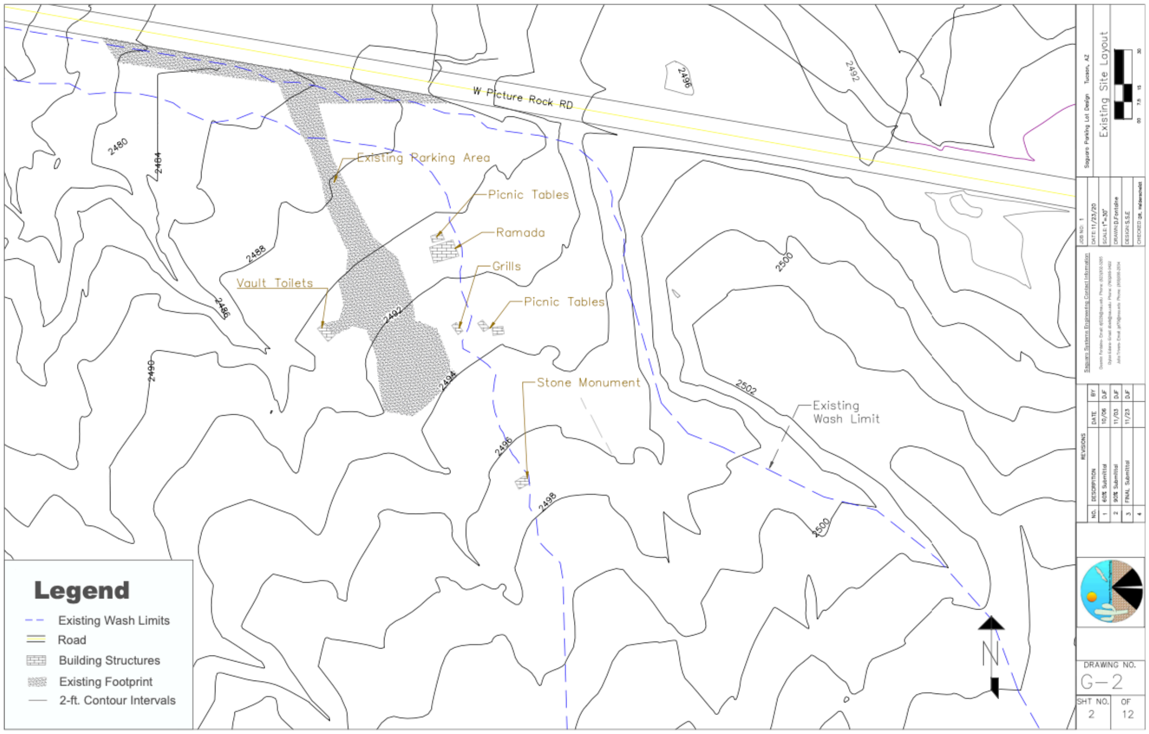


Figure 8- 1: Existing Site Constraints

Below in *Figure 8-2,* the proposed site delineation plan can be found.

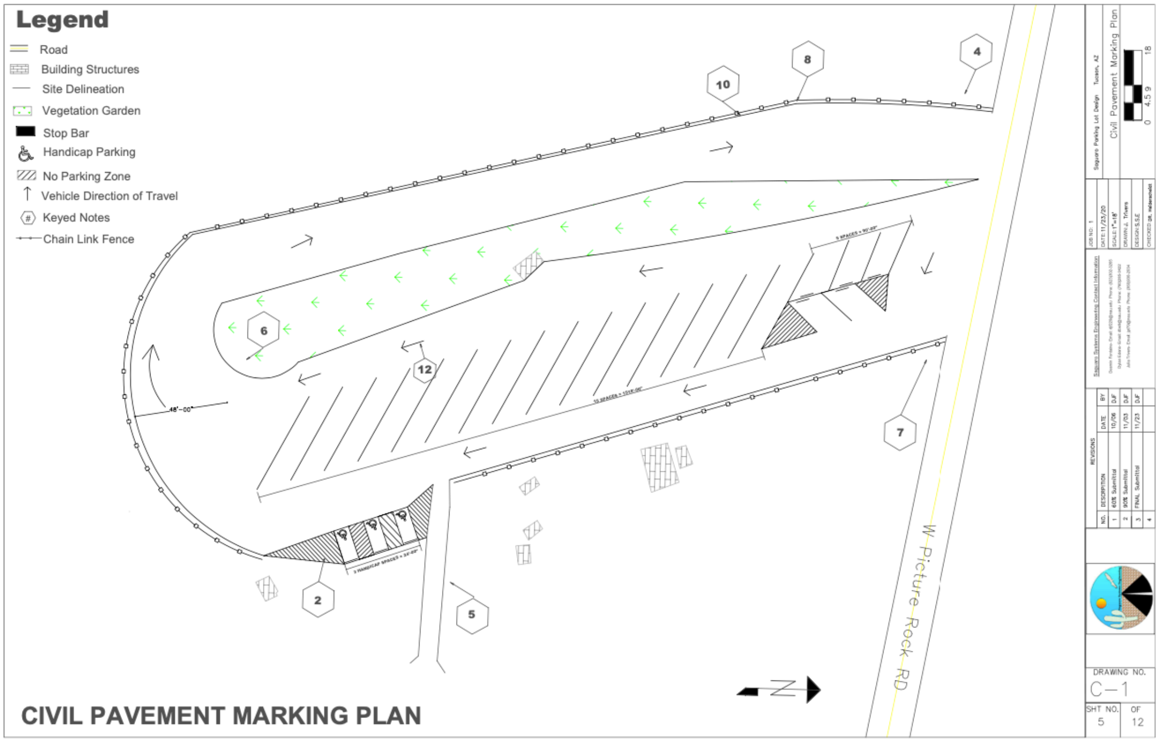


Figure 8- 2: Proposed Site Delineation

8.1.2 Parking Stalls

In order to effectively design the parking stalls in the recreation parking lot, the project team referred to the United States Forest Service's Equestrian Design Guidebook. It states that "proper road and parking area design is critical in recreation sites, especially for vehicles towing trailers. Traffic circulation should be simple, functional, and avoid dead ends." [9] Road design was based on vehicle dimensions and operating characteristics of a typical pickup truck. In a recreation equestrian site, this vehicle is a pickup truck that is pulling a horse trailer. A standard pickup truck measures approximately 15 feet long and common horse trailers are approximately 16 feet in length. The bumper to horse trailer length of 31 feet was added to a 15-foot minimum unloading space totaling to an overall parking spot length of 55 feet. A standard pickup truck is 8 feet in width. This was added to an extra 4 feet on each side for vehicle doors to open for a total of 18 for the width of the parking stall. This site is utilized greatly for equestrian riders, so there is a large demand for staging areas in the back that allow riders and horses to easily unload, groom, and saddle the horse. The total width of 18 feet length of 55 feet allows ample space for riders and horses to prepare for the trail. [9]

The delineated pavement markings shall be installed in accordance with the latest edition of Arizona Manual on Uniform Traffic Control Devices and the Federal Highway Association's Standard Highway Signs Book's Section 10 for Letter and Arrow Detail. All parking spaces are requested to be painted with 2" flat traffic white inverted striping spray paint.

Most drivers prefer to park in pull through parking stalls of 45- or 60-degree angles because they are easier to navigate and reduce confusion on the flow of traffic, so all passenger and horse equestrian trailer stalls were designed as a 45 degree pull through stall. [9] Because the trail is mainly utilized for horses instead of hiking by foot, only 6 parking stalls were designated for passenger vehicles. The passenger vehicle stalls are the same width as the equestrian parking stalls of 18 feet to be flush with the row of parking stalls and 25'-06" in length. These stalls were located farthest away from the entrance head, so the riders and horse have ample access to the trail. All passenger vehicle parking spaces were designed to be all front in spaces to effectively back up and circulate through the parking lot flow of traffic.

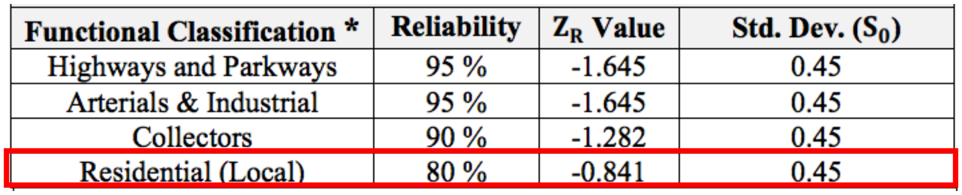
All parking areas in national parks are required to have accessible parking spaces. In order to properly design ADA parking stalls, the project team referred to Chapter 5 of the United States Access Board's ADA Standards. The minimum number of accessible parking spaces for a parking facility totaling of 1-25 spaces is 1 standard parking space. Accessible parking spaces must be located on the shortest accessible route to an entrance, so the design placed the spaces right next to the trial's entrance. Chapter 5 states the requirements for accessible parking spaces addressing the size and markings or regular and van spaces and access aisles. For a standard vehicle space, the required dimensions are 8' in width so the ADA parking stalls were designed to be 8' in width and 18' in length to be uniform with the other parking stalls. The ADA parking spaces are identified with the International Symbol of Accessibility on a handicap parking sign stanchion system in addition to a white International Symbol of Accessibility pavement marking on all four spaces. To allow for ample space to exit and enter the vehicle or a van, the two farthest left spaces includes an 8-foot access isle that will be hatched with 2" white lines at 3' intervals angled at 45 degrees. [10]

8.2 Gravel Parking Lot Pavement Design and Details

For the ADA and passenger parking spaces, this design utilizes 10 8’ landscape timber parking block with two #4 18” rebar. These blocks are 2.5” in height and are small barriers used at the non-pull through parking stalls in the lot to assist drivers with parking the vehicles and not driving out of their spaces onto the vegetation.

The encompassing area of the proposed gravel lot is equal to 75,241.69 ft^2; where the existing protected vegetation at the site will get relocated throughout the eastern region of the park. The top soil at the site will be grubbed for any existing vegetation, debris, or large boulders that may exist in the project area. The gravel parking lot was designed to have two primary layers of subbase; a gravel surface and an aggregate subbase. Our team choose to follow the AASHTO Roadway Design Manual in conjunction with Pima County as the method to determine the layer thicknesses and structural number.

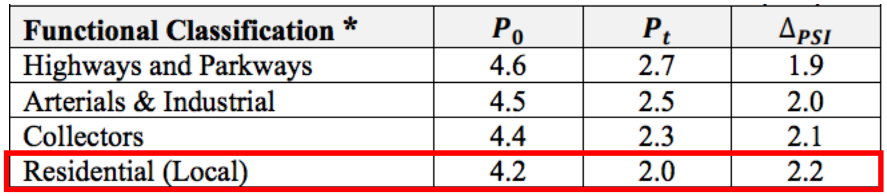
The first step was to calculate an Equivalent Single Axle Loading or ESAL (W_{18}) or overall loading value in millions of kips in which the gravel lot should expect to endure over a 20-year period for most cases. Considering the little traffic data that was given to our team; the client estimated that 20-25 vehicles per day visit the Cam-Boh Picnic Area. Therefore, the team assumed that roughly 65% of those daily visitors drove four tire, single unit (Class 3) while the remaining 35% of visitors were assumed to be consisted of passenger cars (Class 2) visitors. The initial daily traffic of 18-kip ESALs was estimated using *Traffic Equivalency Factors (TEF)* as well as method one of the MCDOT Roadway Design Manual shown in *Appendix T- Method 1: Using Traffic Factors for all Classification*. The (W18) for this site was estimated to be 0.11975 ESALs which is needed for the calculation of the structural number. Reliability (R-%) is the probability that the design will hold up for the specified lifespan and the recommended level of reliability for local and rural streets is 80% which equates to a normal deviation (Z_R) of -0.841 and a standard deviation (S_O) of 0.45 shown in *Table 8-1: Level of Reliability* from the MCDOT Roadway Design Manual below.



Functional Classification *	Reliability	Z_R Value	Std. Dev. (S_0)
Highways and Parkways	95 %	-1.645	0.45
Arterials & Industrial	95 %	-1.645	0.45
Collectors	90 %	-1.282	0.45
Residential (Local)	80 %	-0.841	0.45

Table 8- 1: Level of Reliability

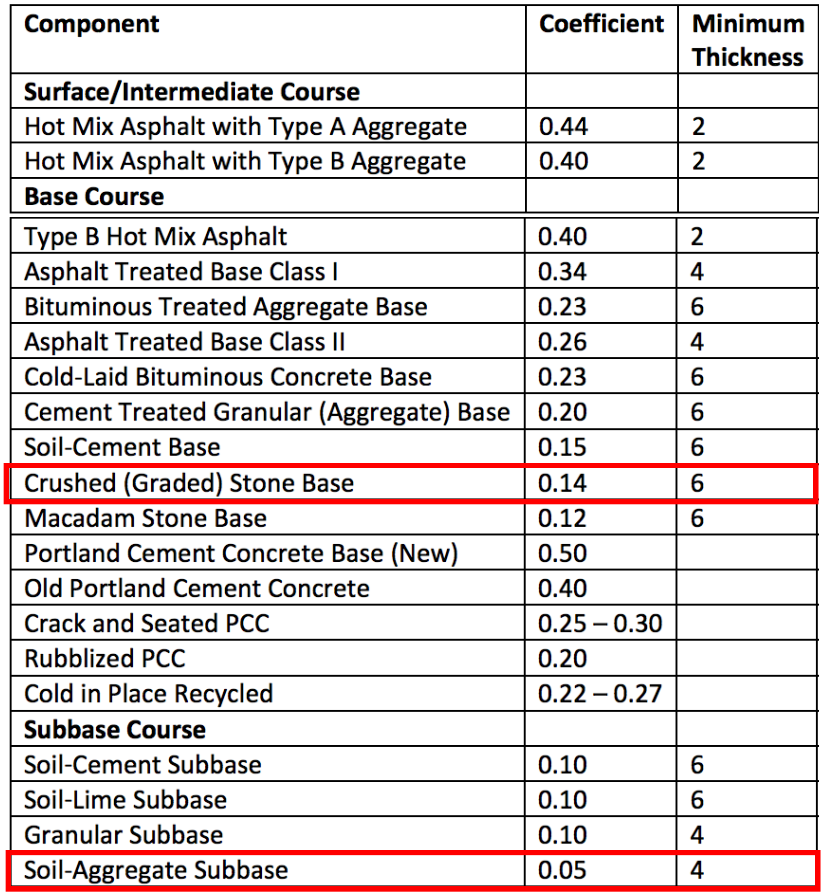
The Present Serviceability Index (PSI) and terminal serviceability (P_t) are used to calculate the change in serviceability (ΔPSI) which was found to be 2.2 for a residential or local roadway shown in the MCDOT Roadway Design Manual in *Table 8-2: Present Serviceability Index (PSI)* below.



Functional Classification *	P_0	P_t	Δ_{PSI}
Highways and Parkways	4.6	2.7	1.9
Arterials & Industrial	4.5	2.5	2.0
Collectors	4.4	2.3	2.1
Residential (Local)	4.2	2.0	2.2

Table 8- 2: Present Serviceability Index (PSI)

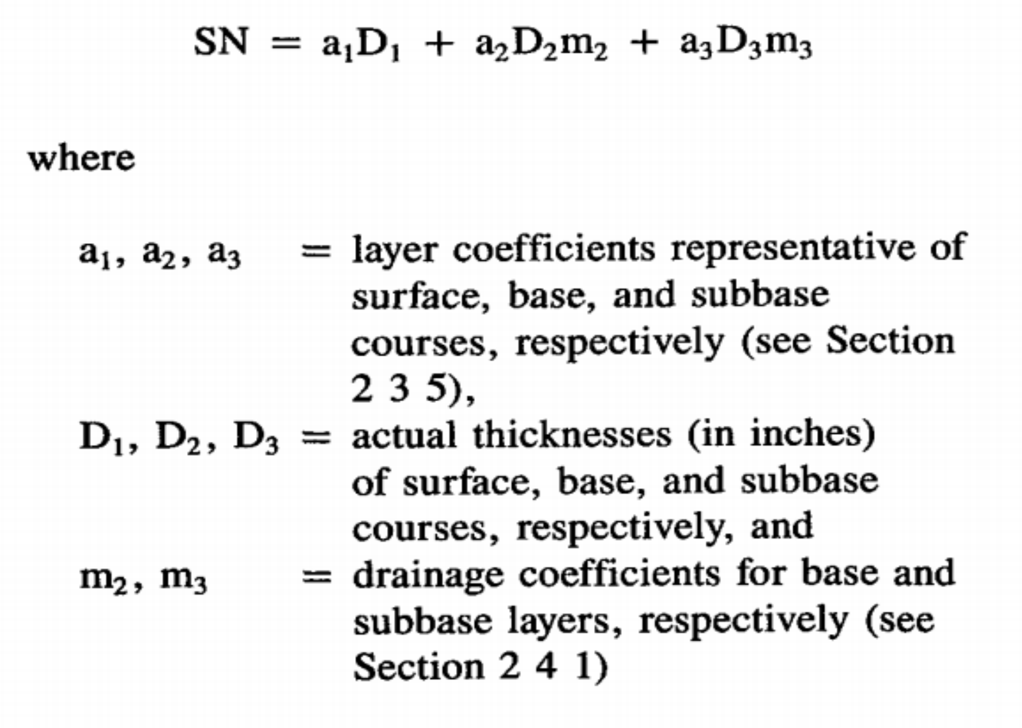
The resilient modulus (M_R) was estimated by using *Table 4-1: Typical CBR and Modulus of Elasticity Values for Various Materials* to be 10,000 psi. The next step was to determine the thicknesses of each layer in the design by using *Table 8-3: Coefficients and minimum thicknesses of Course* from the AASHTO Pavement Thickness Design Guide.



Component	Coefficient	Minimum Thickness
Surface/Intermediate Course		
Hot Mix Asphalt with Type A Aggregate	0.44	2
Hot Mix Asphalt with Type B Aggregate	0.40	2
Base Course		
Type B Hot Mix Asphalt	0.40	2
Asphalt Treated Base Class I	0.34	4
Bituminous Treated Aggregate Base	0.23	6
Asphalt Treated Base Class II	0.26	4
Cold-Laid Bituminous Concrete Base	0.23	6
Cement Treated Granular (Aggregate) Base	0.20	6
Soil-Cement Base	0.15	6
Crushed (Graded) Stone Base	0.14	6
Macadam Stone Base	0.12	6
Portland Cement Concrete Base (New)	0.50	
Old Portland Cement Concrete	0.40	
Crack and Seated PCC	0.25 – 0.30	
Rubblized PCC	0.20	
Cold in Place Recycled	0.22 – 0.27	
Subbase Course		
Soil-Cement Subbase	0.10	6
Soil-Lime Subbase	0.10	6
Granular Subbase	0.10	4
Soil-Aggregate Subbase	0.05	4

Table 8- 3: Coefficients and minimum thicknesses of Course

From using the information provided in *Table 8-3*, the gravel lot will have an initial layer thickness of 6 inches of crushed (graded) stone base with a layer coefficient of 0.14. The secondary subbase layer will be composed of a soil-aggregate subbase that will have a layer thickness of 4 inches with a layer coefficient of 0.05. According to the Pavement Design Manual in Tucson, Arizona the drainage coefficients for the subbase layers will be 1.25. The structural number for the gravel lot was estimated using *Equation 8-1: Calculation of Structural number with actual thicknesses* shown below from the MCDOT Roadway Pavement Design Manual to be 1.39 which rounds to 1. The grading plan consists of excavating and removing approximately 2322.27 yds^3 of soil and reconditioning the remaining sandy clay loam at the site to 95% relative compaction to meet the 1993 AASHTO Pavement Design Manual. The site will get filled with approximately 928.91 yds^3 of aggregate subbase which will be prepared on top of the subgrade in a uniform manner ensuring 95% relative compaction is met. The wearing surface will be consisted of crushed (graded) stone base and will approximately take 1393.36 yds^3 to meet the design specifications ensuring that the wearing surface is compacted to a 95% relative compaction rate. The sloping of the wearing surface is designed for a 4% slope with a crown in the center of the parking lot to ensure that water will not puddle on the surface of the gravel lot.



$$SN = a_1D_1 + a_2D_2m_2 + a_3D_3m_3$$

where

a_1, a_2, a_3 = layer coefficients representative of surface, base, and subbase courses, respectively (see Section 2 3 5),
D_1, D_2, D_3 = actual thicknesses (in inches) of surface, base, and subbase courses, respectively, and
m_2, m_3 = drainage coefficients for base and subbase layers, respectively (see Section 2 4 1)

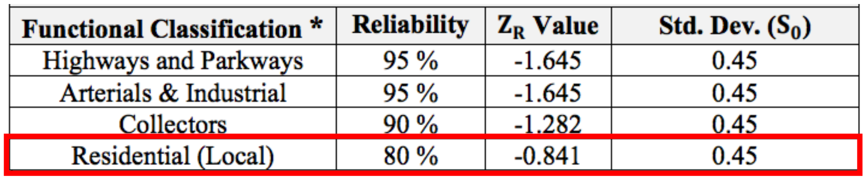
Equation 8- 1: Calculation of Structural number with actual thicknesses [4]

8.3 Asphalt Parking Lot Pavement Design and Details

For the ADA and passenger parking spaces, this design utilizes 10 6’ concrete parking block with two #4 18” rebar. These blocks are 6” in height and are small barriers used at the non-pull through parking stalls in the lot to assist drivers with parking the vehicles and not driving out of their spaces onto the vegetation.

The encompassing area of the proposed asphalt parking lot is equal to 75,241.69 ft^2; where the existing protected vegetation at the site will get relocated throughout the eastern region of the park. The top soil at the site will be grubbed for any existing vegetation, debris, or large boulders that may exist in the project area. The asphalt parking lot was designed to have three primary layers comprised of; a wearing surface, soil cement base, and an aggregate subbase. Our team choose to follow the AASHTO Roadway Design Manual in conjunction with Pima County as the method to determine the layer thicknesses and structural number.

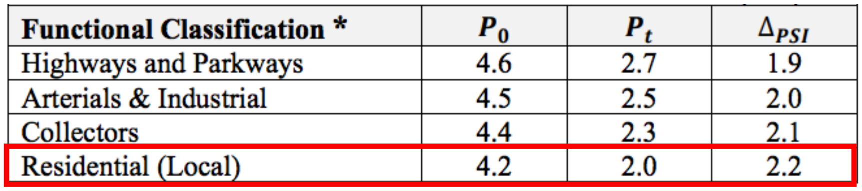
The first step was to determine that flexible pavement will be used as the pavement type in the asphalt parking lot design. The next step was to calculate an ESAL (W_{18}) or overall loading value in millions of kips in which the gravel lot should expect to endure over a 20-year period for most cases. Considering the little traffic data that was given to our team; the client estimated that 20-25 vehicles per day visit the Cam-Boh Picnic Area. Therefore, the team assumed that roughly 65% of those daily visitors drove passenger cars (Class 2) while the remaining 35% of visitors were assumed to be consisted of four tire, single unit (Class 3) visitors. The initial daily traffic of 18-kip ESALs was estimated using *Traffic Equivalency Factors (TEF)* as well as method one of the MCDOT Roadway Design Manual shown in *Appendix T- Method 1: Using Traffic Factors for all Classification*. The (W_{18}) for this site was estimated to be 0.11975 ESALs which is needed for the calculation of the structural number. Reliability (R-%) is the probability that the design will hold up for the specified lifespan and the recommended level of reliability for local and rural streets is 80% which equates to a normal deviation (ZR) of -0.841 and a standard deviation (SO) of 0.45 shown in *Table 8-4: Level of Reliability* from the MCDOT Roadway Design Manual below.



Functional Classification *	Reliability	Z_R Value	Std. Dev. (S_0)
Highways and Parkways	95 %	-1.645	0.45
Arterials & Industrial	95 %	-1.645	0.45
Collectors	90 %	-1.282	0.45
Residential (Local)	80 %	-0.841	0.45

Table 8- 4: Level of Reliability

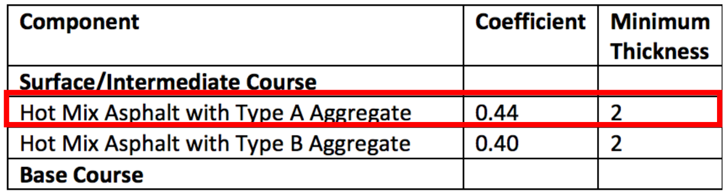
The Present Serviceability Index (PSI) and terminal serviceability (P_t) are used to calculate the change in serviceability (ΔPSI) which was found to be 2.2 for a residential or local roadway shown in the MCDOT Roadway Design Manual in *Table 8-5: Present Serviceability Index (PSI)* below.



Functional Classification *	P_0	P_t	Δ_{PSI}
Highways and Parkways	4.6	2.7	1.9
Arterials & Industrial	4.5	2.5	2.0
Collectors	4.4	2.3	2.1
Residential (Local)	4.2	2.0	2.2

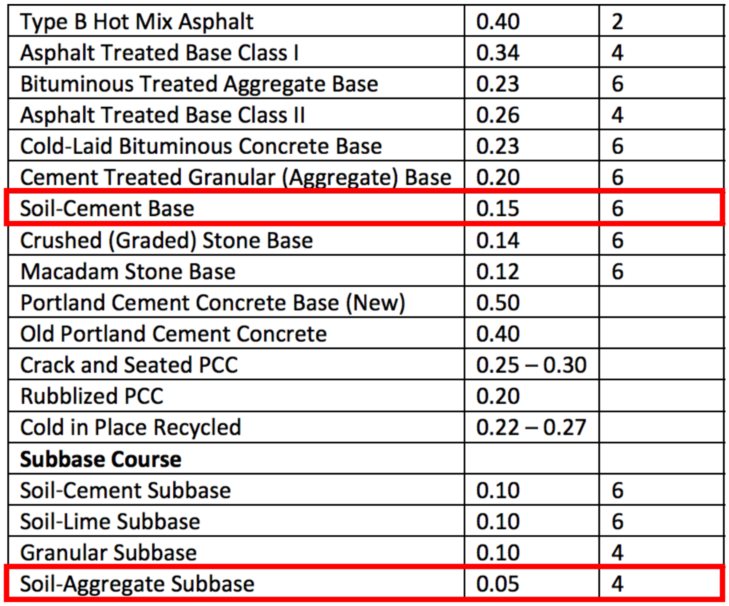
Table 8- 5: Present Serviceability Index (PSI)

The resilient modulus (M_R) was estimated by using *Table 4-1: Typical CBR and Modulus of Elasticity Values for Various Materials* to be 10,000 psi. The next step was to determine the thicknesses of each layer in the design by using *Table 8-6: Coefficients and minimum thicknesses of Course* from the AASHTO Pavement Thickness Design Guide.



Component	Coefficient	Minimum Thickness
Surface/Intermediate Course		
Hot Mix Asphalt with Type A Aggregate	0.44	2
Hot Mix Asphalt with Type B Aggregate	0.40	2
Base Course		

Table 8- 6: Coefficients and minimum thicknesses of Course



Type B Hot Mix Asphalt	0.40	2
Asphalt Treated Base Class I	0.34	4
Bituminous Treated Aggregate Base	0.23	6
Asphalt Treated Base Class II	0.26	4
Cold-Laid Bituminous Concrete Base	0.23	6
Cement Treated Granular (Aggregate) Base	0.20	6
Soil-Cement Base	0.15	6
Crushed (Graded) Stone Base	0.14	6
Macadam Stone Base	0.12	6
Portland Cement Concrete Base (New)	0.50	
Old Portland Cement Concrete	0.40	
Crack and Seated PCC	0.25 – 0.30	
Rubblized PCC	0.20	
Cold in Place Recycled	0.22 – 0.27	
Subbase Course		
Soil-Cement Subbase	0.10	6
Soil-Lime Subbase	0.10	6
Granular Subbase	0.10	4
Soil-Aggregate Subbase	0.05	4

Table 8- 7: Coefficients and minimum thicknesses of Course

From using the information provided in *Table 8-7,* the asphalt parking lot will have an initial layer thickness of 2 inches of hot mix asphalt with a layer coefficient of 0.44. The base course layer will be composed of a soil-cement base that will have a layer thickness of 6 inches with a layer coefficient of 0.15. The subbase course layer will have a layer thickness of 4 inches with a layer coefficient of 0.05. According to the Pavement Design Manual in Tucson, Arizona the drainage coefficients for the subbase layers will be 1.25. The structural number for the asphalt parking lot was estimated using *Equation 8-1: Calculation of Structural number with actual thicknesses* shown below from the MCDOT Roadway Pavement Design Manual to be 3.45 which rounds to 3. The grading plan consists of excavating and removing approximately 2786.73 yds^3 of soil and reconditioning the remaining sandy clay loam at the site to 95% relative compaction to meet the 1993 AASHTO Pavement Design Manual. The site will get filled with approximately 928.91 yds^3 of aggregate subbase which will be prepared on top of the subgrade in a uniform manner ensuring 95% relative compaction is met. The base course will be consisted of a soil-cement base and will approximately take 1393.36 yds^3 ensuring that the soil cement meets 95% relative compaction. A thin bituminous surface is placed on top of the soil-cement before the asphalt gets paved to increase the strength of the subbase. A two-inch layer of asphalt concrete will be poured on top of the uniformed soil-cement base which will approximately take 464.45 yds^3 of asphalt. The sloping of the wearing surface is designed for a 2% slope with a crown in the center of the parking lot to ensure that water will not puddle on the surface of the asphalt lot as well as decreasing the infiltration rate. Due to the added soil cement, the soil is stabilized enough that the expansion potential poses little to no risk or less than 2% for the proposed asphalt lot.

$$SN = a_1D_1 + a_2D_2m_2 + a_3D_3m_3$$

where

a_1, a_2, a_3 = layer coefficients representative of surface, base, and subbase courses, respectively (see Section 2 3 5),

D_1, D_2, D_3 = actual thicknesses (in inches) of surface, base, and subbase courses, respectively, and

m_2, m_3 = drainage coefficients for base and subbase layers, respectively (see Section 2 4 1)

Equation 8-1: Calculation of Structural number with actual thicknesses

8.4 Vegetation Relocation Plan

Because the project team was not able to visit the site, the client provided a vegetation location map for the four protected plant species of ironwood, palo verde, and tall and short saguaro cactus. These plants are requested per NPS to be preserved and relocated because their existing location are within the new parking lot boundary. The project team created a vegetation garden for the relocation of the plants and the remaining plants that did not fit within that garden were placed outside the delineated lot. It was noted that it is the contractor's responsibility to verify the existing locations of the protected species, confirm the relocated location, and to minimize the disturbance of the areas by implementing best management practices as required by Arizona Department of Environmental Quality.

8.5 Erosion Control Plan

As described in the Existing and Proposed Infrastructure Analysis, there was a slight increase in flow from the pre-existing conditions to the gravel and asphalt design and Pima County requires that this change in flow has to be analyzed and considered in the design. To account for this, the project team created a permanent erosion control plan for the existing east wash to account for this difference. The main purpose of this plan is to include measures to prevent erosion, contain sediment and control drainage by slowing down the flow to pre-development conditions. This erosion plan consisted of quarry rocks placed at a depth of 1 foot consisting of 4"-8" rock, referred to as riprap, (40%-70% passing) and 1'-2" rock (10%-20% passing) into the wash in 50-foot sections with a 100-foot gap and then repeating. This design runs along the east wash until the entrance of the parking lot. During construction, implementation, SWPP documentation, and maintenance is the responsibility of the contractor and upon completion, maintenance shall be the responsibility of NPS.

8.6 Signage Plan

Being a location that consist of a mix of visitors and locals, it was important to design and implement signs into the redesigned parking lot. The project team utilized the Pima County Signing Manual for a set of guidelines, practices, and standards or the design, installation, and maintenance of traffic signing in the boundaries of Pima County. The five implemented signs consist of one yield, one do not enter, four handicap parking, one Saguaro National Park Cam-boh Picnic Area, and three back-in parking signs. The standard yield sign was refenced in the Pima County Signing Manual and MUTCD Section 2B.08 and dimensioned as 36” x 36”. The standard do not enter sign was refenced in the Pima County Signing Manual and MUTCD Section 2B.37 and dimensioned as 30” x 30”. The standard handicap parking sign was refenced in the Pima County Signing Manual and 2010 ADA Standards for Accessible Design and dimensioned as 12” x 18”. The Saguaro National Park Cam-boh Picnic Area sign does not have a standard, but the project will utilize an existing sign and move it to the reallocated location. If the project site does not currently have one, NPS will be required to provide one. The back-in parking sign does not have a standard detail, so the contractor has choice in the appearance, but it is requested to 12” x 18” in size. [11]

Two days prior to installing the signs, the contractor is responsible for coordinating all work with Arizona 811 until the completion of the project. All signs are required to have type XI sheeting or an equivalent, all warming signs having yellow background shall have fluorescent yellow sheeting, and all ground mounted signs shall have an anti-graffiti coating applied to sign face, 3M #1160 film or equivalent. It is required that all signs shall have a 3” x 2” pressure sensitive, UV resistant label indicating the sign manufacturer’s name and date in the upper right corner of the back of the sign. [11]

9.0 Final Construction Plan Set

The two designed asphalt and gravel parking lots explained in the Alternatives Section are presented in the project's construction plan set titled Saguaro National Park Parking Lot Assessment and Design. This plan set consists of 12 sheets prepared by the project team. Drawing G-1 contains a cover page detailing a project introduction, the project location, a legend, and a sheet index. Drawing G-2 consists of a topographic map of the existing site conditions of a wash, existing lot, and existing structures. Drawing G-3 consists of the proposed delineated lot with overall dimensions. Drawing L-1 consists of the existing and proposed locations of the protected vegetation on the project site. Drawing C-1 consists of an overall view of the pavement marking plan and Drawing C-2 details the sheet and keyed notes along with details of the passenger, handicap, and pull through parking stalls, and a detail on the designed bumper block. Drawing C-3 consists of a cross section detailing the layers of the pavement design. Drawing C-4 consists of an overall view of the gravel marking plan and Drawing C-5 details the sheet and keyed notes along with the details of the passenger, handicap, and pull through parking stalls, and a detail on the designed landscape timber block. Drawing C-6 consists of a cross section detailing the layers of the gravel design. Drawing C-7 consists of noting the location of the erosion control device of riprap to slow down the increased flow from the redesigned asphalt or gravel parking surface. Drawing S-1 consists of noting the implemented signage for the redesigned parking lot and notes that details the size, material, number, county requirements, and an example of each sign.

10.0 Impact Analysis

In order for the project team to conclude with a final design, the team conducted a feasibility tool to assess the impacts of the project on society, economy, and environment. Below are the impacts explored for the assessment and design of the parking lot at Cam-boh Picnic Area.

10.1 Environmental Analysis

The concept of the National Parks is one of the most popular ideas in the United States. Its mission is to "conserve the scenery and the natural and historic objects and wildlife therein, and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." [12] In order to uphold this promise, the NPS preserve land and protect human heritage and natural habitats of plants and animals in Saguaro National Park. Tucson, Arizona is home to the largest cacti in the United States and this plant is a symbol of the American West. Without the preservation, relocation, and maintenance of protected species in the Cam-boh Picnic Area, these species would negatively be impacted over time. If the current state of the non-delineated lot would continue, the plants in the area, such as the Saguaro Cactus could be driven on, destructing the environment. The project team identified the protected species on site and relocated all within the boundary to a vegetation island to safety protect and relocate the vegetation. Some negative explored environmental impacts included disturbance to wildlife and pollution. If the increasing number of visitors to Saguaro National Park continued without a redesigned lot, the environment would continue to be destructed and driven on. In order to minimize the degradation associated with increased tourism and recreation, the project appropriately identified park boundaries, surveillance, and education on the park history and site preservation. These measures were identified and noted for the client for future implementation.

A negative impact associated with the construction of this asphalt parking lot is the environmental impact from the creation of asphalt and the transportation associated with the materials. During the creation of asphalt, there is a high amount of volatile organic compounds that are released into the atmosphere. The majority of the emissions at a mixing facility is from the combustion of fuel to heat the aggregate rock to keep the rock at high temperatures. In addition, the material needs to be transported from the mixing plant to the site, so there are heavy truck traffic releasing vehicle emissions into the air. In addition to released vehicle emissions, there are additional environmental impacts such as, noise, waste, and dust from construction.

10.2 Social Analysis

National parks in the United States were established to protect the flora and fauna, but they were not created without social consequences for the neighboring communities. On October 14, 2020, the local Tucson news, News 4 Tucson, reported that 8 saguaros were cut down along Saguaro National Park's Scenic Trail. Photos show the cacti severely hacked apart and sawed off with the tops scattered on the trail. The Saguaro Cactus grow extremely slowly and hold special significance to the people around. "These 10-foot cacti could easily be 100 years old and it was killed in a senseless act of vandalism.' [13] The Park's superintendent, Leah McGinnis stated that "all plants, animals, and resources in the national park are protect. Damage to cacti is especially disheartening because they are the reason for the park's establishment. It is unusual thing for the cacti to be damage, we are blessed by the fact that Tucson community really care about the Saguaros." Not knowing who the perpetrator in this crime is, creates an uneasy feeling while being in the area. Because of the extensive size of the park, park rangers patrol regularly but are not stationed at one trail. The police did not know if it was a local or a visitor, but it is apparent that someone felt the need to lash out on the National Park.

In addition, a negative social impact associated with the construction project is an adverse impact on the residents to the west of the project site. There is no way the contractor can guarantee that there will not be any creation of nuisance and load noises from equipment, workers, and site noise.

On the other hand, this national park project will have large social benefits. The combination of physical activity and being out in nature is recognized as providing significant benefits to people. There is widespread research and evidence on the importance of physical activity in nature especially for mental and physical health. Physical activity in this natural environment can be a aid in decreasing stress, depression, and a range of diseases associated with everyday living. Being an equestrian and hiking trail, the Cam-boh Trail provides visitors a safe 3-mile trek out and back through the Park. This allows recreation and sport groups to have a place to ride horses while building strong relationships with the community and nature. Investments in outdoor sports are estimated to be very cost-effective as many positive effects are achieved simultaneously and along the trail little infrastructure is required, as the natural world provides for this. By increasing the capacity and improving the delineation, it has the ability to allow more visitors to detach from the city and connect with the natural world. [14]

10.3 Economical Analysis

In 2019 Saguaro National Park saw over 1 million visitors, an increase of close to 100,000 more visitors from the year prior. This increase of tourists to the Tucson area has a positive impact on the local employment, can develop new industries of businesses, services and/or food, and can lead to new infrastructure to benefit the community. Tourism is a large contributor to employment creation particularly for women, migrant workers, and/or rural communities. As a consequence, tourism can lead to the reduction of poverty and promote socio-economic development in Tucson and southern Arizona. However, if the visitors do not respect and follow NPS and City of Tucson regulations and respect local culture, it can have a negative impact on the community, local heritage, and the environment. The number of park rangers and/or volunteers stationed in Saguaro National Park will have to increase if the visitation trend increases to monitor the park and create conversations and educate the park visitors. Reorganization of park volunteers is outside the scope of this project, but it is important to note to the client. With the increase of park visitors not only bring in money for the local community, but for future projects for NPS. A weekly pass for Saguaro National Park is required for entrance and costs $25.00 per vehicle per a seven-day period. These NPS entrance fees are used for a variety of applications such as repairs, maintenance, facility enhancement related to visitor enjoyment, access, and health and safety. These fees are used to offset the cost to run and maintain the parks for the visitor's enjoyment. Therefore, the more visitors a park sees, the more money will be put into to enhance it for everyone. Money multiplies each time it is spend in the local community, the longer the money stays in the community, the more it multiplies. However, when money leaves the economy and does not circulate that economy it will never return.

On the other hand, a negative economic impact produced from increased visitors to the park would be that there would be increased number of vehicles on the road impacting the integrity of the road. The roads to and inside Saguaro National Park would wear down faster resulting in more money being directed to repair the roads. In order to keep up the park, the park fees might have to increase to reflect the degradation of the roads. Park visitors would be too happy. This might decrease the number of visitors in the years forward.

11.0 Cost of Implementing Design

The total cost estimation of the project was broken down in two different costs at two different total cost. The asphalt parking lot pavement design was estimated to have a total cost of $62,400 whereas the gravel parking lot pavement design was estimated to have a total cost of $26,937. The values for each category of major cost for the project is shown in *Table 11-1* for the pavement design and shown in Table *11-2* for the gravel lot design below. There is a roughly 5% contingency added to the cost of construction for the design is purely on a conceptual basis. The contingency is in place to ensure to address any issues that may arise during the construction process of the project. A miscellaneous category was added to ensure maintenance for both designs are taken care of for both designs. For the asphalt lot this consists of restriping and filling in potholes that may develop. The maintenance costs for the gravel lot was added to ensure the gravel lot can be re-striped when needed as well as regrading and compacting the gravel lot over time as needed. A detailed breakdown of the cost estimate for asphalt parking lot pavement design is located in *Appendix U* as well as the cost breakdown for the gravel parking lot pavement design in *Appendix V*.

Item	Total ($)
Geotechnical Analysis	N/A
Earthwork	$3,360.00
Paving/Subgrade Materials	$47,150.00
Striping and Signage	$2,000.00
Miscellaneous	$6,890.00
Contingency	$3,000.00
Total Cost ($)	$62,400.00

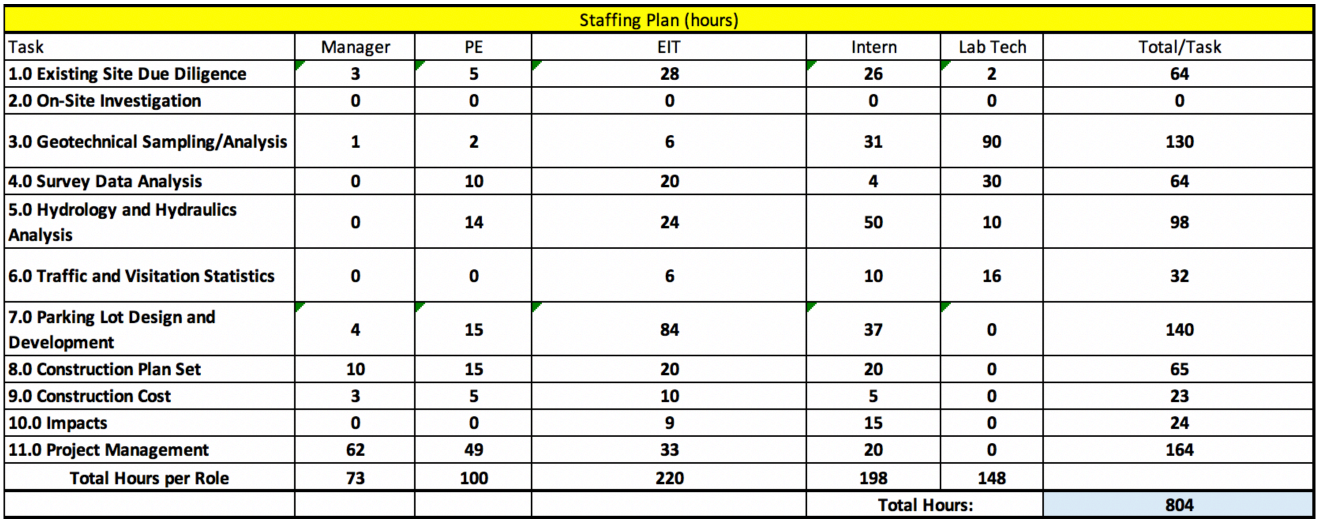
Table 11- 1: Cost estimation for pavement design

Item	Total ($)
Geotechnical Analysis	N/A
Earthwork	$2,420.00
Subgrade Materials	$16,400.00
Striping and Signage	$500.00
Miscellaneous	$6,117.00
Contingency	$1,500.00
Total Cost ($)	$26,937.00

Table 11- 2: Cost estimation for gravel lot design

12.0 Summary of Engineering Costs

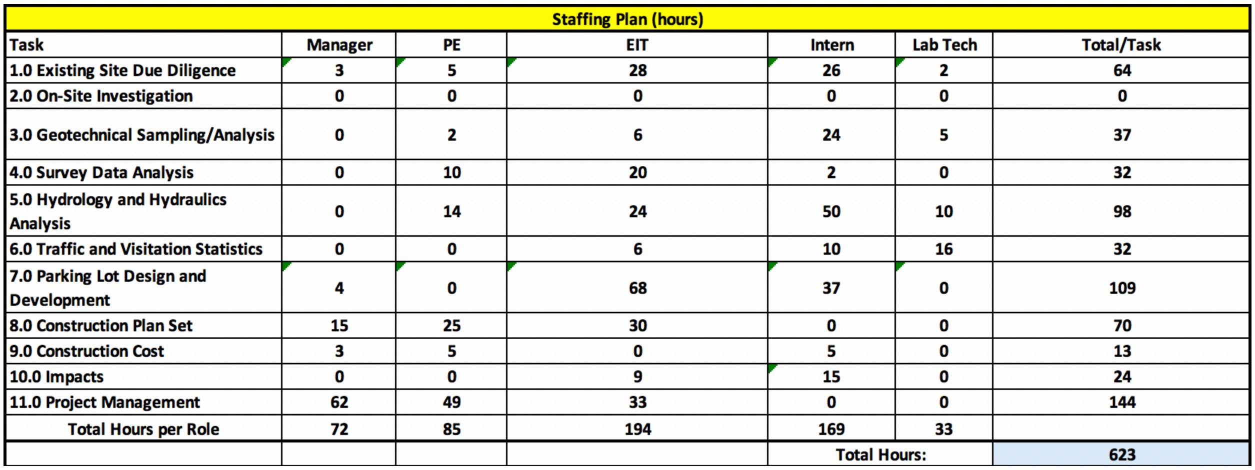
Appendix B shows the original schedule that the team created showing each tasks that needs to be done to complete the design. *Table 12-1* below provides the original allocation of hours for each role for each task whereas *Table 12-2* provides the updated working hours of each role.



Staffing Plan (hours)

Task	Manager	PE	EIT	Intern	Lab Tech	Total/Task
1.0 Existing Site Due Diligence	**3**	**5**	**28**	**26**	**2**	**64**
2.0 On-Site Investigation	**0**	**0**	**0**	**0**	**0**	**0**
3.0 Geotechnical Sampling/Analysis	**1**	**2**	**6**	**31**	**90**	**130**
4.0 Survey Data Analysis	**0**	**10**	**20**	**4**	**30**	**64**
5.0 Hydrology and Hydraulics Analysis	**0**	**14**	**24**	**50**	**10**	**98**
6.0 Traffic and Visitation Statistics	**0**	**0**	**6**	**10**	**16**	**32**
7.0 Parking Lot Design and Development	**4**	**15**	**84**	**37**	**0**	**140**
8.0 Construction Plan Set	**10**	**15**	**20**	**20**	**0**	**65**
9.0 Construction Cost	**3**	**5**	**10**	**5**	**0**	**23**
10.0 Impacts	**0**	**0**	**9**	**15**	**0**	**24**
11.0 Project Management	**62**	**49**	**33**	**20**	**0**	**164**
Total Hours per Role	**73**	**100**	**220**	**198**	**148**	
				Total Hours:		**804**

Table 12- 1: Original working Hours of each team member by task



Staffing Plan (hours)

Task	**Manager**	**PE**	**EIT**	**Intern**	**Lab Tech**	**Total/Task**
1.0 Existing Site Due Diligence	**3**	**5**	**28**	**26**	**2**	**64**
2.0 On-Site Investigation	**0**	**0**	**0**	**0**	**0**	**0**
3.0 Geotechnical Sampling/Analysis	**0**	**2**	**6**	**24**	**5**	**37**
4.0 Survey Data Analysis	**0**	**10**	**20**	**2**	**0**	**32**
5.0 Hydrology and Hydraulics Analysis	**0**	**14**	**24**	**50**	**10**	**98**
6.0 Traffic and Visitation Statistics	**0**	**0**	**6**	**10**	**16**	**32**
7.0 Parking Lot Design and Development	**4**	**0**	**68**	**37**	**0**	**109**
8.0 Construction Plan Set	**15**	**25**	**30**	**0**	**0**	**70**
9.0 Construction Cost	**3**	**5**	**0**	**5**	**0**	**13**
10.0 Impacts	**0**	**0**	**9**	**15**	**0**	**24**
11.0 Project Management	**62**	**49**	**33**	**0**	**0**	**144**
Total Hours per Role	**72**	**85**	**194**	**169**	**33**	
				Total Hours:		**623**

Table 12- 2: Actual working Hours of each team member by task

Table 12-3 provides the original projection for cost of engineering services and *Table 12-4* provides the updated projection of cost of engineering services. The Engineer in training, lab technician, and intern work closely with each other performing a majority of the work while the project manager and project engineer were in a supervising role for each specific task. The billing rate was calculated by using a multiplier for each specific role that represents the actual costs of engineering services. The updated total engineering costs shows that the team originally anticipated more hours were going to be spent on the project which ultimately led to a higher overall costs for engineering services originally. *Appendix W* shows the updated schedule that shows the changed tasks which occurred throughout the process of the design of the project.

Roles	Total Hours Worked	Billing Rate ($/Hr)	Total $ Spent
Project Manager	82	320	$26,240.00
Project Engineer	118	234	$15,340.00
EIT	403	220	$40,300.00
Intern	349	75	$10,470.00
Lab Tech	356	156	$21,360.00
Travel	0.4/mile	6 meetings * 504 miles	$3,024.00
			$116,734.00

Table 12- 3: Original cost of engineering services

Roles	Total Hours Worked	Billing Rate ($/Hr)	Total $ Spent
Project Manager	22	320	$7,040.00
Project Engineer	33	234	$4,290.00
EIT	213	220	$21,300.00
Intern	209	75	$6,270.00
Lab Tech	286	156	$17,160.00
Travel	0.4/mile	3 meetings * 504 miles	$1,512.00
			$57,572.00

Table 12- 4: Updated cost of engineering services

13.0 Conclusion

This project was designed to meet the original objectives, criteria, and constraints presented by the client. Due to external circumstances of COVID-19, these objectives were altered while still achieving two delineated designs. The cost estimate provides an approximate evaluation of cost for constructing the site and will aid the client in determining project feasibility and implementation.

The project team did not conclude to a final design of surface, instead two designed surface materials with identical layouts were presented to be chosen by the client. This proposed delineation avoided a large environmental impact, while still maximizing the amount of available parking stalls. The final plan was designed using cost effective methods while keep the environment, community, and park visitors in mind. In order to fully conclude with a final design, it is recommended that a site visit is to be conducted to further analyze the existing conditions, hydraulic infrastructure, and site topography.

14.0 References

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Appendices

Appendix A - 7.5 Minute Topographic Map

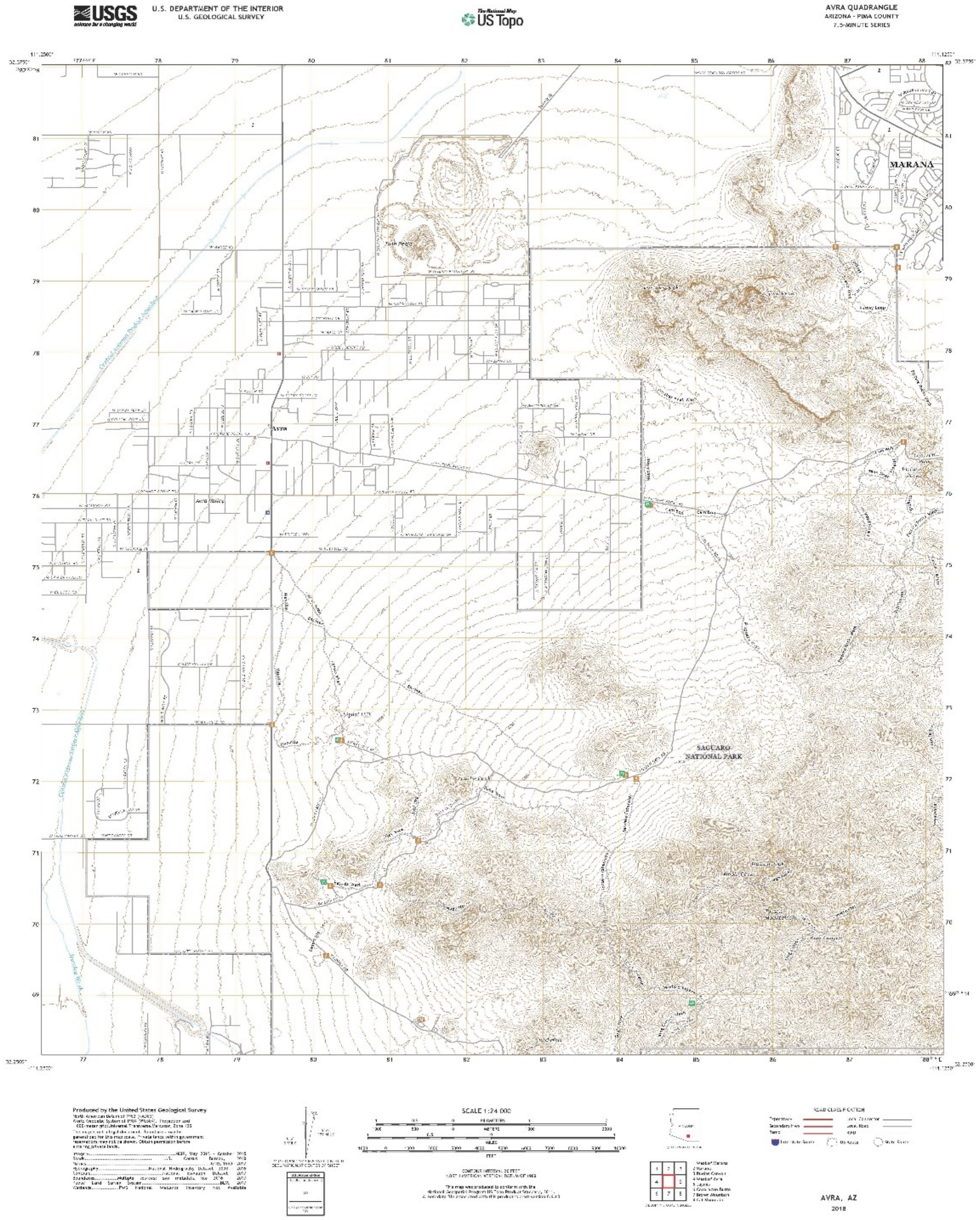


Figure 8- 3 7.5 Minute Topographic Map of Avra Quadrangle

Appendix B - *100% Progress Schedule*

ID	Task Name	Duration
0	**90% Progress-FALL 2020 SCHEDULE-Version 3**	**93 days**
1	Task 1: Existing Due Diligence	7 days
2	**Task 2: On Site Investigation**	**10 days**
3	~~Task 2.1: Site Land Surveying~~	~~3 days~~
4	Task 2.2: Soil Sample Planning and Soil Sampling	4 days
5	Task 2.3: Formal Report	10 days
6	**Task 3: Geotechnical Analysis**	**10 days**
7	**Task 3.1: Complete Soil Testing**	**0 days**
8	~~Task 3.1.1: Moisture Content~~	~~3 days~~
9	~~Task 3.1.2: Atterberg Limits~~	~~4 days~~
10	~~Task 3.1.3: Sieve Analysis~~	~~3 days~~
11	30% Milestone	0 days
12	~~Task 3.1.4: AASHTO/ USCS Soil Classification~~	~~1 day~~
13	~~Task 3.1.5: Hydrometer Test~~	~~3 days~~
14	~~Task 3.1.6: Direct Shear Test~~	~~3 days~~
15	~~Task 3.1.7: Relative Compaction Test~~	~~3 days~~
16	Task 3.2: Soil Report	10 days
17	**Task 4: Survey Data Analysis**	7 days
18	**Task 5: Hydrology and Hydraulic Analysis**	**9 days**
19	Task 5.1: Watershed and Stormwater Runoff Analysis	9 days
20	Task 5.2: Existing and Proposed Infrastructure Analysis	7 days
21	**Task 6: Traffic and Visitation Statistics**	**32 days**
25	**Task 7: Parking Lot Design and Development**	12 days
26	60% Milestone	0 days
27	**Task 8: Construction Plan Set**	30 days
28	**Task 9: Construction Costs**	7 days
29	**Task 10: Impact Analysis**	3 days
30	90% Milestone	0 days
31	**Task 11: Project Management**	**92 days**
32	**Task 11.1: Meetings**	**73.04 days**
57	**Task 11.2: Resource and Schedulig Management**	**56 days**
66	**Task 11.3: Deliverables**	**78 days**
67	Task 11.3.1: 30% Submittal	5 days
68	Task 11.3.2: 60% Submittal	6 days
69	Task 11.3.3: 90% Submittal	6 days
70	Task 11.3.4: Final Submittal and Website	12 days

Project: 90% Progress-FALL 202
Date: Tue 11/17/20

Completed Task	🟩	Summary	▬	Manual Milestone	◆	In-Progress Tasks	🟦
Split	┈	Project Summary	▬	Progress	▬	Future Tasks	🟦

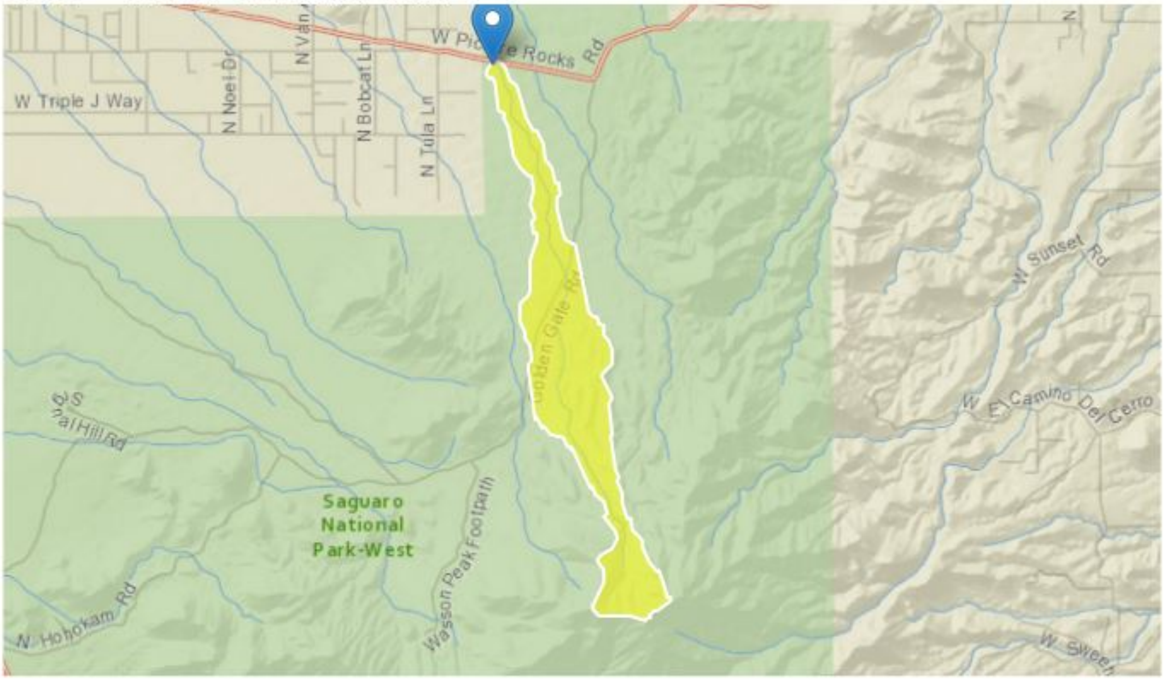
Page 1

Figure 8- 4 Schedule for the 100% Progress including the Milestones

Appendix C - Cam-boh Picnic Area Contributing Watershed Area

StreamStats Report - Cam-boh Picnic Area Saguaro NP

Region ID: AZ
Workspace ID: AZ20200818154959634000
Clicked Point (Latitude, Longitude): 32.31960, -111.16568
Time: 2020-08-18 11:50:17 -0400

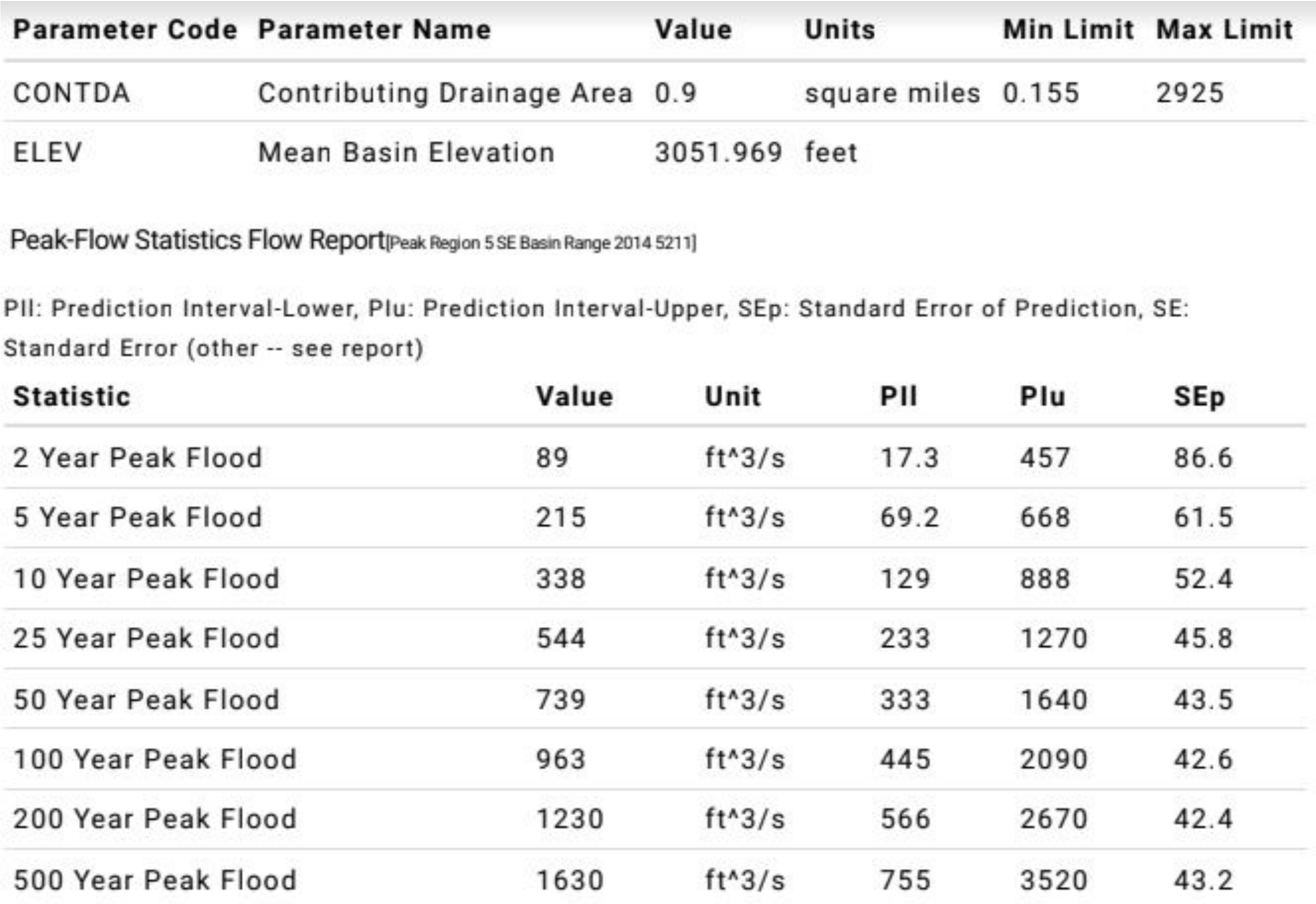


Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
CONTDA	Area that contributes flow to a point on a stream	0.9	square miles
ELEV	Mean Basin Elevation	3051.969	feet

Figure 8- 5 Cam-boh Picnic Area Contributing Watershed Area

Appendix D - Peak-Flow Statistics Flow Report



Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
CONTDA	Contributing Drainage Area	0.9	square miles	0.155	2925
ELEV	Mean Basin Elevation	3051.969	feet		

Peak-Flow Statistics Flow Report[Peak Region 5 SE Basin Range 2014 5211]

PII: Prediction Interval-Lower, Plu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	Plu	SEp
2 Year Peak Flood	89	ft^3/s	17.3	457	86.6
5 Year Peak Flood	215	ft^3/s	69.2	668	61.5
10 Year Peak Flood	338	ft^3/s	129	888	52.4
25 Year Peak Flood	544	ft^3/s	233	1270	45.8
50 Year Peak Flood	739	ft^3/s	333	1640	43.5
100 Year Peak Flood	963	ft^3/s	445	2090	42.6
200 Year Peak Flood	1230	ft^3/s	566	2670	42.4
500 Year Peak Flood	1630	ft^3/s	755	3520	43.2

Figure 8- 6 Peak-Flow Statistics Report

Appendix E – Critical Basins Map within Unincorporated Pima County

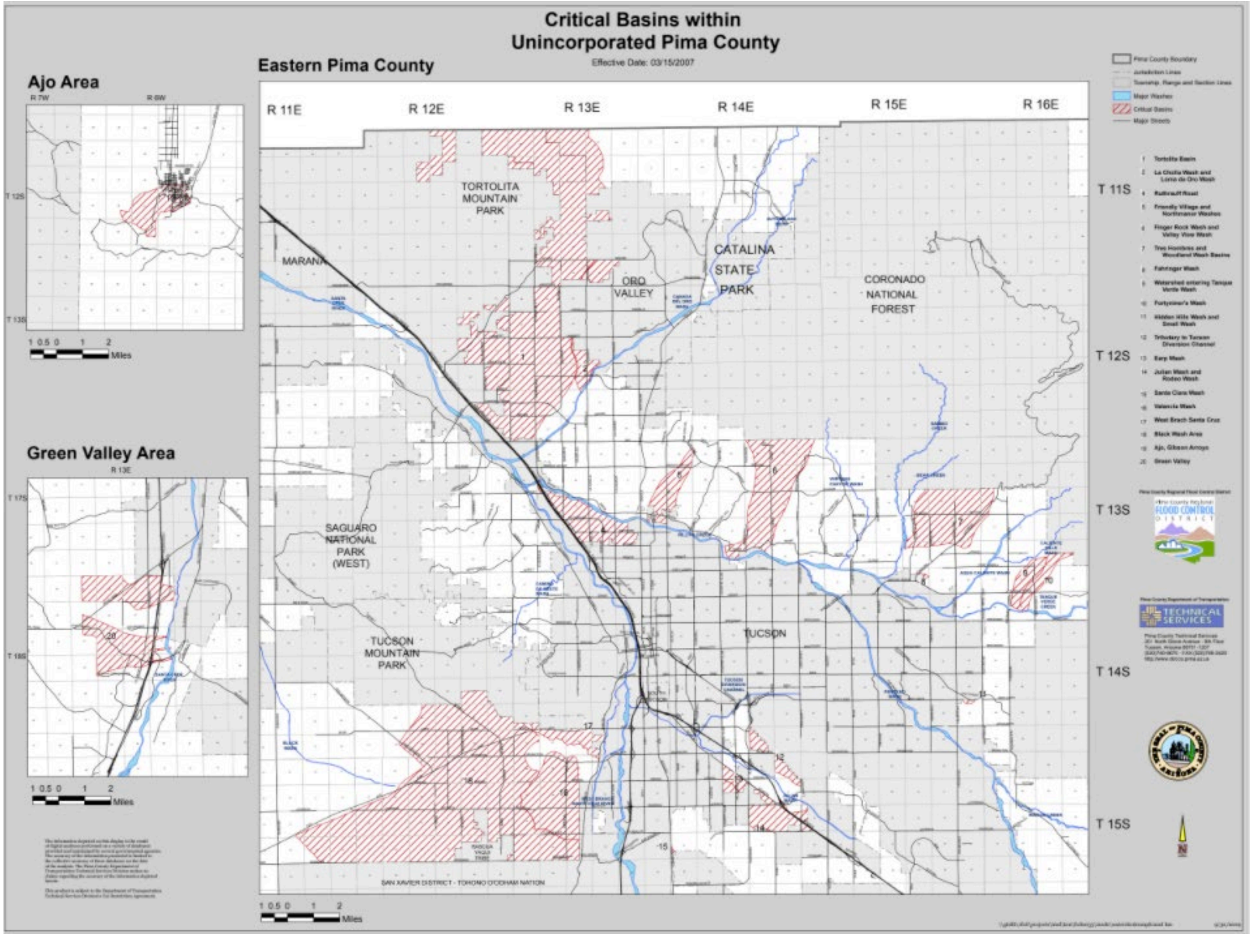


Figure 8- 7 Critical Basins Map within Unincorporated Pima County

Appendix F – Concentration Point Traced to the Highest Reach

Figure 8- 8 Concentration Point Traced to the Highest Reach

Appendix G – Pima County Soil Types

Type A: (Low runoff potential). These soils have a high infiltration rate even when thoroughly wetted. They chiefly consist of deep, well drained to excessively drained sands or gravels. They have a high rate of water transmission (8 to12 mm/hr), and are generally described as sand, loamy sand, and sandy loam.

Type B: (Moderately low runoff potential). These soils have a moderate infiltration rate when thoroughly wetted. They chiefly are moderately deep to deep, moderately well drained to well drained, soils that have moderately fine to moderately coarse textures. They have a moderate rate of water transmission (4 to 8 mm/hr), and are generally described as silty loam, and loam.

Type C: (Moderately high runoff potential). These soils have a slow infiltration rate when thoroughly wetted. They chiefly have a layer that impedes downward movement of water or have moderately fine to fine texture. They have a slow rate of water transmission (1 to 4 mm/hr), and are generally described as sandy clay loam.

Type D: (High runoff potential). These soils have a very slow infiltration rate when thoroughly wetted. They chiefly consist of clay soils that have high swelling potential, soils that have a permanent high water table, soils that have a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. They have a very slow rate of water transmission (0 to 1 mm/hr), and are generally described as clay loam, and silty clay loam.

Figure 8- 9 Pima County Soil Types

Appendix H – Chart for Estimating Basin Curve Numbers

2.4.3.5 SCS Curve Number

In general, the base Curve Number shall be found by referring to the graph of Hydrologic Soil-Cover Complexes and Associated Curve Numbers found on Figure 2 and Appendix D (ADOT, 1968).

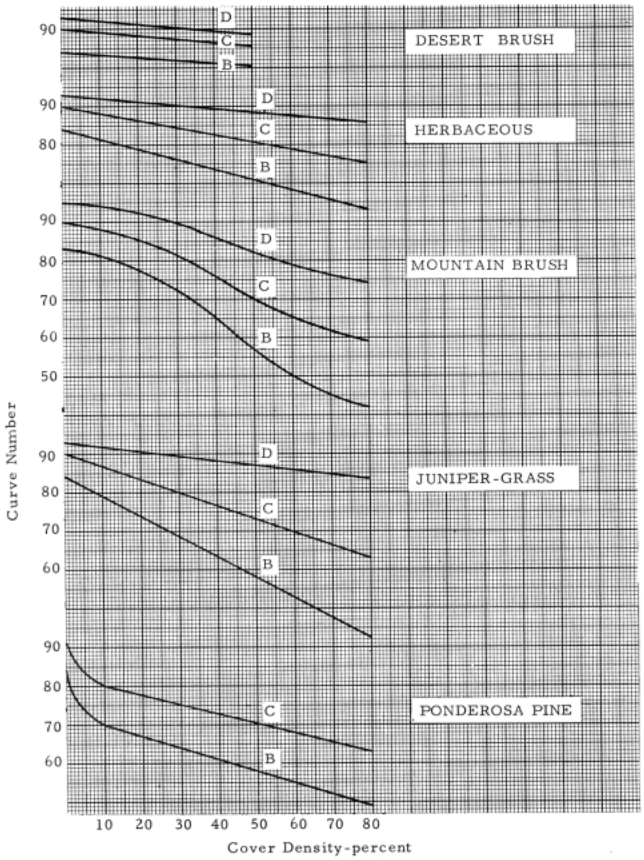
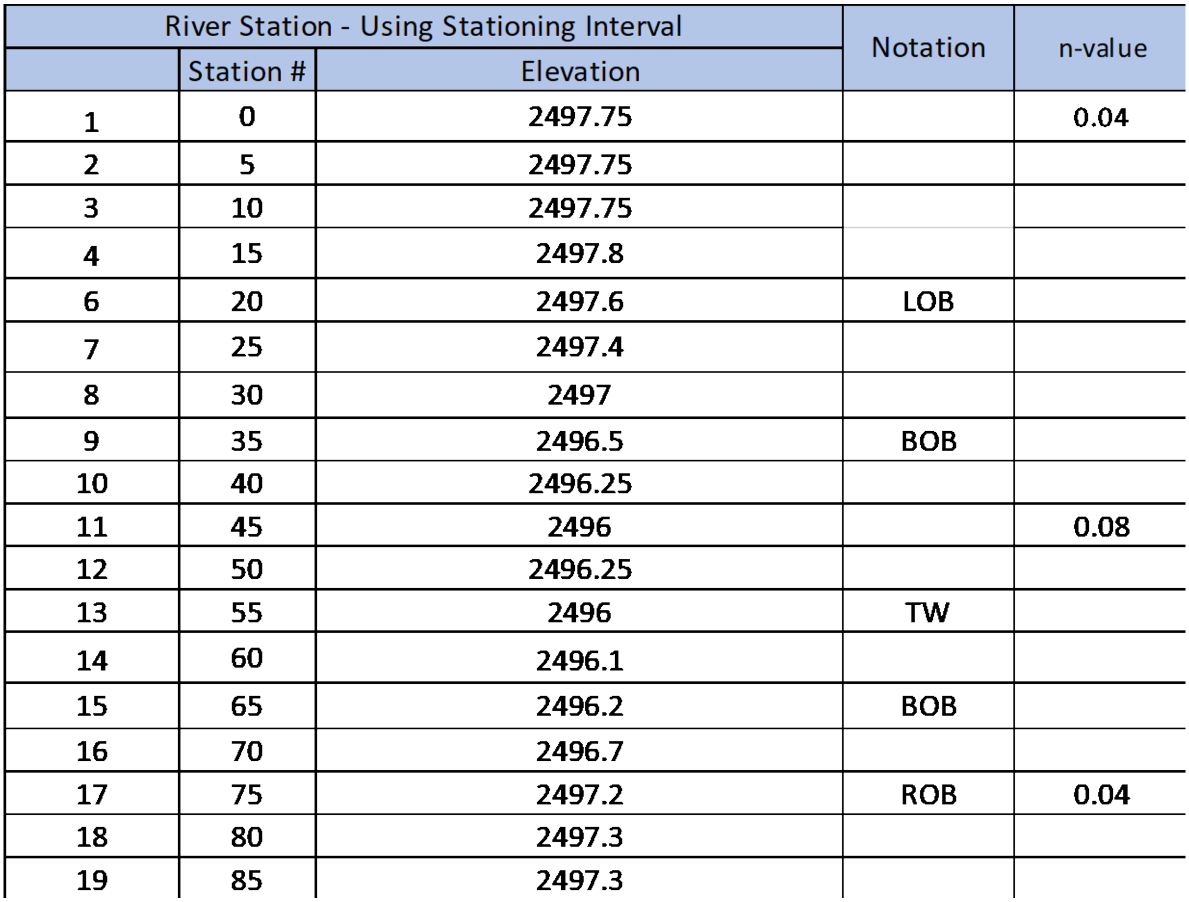


Figure 2 – Chart for Estimating Base Curve Numbers

Figure 8- 10 Chart for Estimating Basin Curve Numbers

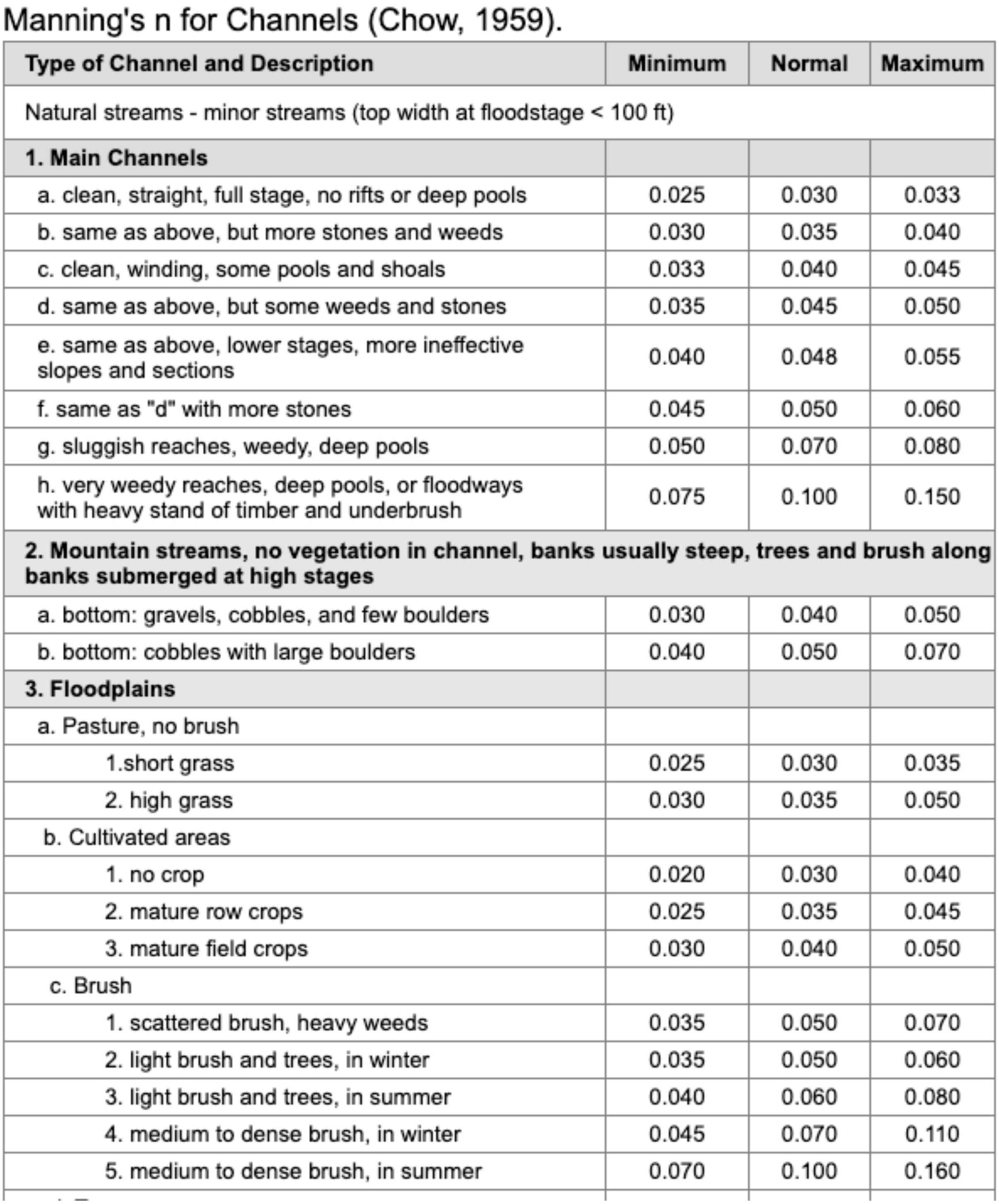
Appendix I – Cross-Section Data of Channel of Interest

Table 8- 8 Cross-Section Data of Channel of Interest



River Station - Using Stationing Interval			Notation	n-value
	Station #	Elevation		
1	0	2497.75		0.04
2	5	2497.75		
3	10	2497.75		
4	15	2497.8		
6	20	2497.6	LOB	
7	25	2497.4		
8	30	2497		
9	35	2496.5	BOB	
10	40	2496.25		
11	45	2496		0.08
12	50	2496.25		
13	55	2496	TW	
14	60	2496.1		
15	65	2496.2	BOB	
16	70	2496.7		
17	75	2497.2	ROB	0.04
18	80	2497.3		
19	85	2497.3		

Appendix J – Manning's n for Channels



Manning's n for Channels (Chow, 1959).

Type of Channel and Description	**Minimum**	**Normal**	**Maximum**
Natural streams - minor streams (top width at floodstage < 100 ft)			
1. Main Channels			
a. clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. same as above, but more stones and weeds	0.030	0.035	0.040
c. clean, winding, some pools and shoals	0.033	0.040	0.045
d. same as above, but some weeds and stones	0.035	0.045	0.050
e. same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
f. same as "d" with more stones	0.045	0.050	0.060
g. sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
2. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
a. bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
b. bottom: cobbles with large boulders	0.040	0.050	0.070
3. Floodplains			
a. Pasture, no brush			
1.short grass	0.025	0.030	0.035
2. high grass	0.030	0.035	0.050
b. Cultivated areas			
1. no crop	0.020	0.030	0.040
2. mature row crops	0.025	0.035	0.045
3. mature field crops	0.030	0.040	0.050
c. Brush			
1. scattered brush, heavy weeds	0.035	0.050	0.070
2. light brush and trees, in winter	0.035	0.050	0.060
3. light brush and trees, in summer	0.040	0.060	0.080
4. medium to dense brush, in winter	0.045	0.070	0.110
5. medium to dense brush, in summer	0.070	0.100	0.160

Figure 8- 11 Manning's n for Channels

Appendix K – Basin Factors

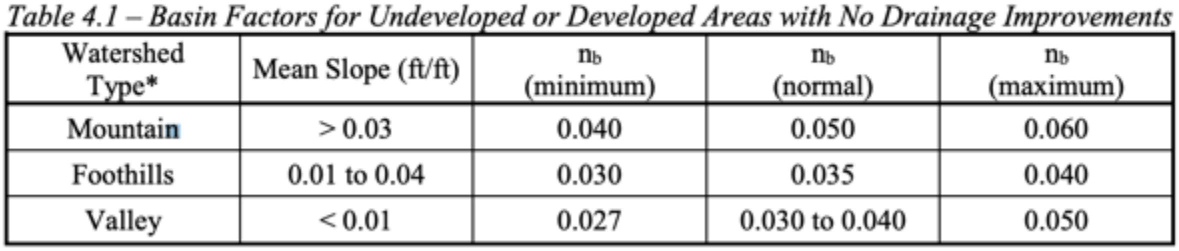


Table 4.1 – Basin Factors for Undeveloped or Developed Areas with No Drainage Improvements

Watershed Type*	Mean Slope (ft/ft)	n_b (minimum)	n_b (normal)	n_b (maximum)
Mountain	> 0.03	0.040	0.050	0.060
Foothills	0.01 to 0.04	0.030	0.035	0.040
Valley	< 0.01	0.027	0.030 to 0.040	0.050

Figure 8- 12 Basin Factors

Appendix L – USDA Soil Textural Triangle

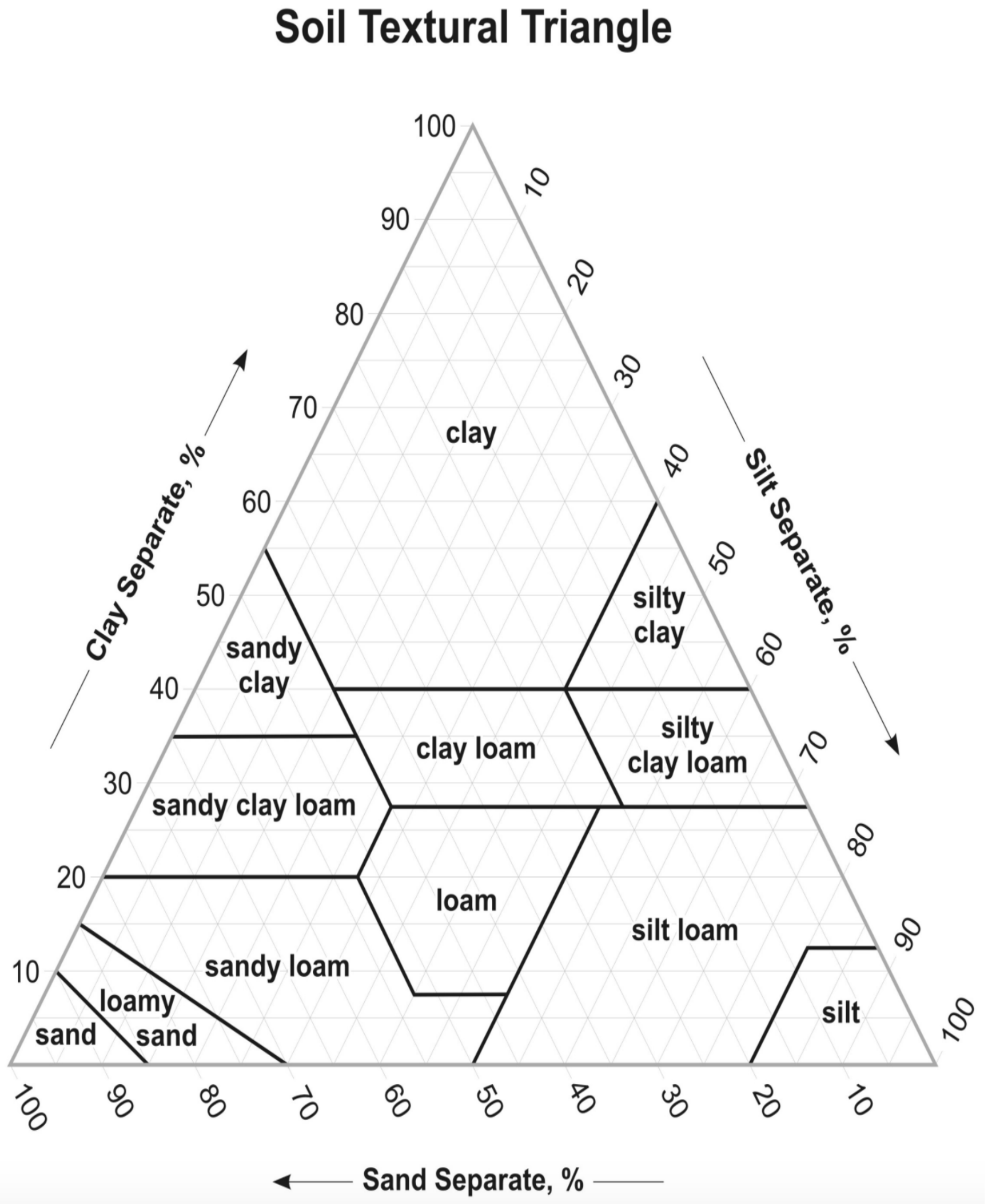
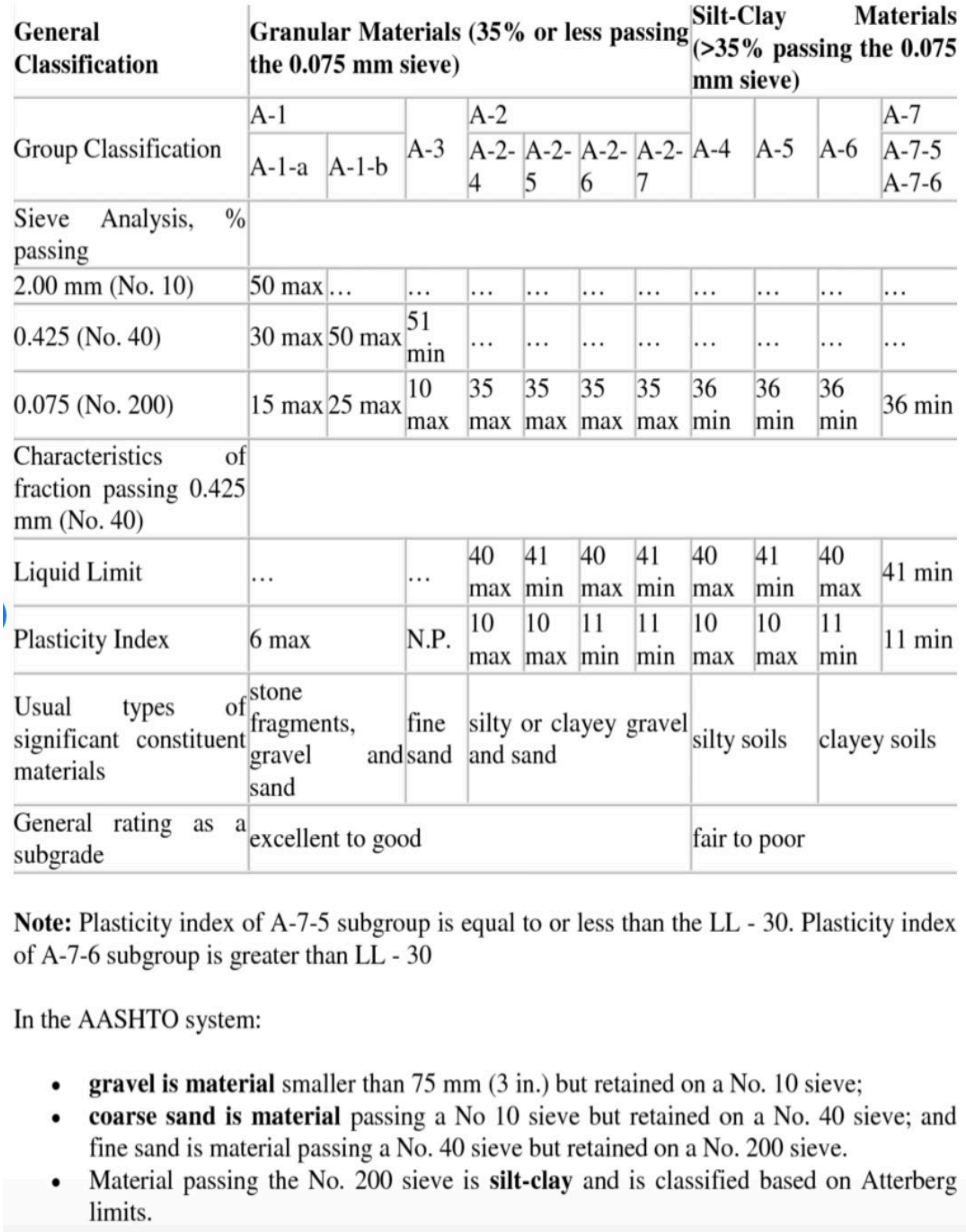


Figure 8- 13 USDA Soil Textural Triangle

Appendix M – AASHTO Classification System



General Classification	**Granular Materials (35% or less passing the 0.075 mm sieve)**							**Silt-Clay Materials (>35% passing the 0.075 mm sieve)**			
Group Classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5 A-7-6
Sieve Analysis, % passing											
2.00 mm (No. 10)	50 max	…	…	…	…	…	…	…	…	…	…
0.425 (No. 40)	30 max	50 max	51 min	…	…	…	…	…	…	…	…
0.075 (No. 200)	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
Characteristics of fraction passing 0.425 mm (No. 40)											
Liquid Limit	…		…	40 max	41 min	40 max	41 min	40 max	41 min	40 max	41 min
Plasticity Index	6 max		N.P.	10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min
Usual types of significant constituent materials	stone fragments, gravel and sand		fine sand	silty or clayey gravel and sand				silty soils		clayey soils	
General rating as a subgrade	excellent to good							fair to poor			

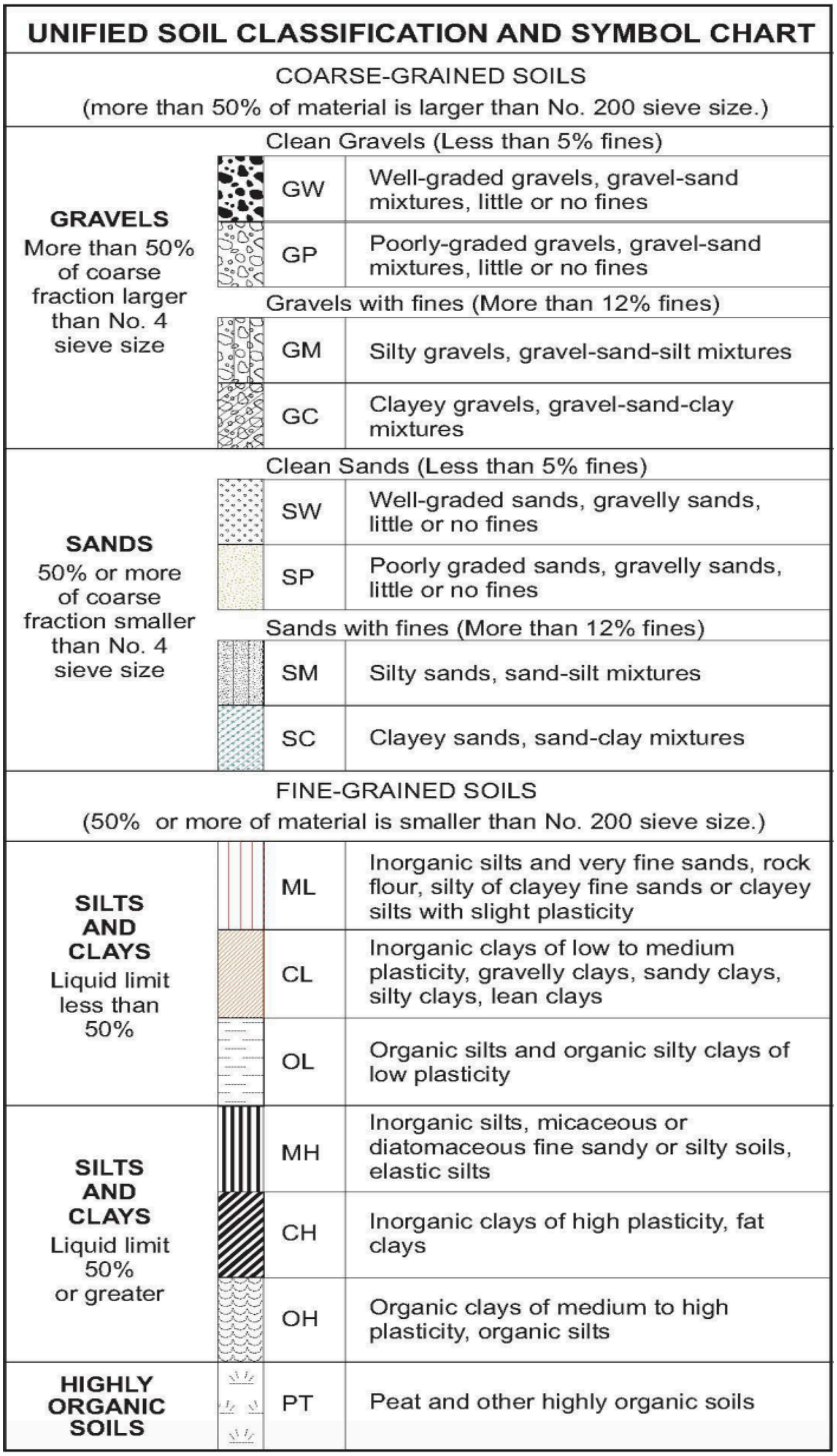
Note: Plasticity index of A-7-5 subgroup is equal to or less than the LL - 30. Plasticity index of A-7-6 subgroup is greater than LL - 30

In the AASHTO system:

- **gravel is material** smaller than 75 mm (3 in.) but retained on a No. 10 sieve;
- **coarse sand is material** passing a No 10 sieve but retained on a No. 40 sieve; and fine sand is material passing a No. 40 sieve but retained on a No. 200 sieve.
- Material passing the No. 200 sieve is **silt-clay** and is classified based on Atterberg limits.

Figure 8- 14 AASHTO Classification System

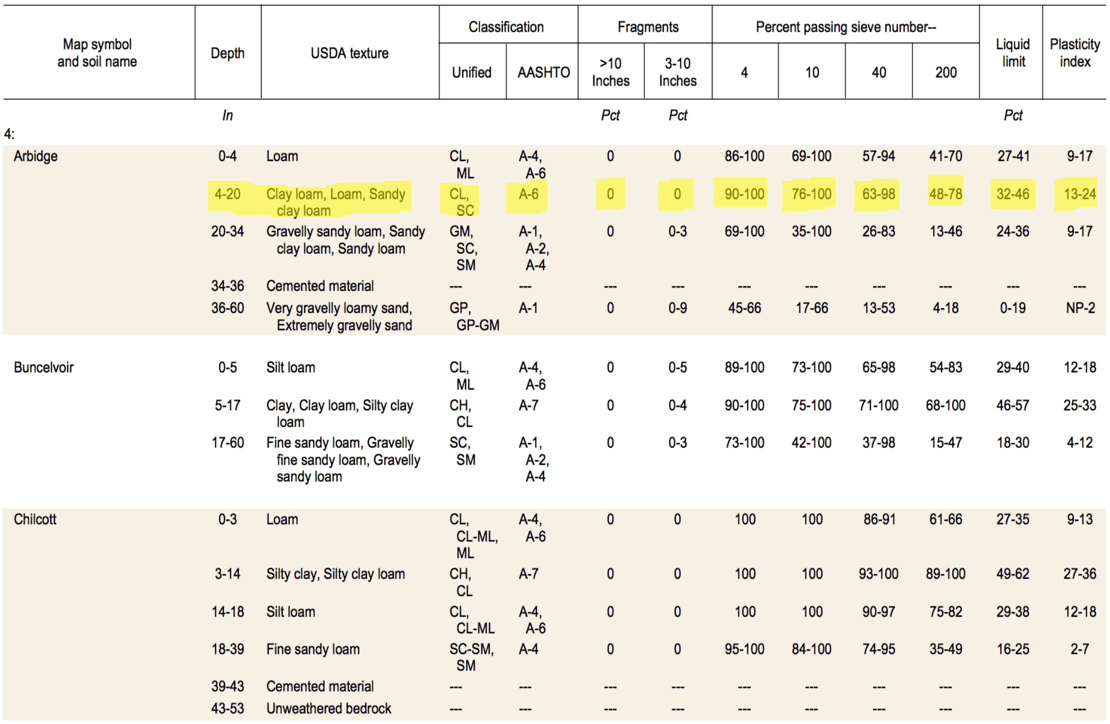
Appendix N – USCS Classification System



UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART			
COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)		
	▨	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
	▨	GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)		
	▨	GM	Silty gravels, gravel-sand-silt mixtures
	▨	GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)		
	▨	SW	Well-graded sands, gravelly sands, little or no fines
	▨	SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)		
	▨	SM	Silty sands, sand-silt mixtures
	▨	SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%	▨	ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
	▨	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
	▨	OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater	▨	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
	▨	CH	Inorganic clays of high plasticity, fat clays
	▨	OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS	▨	PT	Peat and other highly organic soils

Figure 8- 15 USCS Classification System

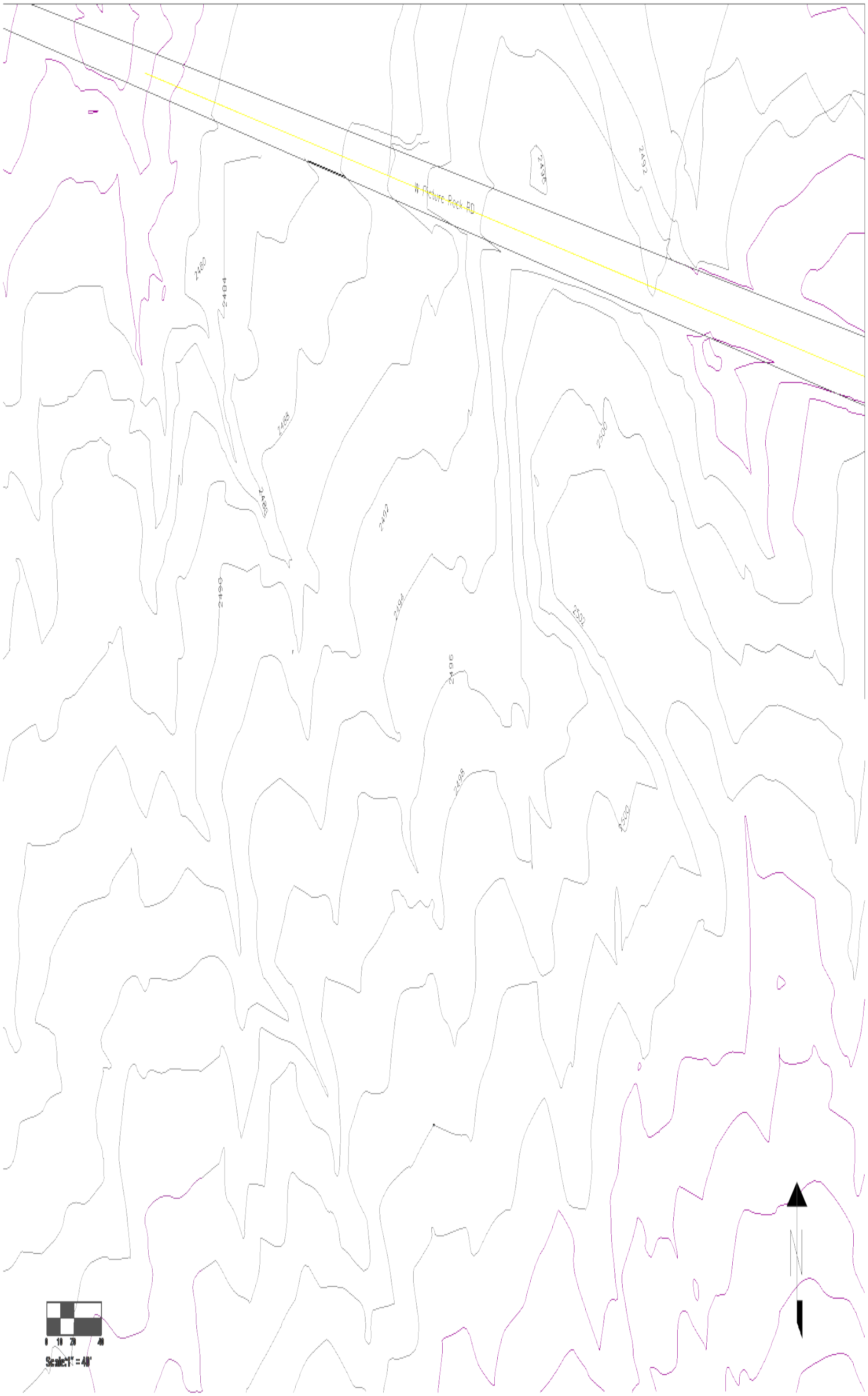
Appendix O – Assumed Sandy Clay Loam Classification



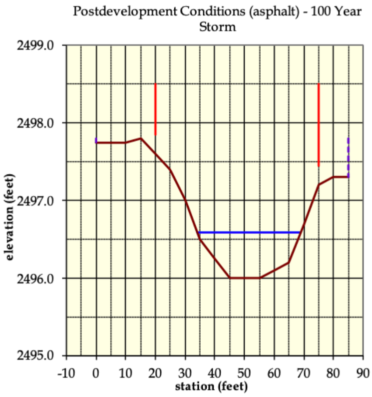
Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percent passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 Inches	3-10 Inches	4	10	40	200		
	In				*Pct*	*Pct*					*Pct*	
4:												
Arbidge	0-4	Loam	CL, ML	A-4, A-6	0	0	86-100	69-100	57-94	41-70	27-41	9-17
	4-20	Clay loam, Loam, Sandy clay loam	CL, SC	A-6	0	0	90-100	76-100	63-98	48-78	32-46	13-24
	20-34	Gravelly sandy loam, Sandy clay loam, Sandy loam	GM, SC, SM	A-1, A-2, A-4	0	0-3	69-100	35-100	26-83	13-46	24-36	9-17
	34-36	Cemented material	---	---	---	---	---	---	---	---	---	---
	36-60	Very gravelly loamy sand, Extremely gravelly sand	GP, GP-GM	A-1	0	0-9	45-66	17-66	13-53	4-18	0-19	NP-2
Buncelvoir	0-5	Silt loam	CL, ML	A-4, A-6	0	0-5	89-100	73-100	65-98	54-83	29-40	12-18
	5-17	Clay, Clay loam, Silty clay loam	CH, CL	A-7	0	0-4	90-100	75-100	71-100	68-100	46-57	25-33
	17-60	Fine sandy loam, Gravelly fine sandy loam, Gravelly sandy loam	SC, SM	A-1, A-2, A-4	0	0-3	73-100	42-100	37-98	15-47	18-30	4-12
Chilcott	0-3	Loam	CL, CL-ML, ML	A-4, A-6	0	0	100	100	86-91	61-66	27-35	9-13
	3-14	Silty clay, Silty clay loam	CH, CL	A-7	0	0	100	100	93-100	89-100	49-62	27-36
	14-18	Silt loam	CL, CL-ML	A-4, A-6	0	0	100	100	90-97	75-82	29-38	12-18
	18-39	Fine sandy loam	SC-SM, SM	A-4	0	0	95-100	84-100	74-95	35-49	16-25	2-7
	39-43	Cemented material	---	---	---	---	---	---	---	---	---	---
	43-53	Unweathered bedrock	---	---	---	---	---	---	---	---	---	---

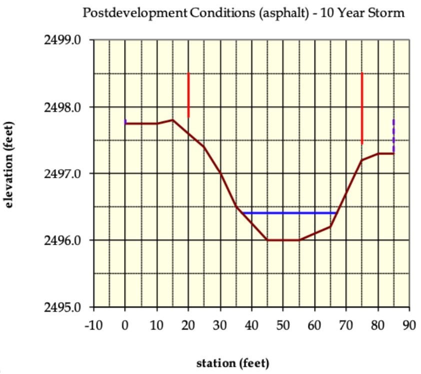
Figure 8- 16 Assumed Sandy Clay Loam Classification

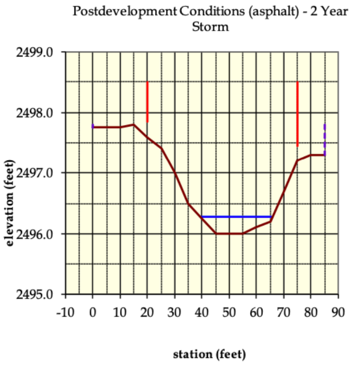
Appendix P – Provided Site Topography from Pima County

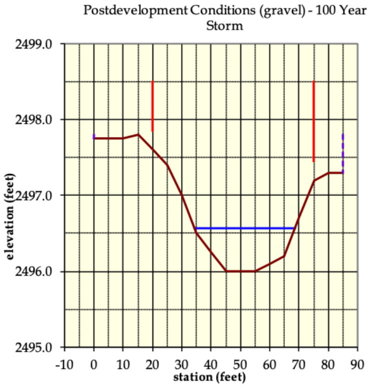


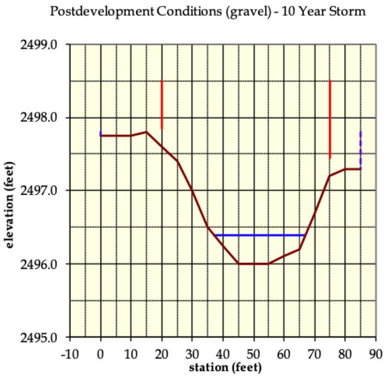
Appendix Q Cross Section Analysis of Channel

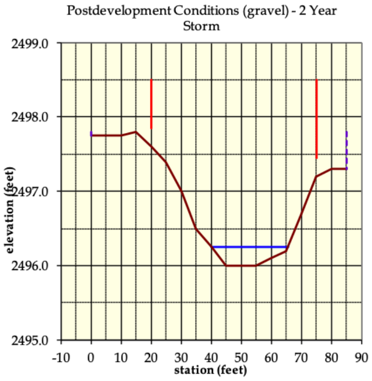

Postdevelopment Conditions (asphalt) - 100 Year Storm

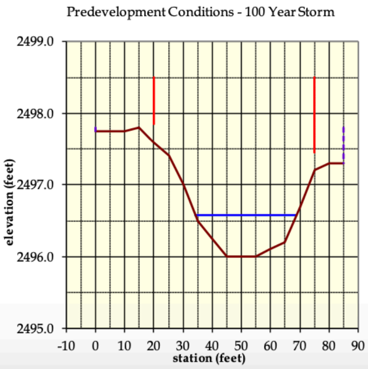

Postdevelopment Conditions (asphalt) - 10 Year Storm

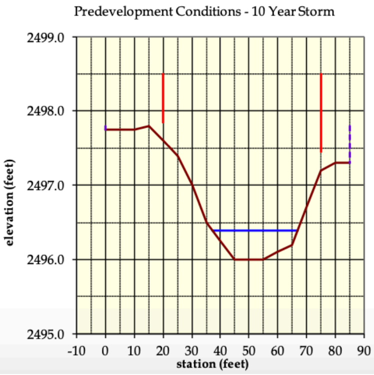

Postdevelopment Conditions (asphalt) - 2 Year Storm

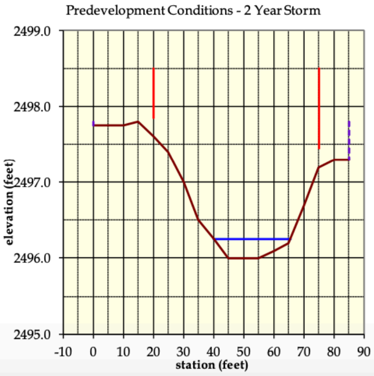

Postdevelopment Conditions (gravel) - 100 Year Storm


Postdevelopment Conditions (gravel) - 10 Year Storm

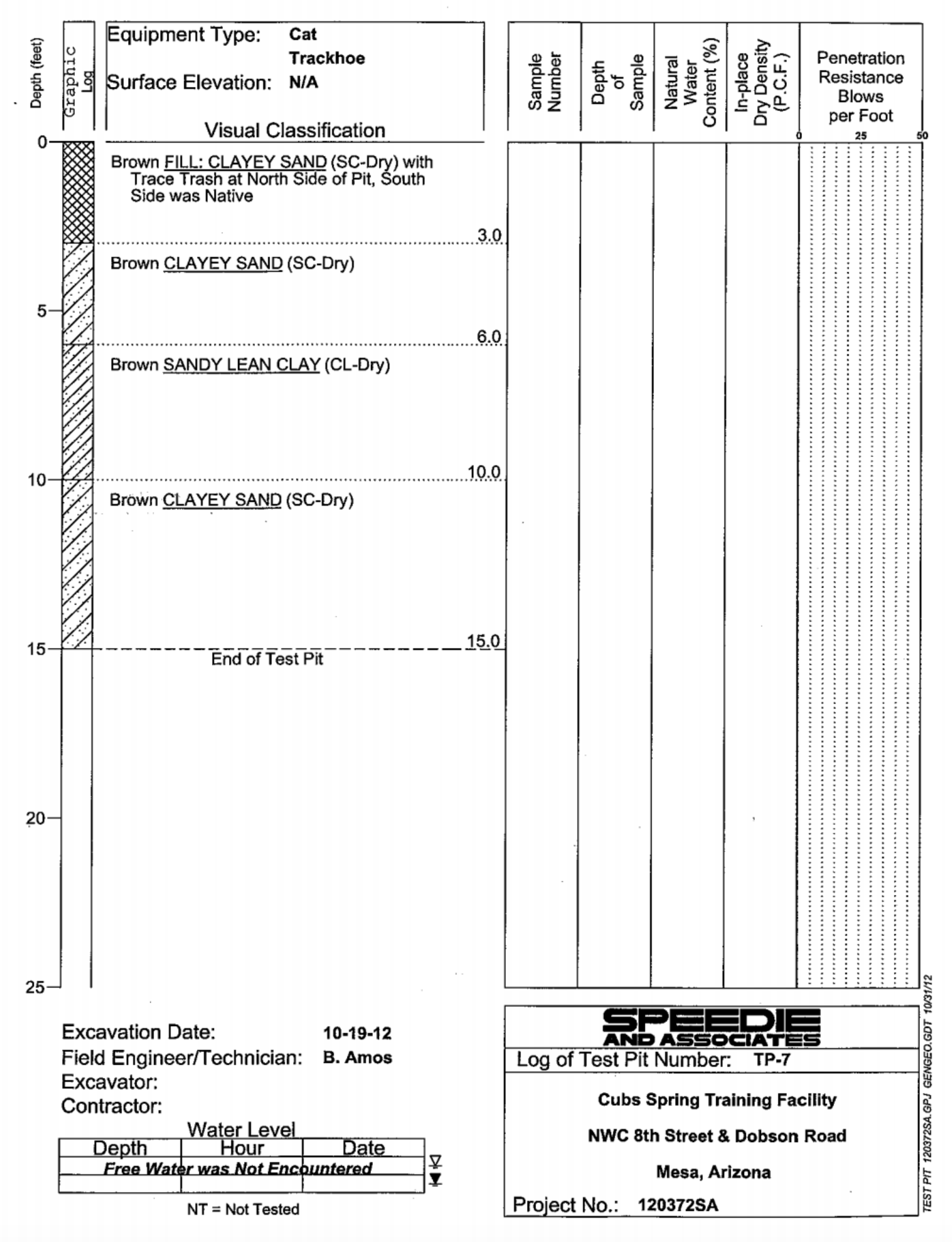

Postdevelopment Conditions (gravel) - 2 Year Storm


Predevelopment Conditions - 100 Year Storm


Predevelopment Conditions - 10 Year Storm


Predevelopment Conditions - 2 Year Storm

Appendix R – Boring Log of Union Office Complex in Mesa, Arizona



Equipment Type: **Cat Trackhoe**

Surface Elevation: **N/A**

Visual Classification

Sample Number	Depth of Sample	Natural Water Content (%)	In-place Dry Density (P.C.F.)	Penetration Resistance Blows per Foot

Brown FILL: CLAYEY SAND (SC-Dry) with Trace Trash at North Side of Pit, South Side was Native

3.0

Brown CLAYEY SAND (SC-Dry)

6.0

Brown SANDY LEAN CLAY (CL-Dry)

10.0

Brown CLAYEY SAND (SC-Dry)

15.0

End of Test Pit

Excavation Date: **10-19-12**

Field Engineer/Technician: **B. Amos**

Excavator:

Contractor:

Water Level

Depth	Hour	Date
Free Water was Not Encountered		

NT = Not Tested

SPEEDIE AND ASSOCIATES

Log of Test Pit Number: **TP-7**

Cubs Spring Training Facility

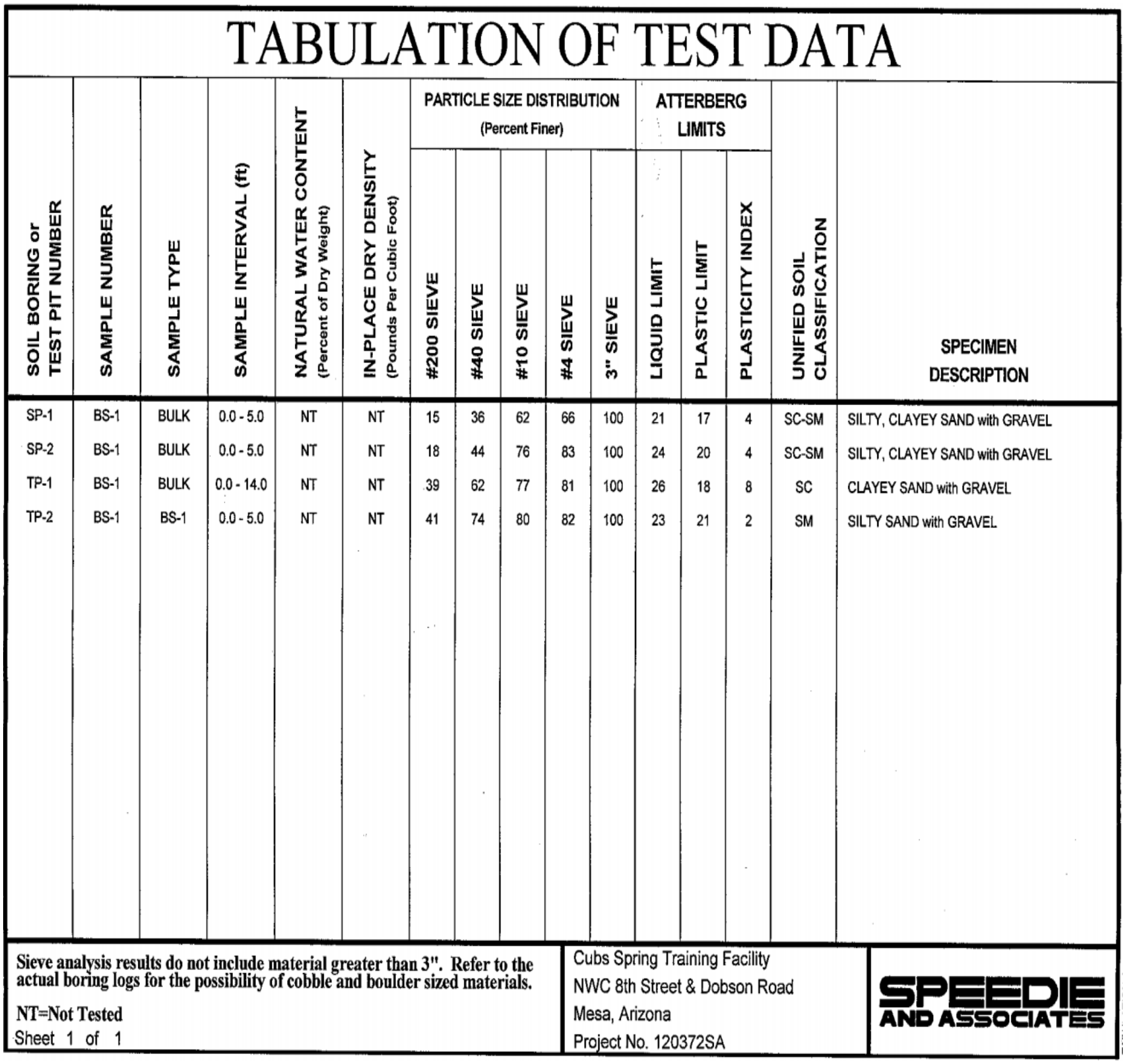
NWC 8th Street & Dobson Road

Mesa, Arizona

Project No.: **120372SA**

TEST PIT 120372SA.GPJ GENGEO.GDT 10/31/12

Appendix S – Tabulation of Boring Log data in Mesa, Arizona



TABULATION OF TEST DATA

SOIL BORING or TEST PIT NUMBER	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE INTERVAL (ft)	NATURAL WATER CONTENT (Percent of Dry Weight)	IN-PLACE DRY DENSITY (Pounds Per Cubic Foot)	PARTICLE SIZE DISTRIBUTION (Percent Finer)					ATTERBERG LIMITS			UNIFIED SOIL CLASSIFICATION	SPECIMEN DESCRIPTION
						#200 SIEVE	#40 SIEVE	#10 SIEVE	#4 SIEVE	3" SIEVE	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX		
SP-1	BS-1	BULK	0.0 - 5.0	NT	NT	15	36	62	66	100	21	17	4	SC-SM	SILTY, CLAYEY SAND with GRAVEL
SP-2	BS-1	BULK	0.0 - 5.0	NT	NT	18	44	76	83	100	24	20	4	SC-SM	SILTY, CLAYEY SAND with GRAVEL
TP-1	BS-1	BULK	0.0 - 14.0	NT	NT	39	62	77	81	100	26	18	8	SC	CLAYEY SAND with GRAVEL
TP-2	BS-1	BS-1	0.0 - 5.0	NT	NT	41	74	80	82	100	23	21	2	SM	SILTY SAND with GRAVEL

Sieve analysis results do not include material greater than 3". Refer to the actual boring logs for the possibility of cobble and boulder sized materials.

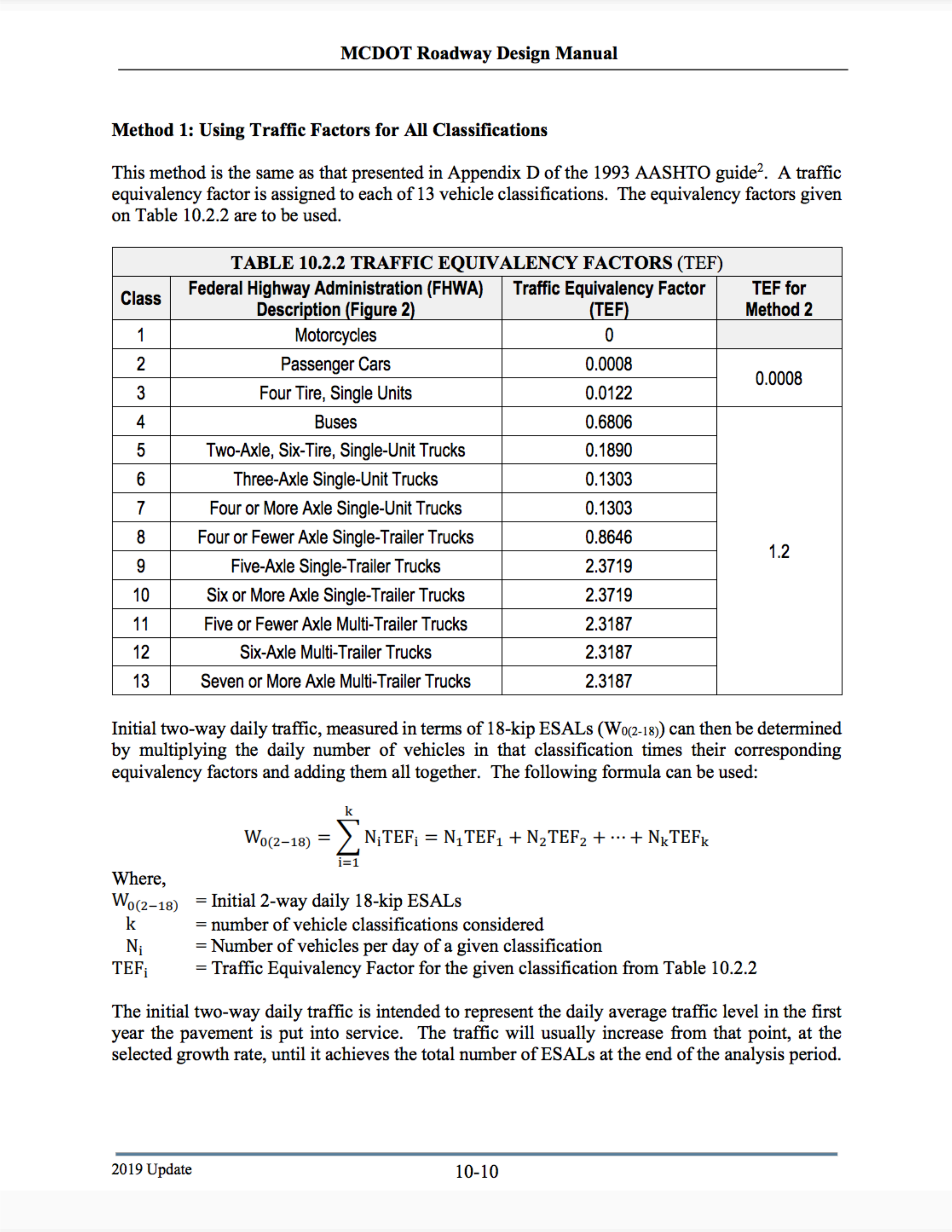
NT=Not Tested

Sheet 1 of 1

Cubs Spring Training Facility
NWC 8th Street & Dobson Road
Mesa, Arizona
Project No. 120372SA

SPEEDIE
AND ASSOCIATES

Appendix T- Method 1: Using Traffic Factors for all Classification



Method 1: Using Traffic Factors for All Classifications

This method is the same as that presented in Appendix D of the 1993 AASHTO guide[2]. A traffic equivalency factor is assigned to each of 13 vehicle classifications. The equivalency factors given on Table 10.2.2 are to be used.

TABLE 10.2.2 TRAFFIC EQUIVALENCY FACTORS (TEF)

Class	Federal Highway Administration (FHWA) Description (Figure 2)	Traffic Equivalency Factor (TEF)	TEF for Method 2
1	Motorcycles	0	
2	Passenger Cars	0.0008	0.0008
3	Four Tire, Single Units	0.0122	
4	Buses	0.6806	1.2
5	Two-Axle, Six-Tire, Single-Unit Trucks	0.1890	
6	Three-Axle Single-Unit Trucks	0.1303	
7	Four or More Axle Single-Unit Trucks	0.1303	
8	Four or Fewer Axle Single-Trailer Trucks	0.8646	
9	Five-Axle Single-Trailer Trucks	2.3719	
10	Six or More Axle Single-Trailer Trucks	2.3719	
11	Five or Fewer Axle Multi-Trailer Trucks	2.3187	
12	Six-Axle Multi-Trailer Trucks	2.3187	
13	Seven or More Axle Multi-Trailer Trucks	2.3187	

Initial two-way daily traffic, measured in terms of 18-kip ESALs ($W_{0(2\text{-}18)}$) can then be determined by multiplying the daily number of vehicles in that classification times their corresponding equivalency factors and adding them all together. The following formula can be used:

$$W_{0(2-18)} = \sum_{i=1}^{k} N_i TEF_i = N_1 TEF_1 + N_2 TEF_2 + \cdots + N_k TEF_k$$

Where,

$W_{0(2-18)}$ = Initial 2-way daily 18-kip ESALs

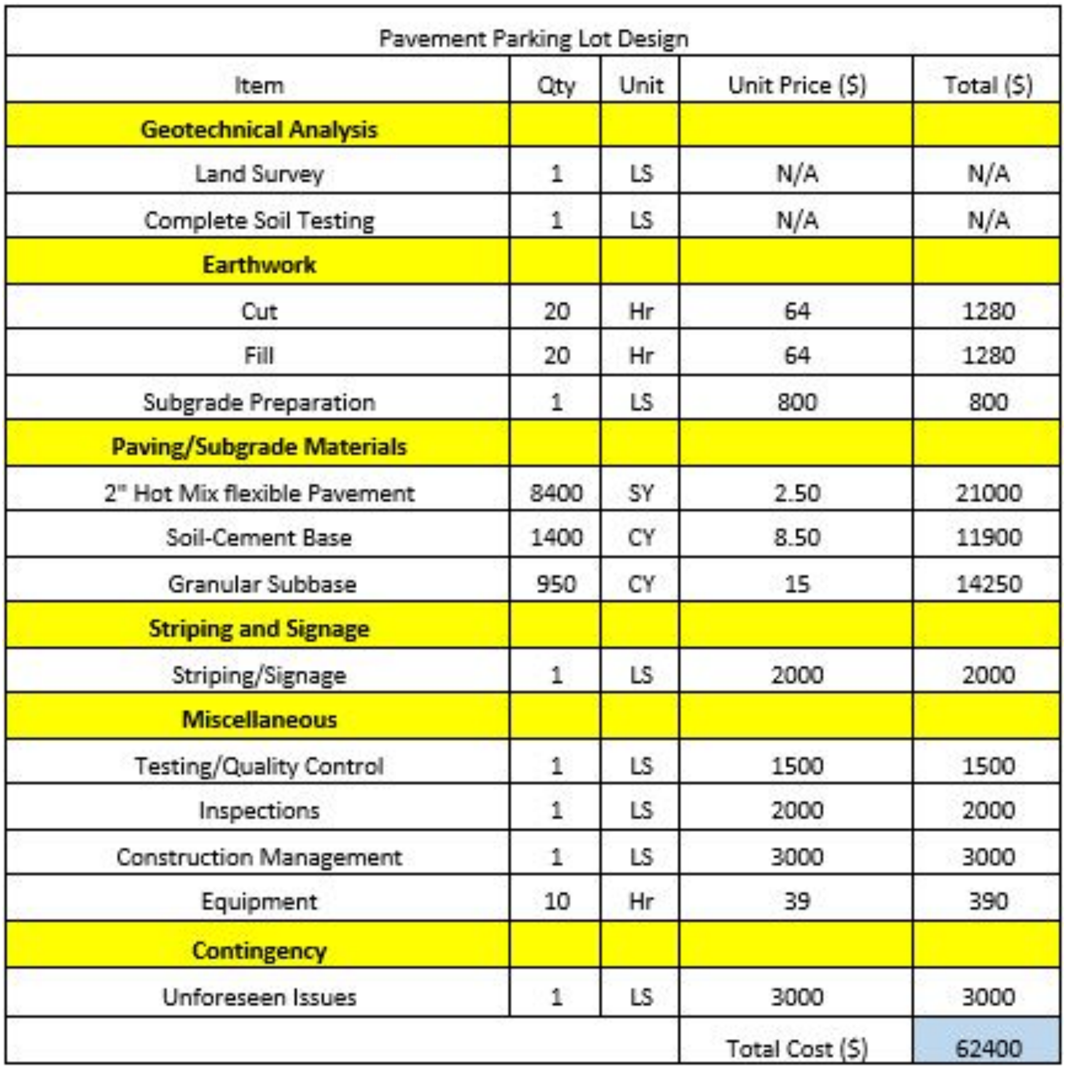
k = number of vehicle classifications considered

N_i = Number of vehicles per day of a given classification

TEF_i = Traffic Equivalency Factor for the given classification from Table 10.2.2

The initial two-way daily traffic is intended to represent the daily average traffic level in the first year the pavement is put into service. The traffic will usually increase from that point, at the selected growth rate, until it achieves the total number of ESALs at the end of the analysis period.

Appendix U- Cost breakdown for the asphalt parking lot pavement design



Pavement Parking Lot Design

Item	Qty	Unit	Unit Price ($)	Total ($)
Geotechnical Analysis				
Land Survey	1	LS	N/A	N/A
Complete Soil Testing	1	LS	N/A	N/A
Earthwork				
Cut	20	Hr	64	1280
Fill	20	Hr	64	1280
Subgrade Preparation	1	LS	800	800
Paving/Subgrade Materials				
2" Hot Mix flexible Pavement	8400	SY	2.50	21000
Soil-Cement Base	1400	CY	8.50	11900
Granular Subbase	950	CY	15	14250
Striping and Signage				
Striping/Signage	1	LS	2000	2000
Miscellaneous				
Testing/Quality Control	1	LS	1500	1500
Inspections	1	LS	2000	2000
Construction Management	1	LS	3000	3000
Equipment	10	Hr	39	390
Contingency				
Unforeseen Issues	1	LS	3000	3000
			Total Cost ($)	62400

Appendix V- Cost breakdown for the gravel parking lot pavement design

Gravel Lot Design

Item	Qty	Unit	Unit Price ($)	Total ($)
Geotechnical Analysis				
Land Survey	1	LS	N/A	N/A
Complete Soil Testing	1	LS	N/A	N/A
Earthwork				
Cut	15	Hr	64	960
Fill	15	Hr	64	960
Subgrade Preparation	1	LS	500	500
Subgrade Materials				
Crushed (Graded) Stone	1400	CY	8.50	11900
soil-aggregate Subbase	1000	CY	4.50	4500
Striping and Signage				
Striping/Signage	1	LS	500	500
Miscellaneous				
Testing/Quality Control	1	LS	1000	1000
Inspections	1	LS	2000	2000
Construction Management	1	LS	3000	3000
Equipment	3	Hr	39	117
Contingency				
Unforeseen Issues	1	LS	1500	1500
			Total Cost ($)	26937

Appendix W- Proposal Schedule for the 100% Progress including the Milestones

ID	Task Name	Duration
1	Task 1: Existing Due Diligence	7 days
2	**Task 2: On Site Investigation**	**13 days**
3	Task 2.1: Site Land Surveying	3 days
4	Task 2.2: Soil Sample Planning and Soil Sampling	4 days
5	Task 2.3: Formal Report	10 days
6	**Task 3: Geotechnical Analysis**	**15 days**
7	**Task 3.1: Complete Soil Testing**	**8 days**
8	Task 3.1.1: Moisture Content	3 days
9	Task 3.1.2: Atterberg Limits	4 days
10	Task 3.1.3: Sieve Analysis	3 days
11	Task 3.1.4: AASHTO/ USCS Soil Classification	1 day
12	Task 3.1.5: Hydrometer Test	3 days
13	Task 3.1.6: Direct Shear Test	3 days
14	Task 3.1.7: Relative Compaction Test	3 days
15	Task 3.2: Soil Report	10 days
16	Task 4: Survey Data Analysis	7 days
17	**Task 5: Hydrology and Hydraulic Analysis**	**9 days**
18	Task 5.1: Watershed and Stormwater Runoff Analysis	9 days
19	Task 5.2: Existing and Proposed Infrastructure Analysis	7 days
20	**Task 6: Traffic and Visitation Statistics**	**142 days**
25	Task 7: Parking Lot Deisgn and Development	12 days
26	Task 8: Construction Plan Set	14 days
27	Task 9: Construction Costs	7 days
28	Task 10: Impact Analysis	3 days
29	**Task 11: Project Management**	**76 days**
30	**Task 11.1: Meetings**	**72.25 days**
31	**Task 11.1.1: Technical Advisor Meetings**	**71 days**
37	**Task 11.1.2: Client Meetings**	**45.25 days**
41	**Task 11.1.3: Grading Instructor**	**70.25 days**
57	**Task 11.2: Resource and Schedulig Management**	**71 days**
66	**Task 11.3: Deliverables**	**60 days**
67	Task 11.3.1: 30% Submittal	6 days
68	Task 11.3.2: 60% Submittal	6 days
69	Task 11.3.3: 90% Submittal Website	6 days
70	Task 11.3.4: Final Submittal and Website	6 days

Project: FINAL SCHEDULE-Versi
Date: Thu 4/23/20

Page 1

Figure 8- 17: Proposal Schedule for the 100% Progress including the Milestones