Chiricahua National Monument Site Design

CENE 486C

May 2nd, 2025

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Project Purpose & Location

- 30 miles SE of Willcox, AZ
- East of Pinery Canyon Rd, off State Route 181
- Adds essential housing options
- Supports volunteer/seasonal staff, benefits park employees, and creates jobs
- Client: Sam Bell, NPS Chief of Facilities

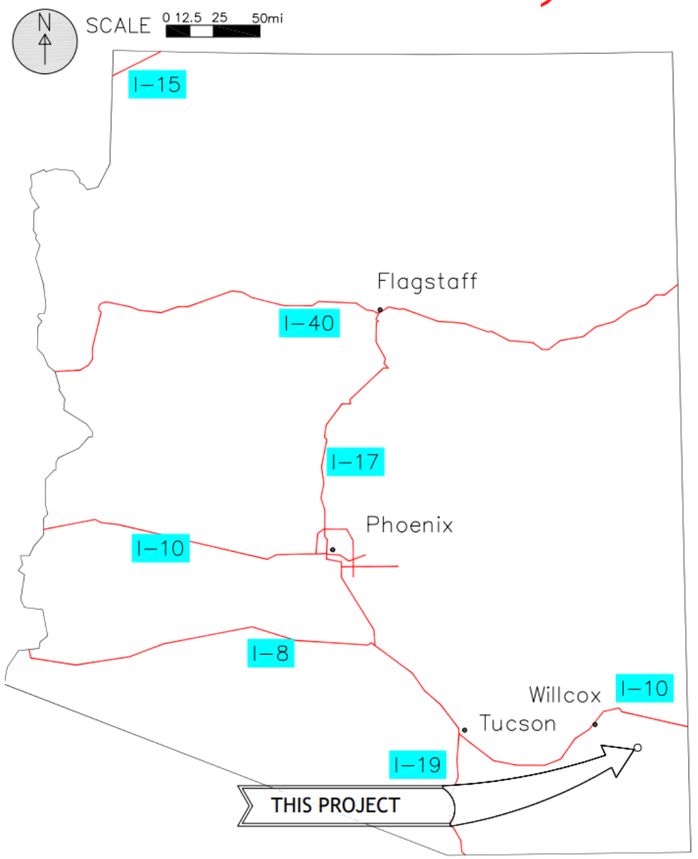


Figure 1: Location Map

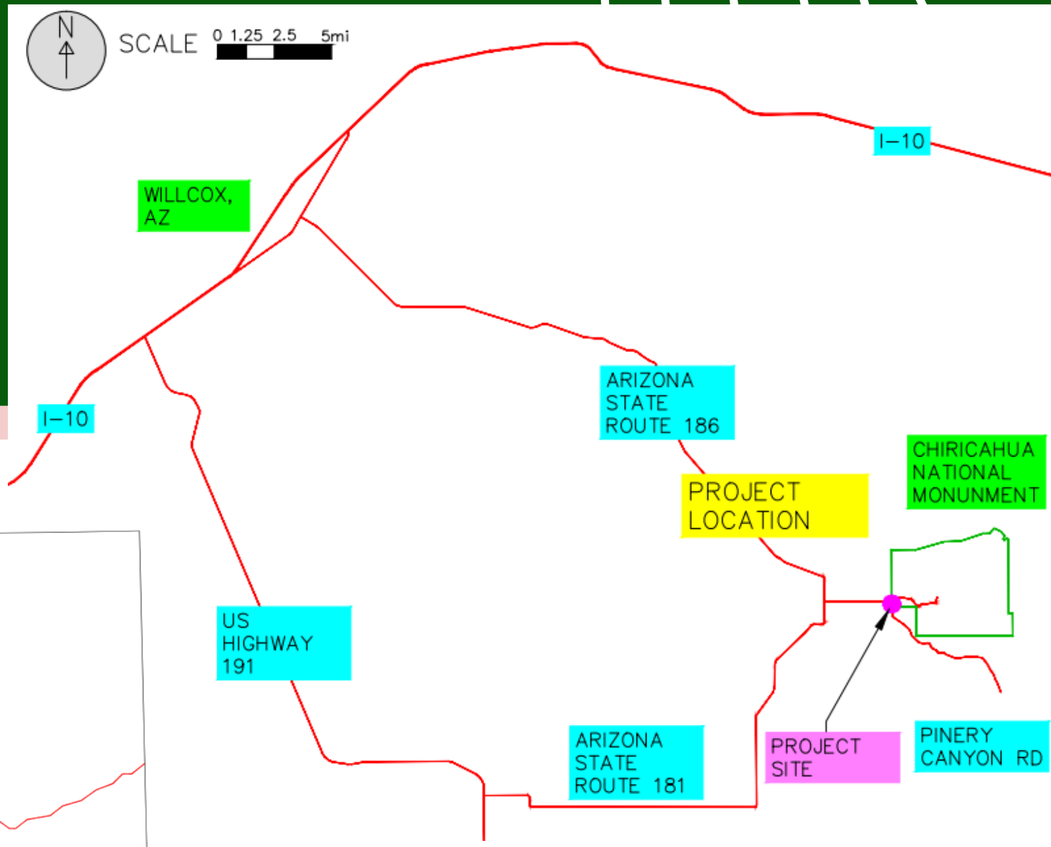


Figure 2: Vicinity Map

Current Conditions & Area of Work

- Flat land with mostly dead vegetation
- Channel very natural and vegetated
- Culvert conveying a flow but quite covered in debris
- No protected plant life or large trees
- Well pump-house, electric pole can’t be displaced
- Smooth, wide dirt road

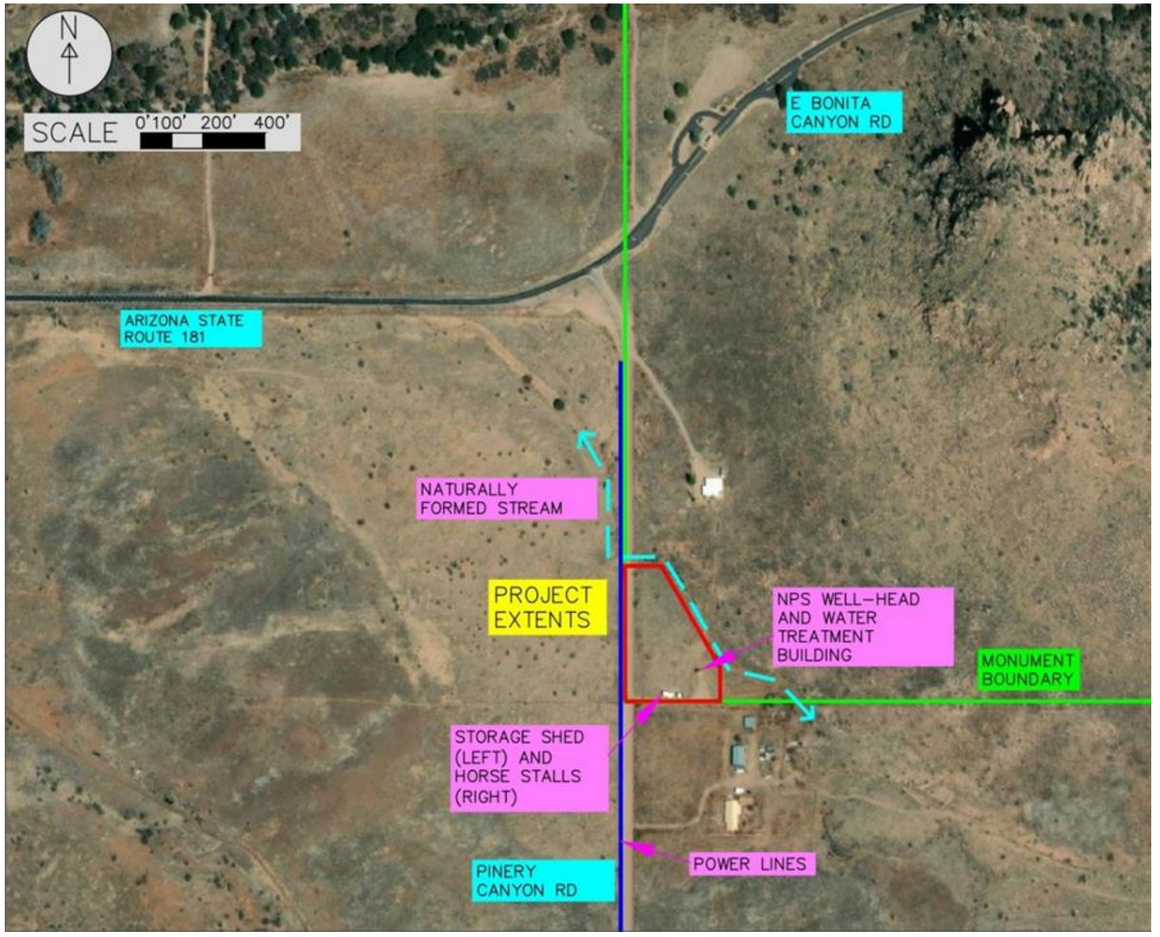


Figure 3: Project Map

General Site Conditions

Figure 4: GPS Base Station (Facing Northeast)

Figure 5: Site Conditions (Facing South-West)

Soil & Survey Data Collection

Soil Sample Collection

- Soil is very rocky, dry, & compacted
- 4 samples
- Holes 3-4in deep, 4-5in wide

Figure 6: Inside of Culvert

Figure 7 Sample #1

Surveying

- 750 points
- 2% slope downwards South to North
- Survey boundaries extend past the site boundaries

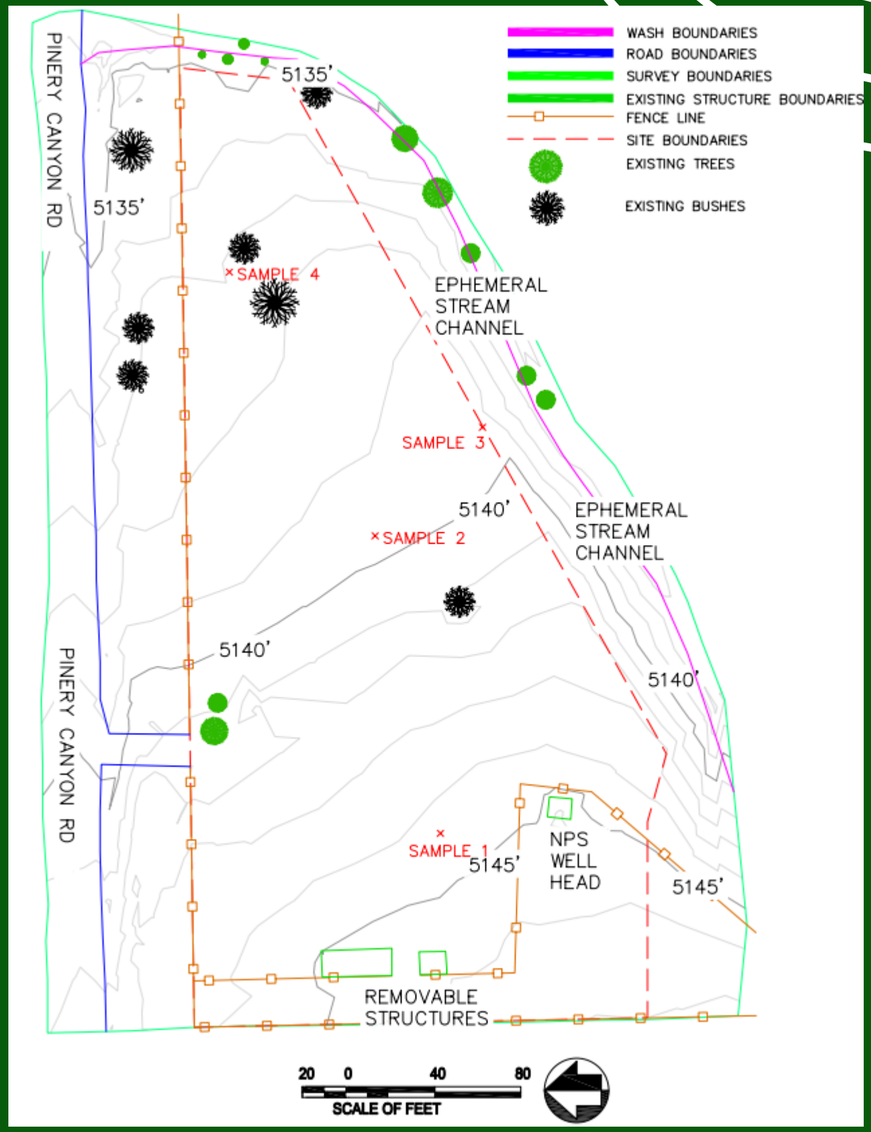


Figure 8 Topographic Map

Sieve Particle Distribution

Sieve Particle Distribution Test

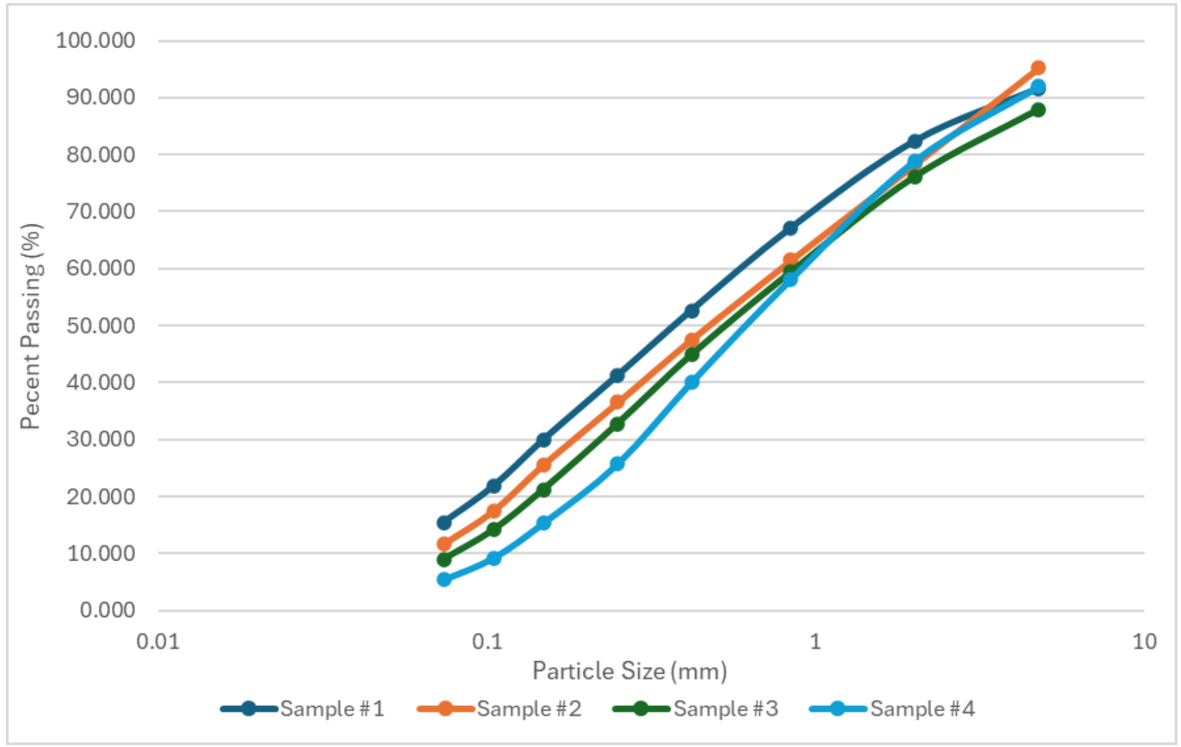
Sieves Used:

- Sieve No.4
- Sieve No.10
- Sieve No.20
- Sieve No.40
- Sieve No.60
- Sieve No.100
- Sieve No.140
- Sieve No.200
- Bottom Pan

- ~750g of soil per test used
- Shaken for 20 minutes

Figure 9: Sieves Used

Sieve Particle Distribution Curves



Atterberg Limit Test

Atterberg Limits Test

- Only soil that made it through #40 sieve was used
- 250-300g test samples
- 5 sub-samples for liquid limit
- 3 sub-samples for plastic limit
- Plastic Index determined

Figure 10: Liquid Limit Test

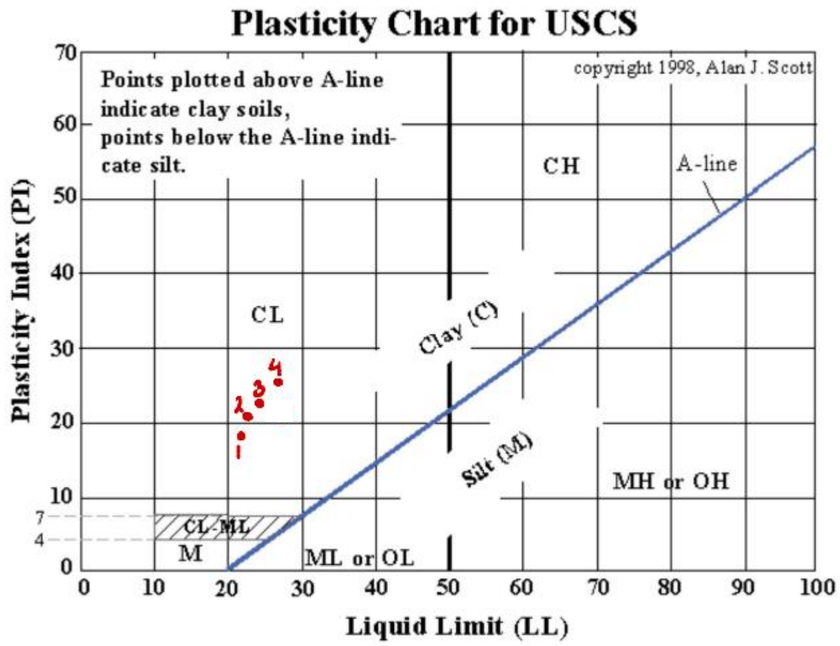
Atterberg Limits Results

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

Figure 11: Plastic Limit Test

Soil Types Results

- Soil Classification



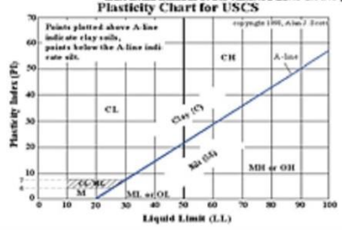
UNIFIED SOIL CLASSIFICATION SYSTEM

Soils are visually classified for engineering purposes by the Unified Soil Classification System. Grain-size analyses and Atterberg Limits tests often are performed on selected samples to aid in classification. The classification system is briefly outlined on this chart. Graphic symbols are used on boring logs presented in this report. For a more detailed description of the system, see "Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)" ASTM Designation: 2488-84 and "Standard Test Method for Classification of Soils for Engineering Purposes" ASTM Designation: 2487-85.

	MAJOR DIVISIONS		GRAPHIC SYMBOL	GROUP SYMBOL	TYPICAL NAMES
COARSE-GRAINED SOILS (Less than 50% passes No. 200 sieve)	GRAVELS (50% or less of coarse fraction passes No. 4 sieve)	CLEAN GRAVELS (Less than 5% passes No. 200 sieve)		GW	Well graded gravels, gravel-sand mixtures, or sand-gravel-cobble mixtures
				GP	Poorly graded gravels, gravel-sand mixtures, or sand-gravel-cobble mixtures
		GRAVELS WITH FINES (More than 12% passes No. 200 sieve) — Limits plot below "A" line & hatched zone on plasticity chart		GM	Silty gravels, gravel-sand-silt mixtures
		GRAVELS WITH FINES (More than 12% passes No. 200 sieve) — Limits plot above "A" line & hatched zone on plasticity chart		GC	Clayey gravels, gravel-sand-clay mixtures
	SANDS (50% or more of coarse fraction passes No. 4 sieve)	CLEAN SANDS (Less than 5% passes No. 200 sieve)		SW	Well graded sands, gravelly sands
				SP	Poorly graded sands, gravelly sands
		SANDS WITH FINES (More than 12% passes No. 200 sieve) — Limits plot below "A" line & hatched zone on plasticity chart		SM	Silty sands, sand-silt mixtures
		SANDS WITH FINES (More than 12% passes No. 200 sieve) — Limits plot above "A" line & hatched zone on plasticity chart		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more passes No. 200 sieve)	SILTS (Limits plot below "A" line & hatched zone on plasticity chart)	SILTS OF LOW PLASTICITY (Liquid Limit less than 50)		ML	Inorganic silts, clayey silts of low to medium plasticity
		SILTS OF HIGH PLASTICITY (Liquid Limit 50 or more)		MH	Inorganic silts, micaceous or diatomaceous silty soils, elastic silts
	CLAYS (Limits plot above "A" line & hatched zone on plasticity chart)	CLAYS OF LOW PLASTICITY (Liquid Limit less than 50)		CL	Inorganic clays of low to medium plasticity, gravelly, sandy, and silty clays
		CLAYS OF HIGH PLASTICITY (Liquid Limit 50 or more)		CH	Inorganic clays of high plasticity, fat clays, sandy clays of high plasticity
	ORGANIC SILTS AND CLAYS	ORGANIC SILTS AND CLAYS OF LOW PLASTICITY (Liquid Limit less than 50)		OL	Organic silts and clays of low to medium plasticity, sandy organic silts and clays
		ORGANIC SILTS AND CLAYS OF HIGH PLASTICITY (Liquid Limit 50 or more)		OH	Organic silts and clays of high plasticity, sandy organic silts and clays
ORGANIC SOILS	PRIMARILY ORGANIC MATTER (dark in color and organic odor)			PT	Peat

NOTE: Coarse-grained soils with between 5% and 12% passing the No. 200 sieve and fine-grained soils with limits plotting in the hatched zone on the plasticity chart have dual classifications.

Plasticity Chart for USCS



DEFINITION OF SOIL FRACTIONS

SOIL COMPONENT	PARTICLE SIZE RANGE
Boulders	Above 12 in.
Cobbles	12 in. to 3 in.
Gravel	3 in. to No. 4 sieve
Coarse gravel	3 in. to 3/4 in.
Fine gravel	3/4 in. to No. 4 sieve
Sand	No. 4 to No. 200 sieve
Coarse sand	No. 4 to No. 10 sieve
Medium sand	No. 10 to No. 40 sieve
Fine sand	No. 40 to No. 200 sieve
Fines (silt and clay)	Less than No. 200 sieve

Sample #1

Sample #2, #3, #4

Proctor Compaction Test

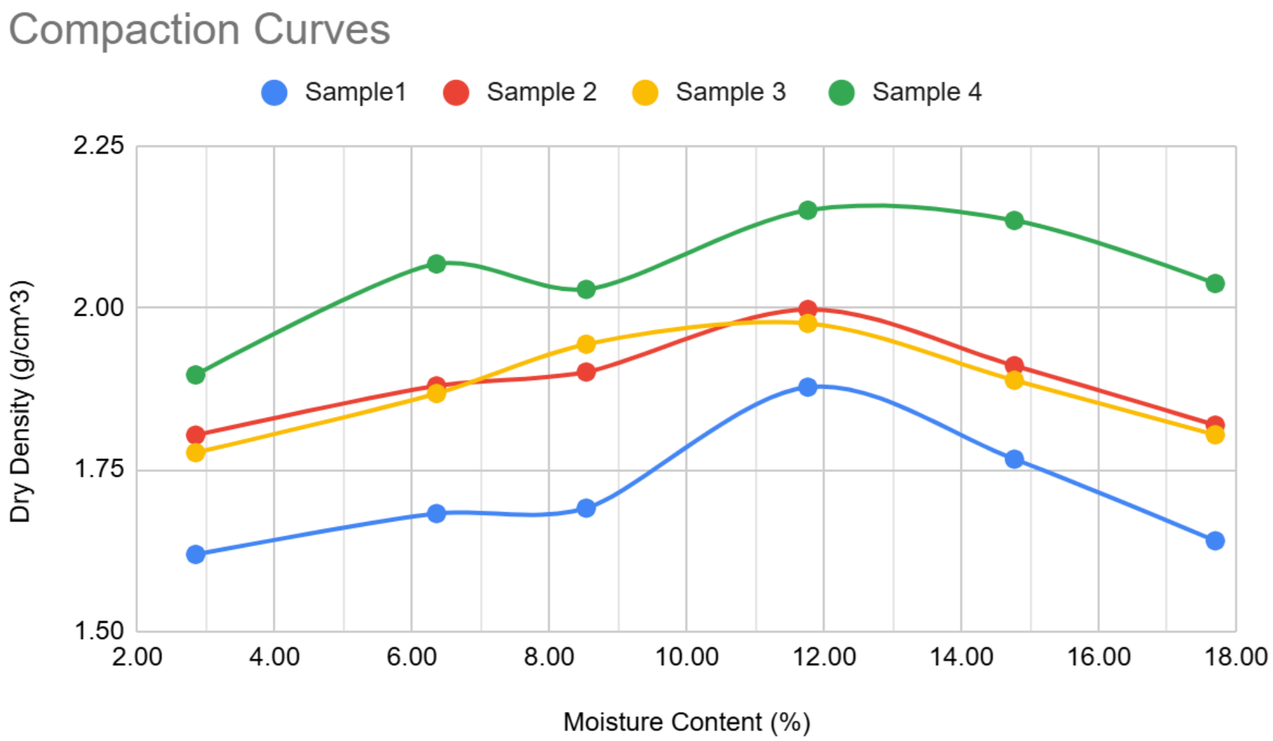
Modified Proctor Compaction Test

- Used only soil that makes it through #4 sieve
- 2000-3000g test samples
- 3% moisture added per test, each test had a total of 5 layers with 25 blows between each layer
- 4-5 tests before weight reduced or soil became soupy

Figure 12: Compacted Soil

Proctor Compaction Test (con)

Modified Proctor Compaction Test results



	Sample 1	Sample 2	Sample 3	Sample 4
max dry density (g/cm^3)	1.88	2	1.98	2.15
optimal moisture content (%)	11.76	10.86	12.26	12.11

Hydrological Analysis

Watershed Delineation

- Area of Watershed: 0.41mi²/ 262.4 acres
- Length of Longest Water Course: 6869ft

Figure 13: Site Watershed

Hydrological Analysis (con)

Parameters

- Watershed Area: 0.41mi²/ 262.4 acres
- Watershed Type: Undeveloped Foothills
- Length of Longest Watercourse: 6869ft
- Impervious Cover: 0%
- NRC-SCS Soil Type: Spread of B, C, and D
- Soil Percentage: 100%
- Veg. Type: Herbaceous
- Veg. Percentage: 9% as per soil map report
- NOAA's Rainfall Data

Results

	50-year	100-year	Units
Weighted Runoff Coef. (Wc)	0.58	0.61	Unitless
Time of Concentration	12.7	11.8	min
Rainfall Intensity (i)	7.33	8.7	in/hr
Runoff Supply Rate (q)	4.25	5.1	in/hr
Peak Discharge	1124.9	1347.7	cfs

Table 1: Results of Hydrological Analysis

Hydrological Analysis (con)

- Manning's Equation

$$Q = VA = \left(\frac{1.49}{n}\right) AR^{\frac{2}{3}} \sqrt{S} \quad [U.S.]$$

Area (A)	72.5	ft^2
Hydraulics Radius (R)	3.18	ft
n	0.06	Unitless
Slope (S)	0.02	Unitless
Velocity (V)	7.5	ft/s
Flow (Q)	544.54	cfs

Alternatives Pursued

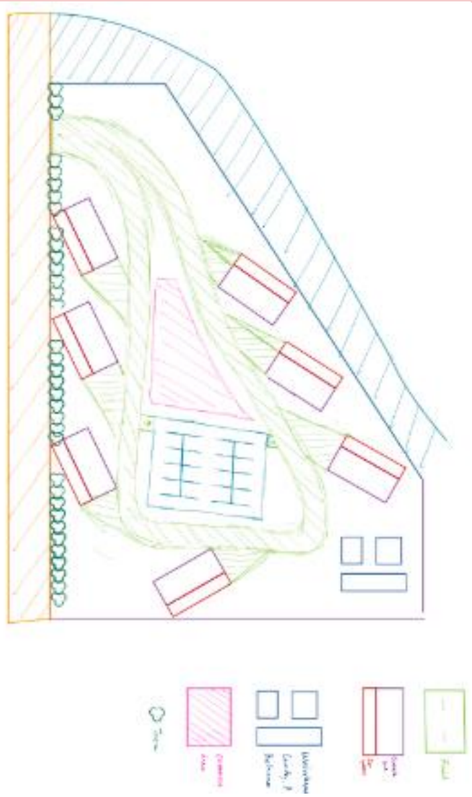


Figure 14: Alternative 1

Figure 15: Alternative 2

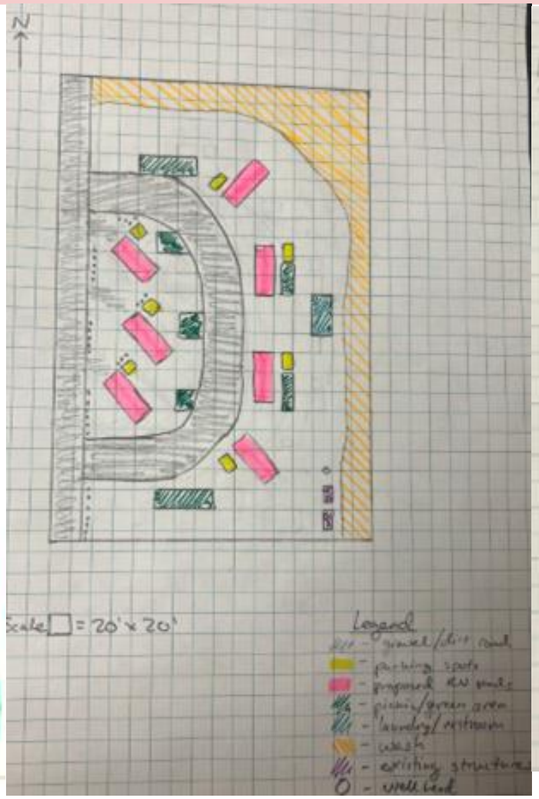


Figure 16: Alternative 3

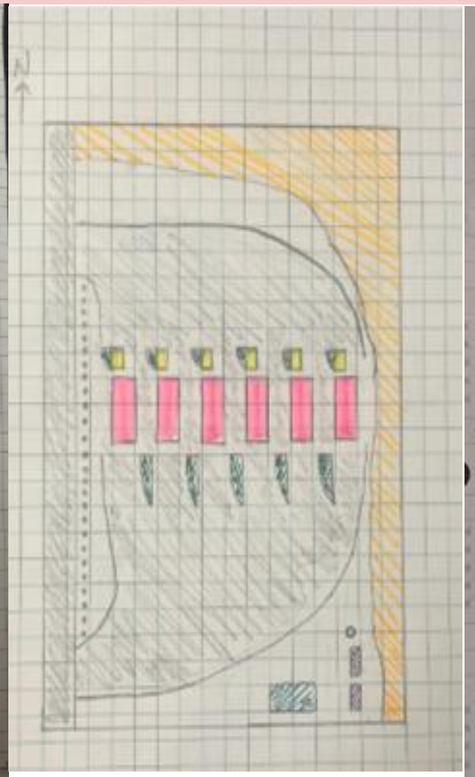


Figure 17: Alternative 4

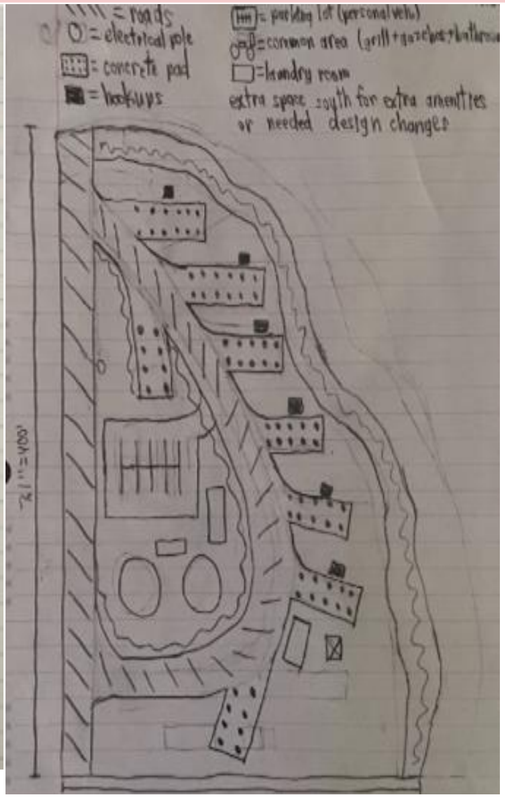


Figure 18: Alternative 5

Decision Matrix

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

1= Does not meets expectations

2= Has qualities above and below

3= Meets expectations

4= Has qualities above and below

5= Exceeds expectations

Alternatives Pursued (con)

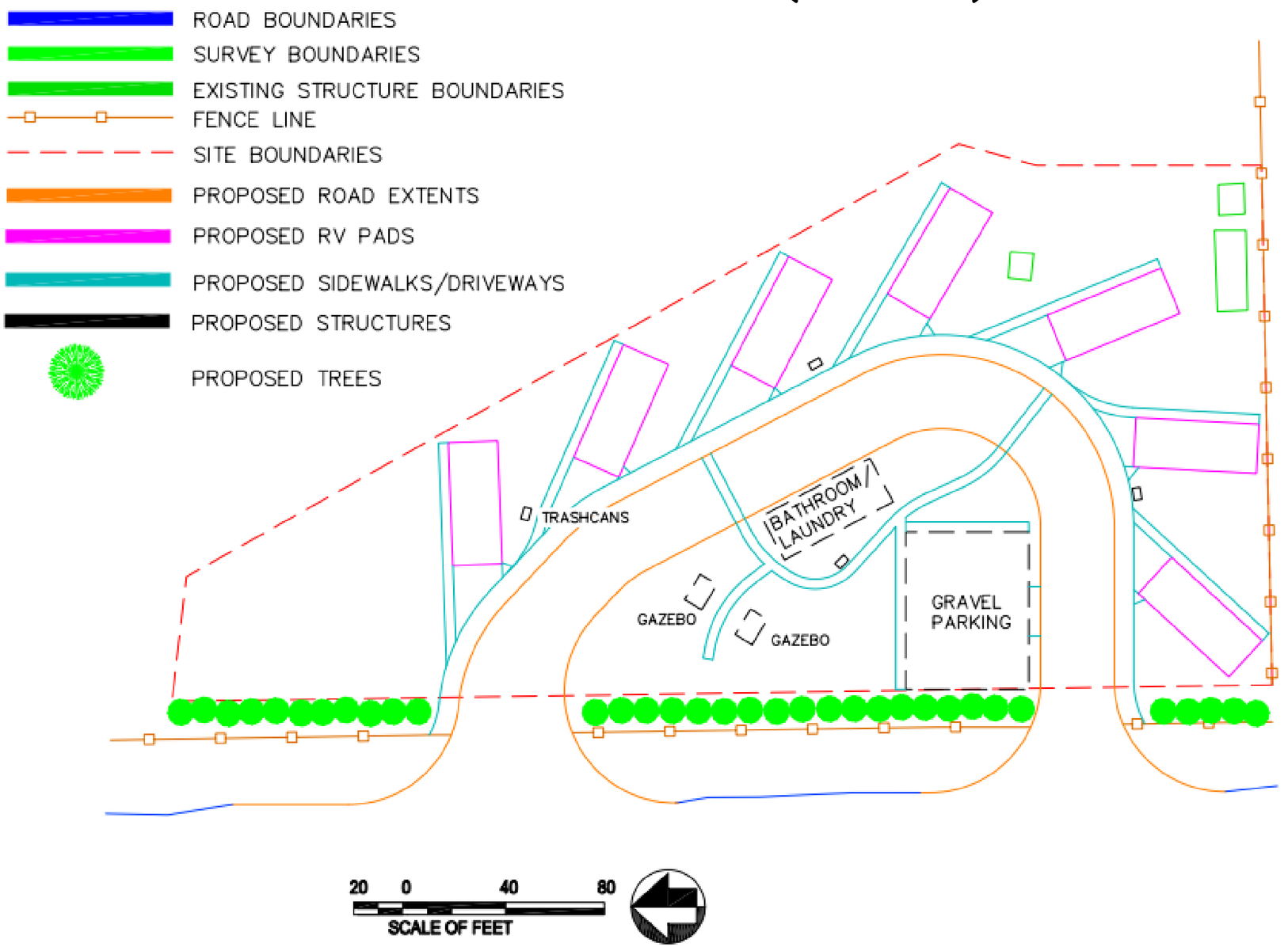
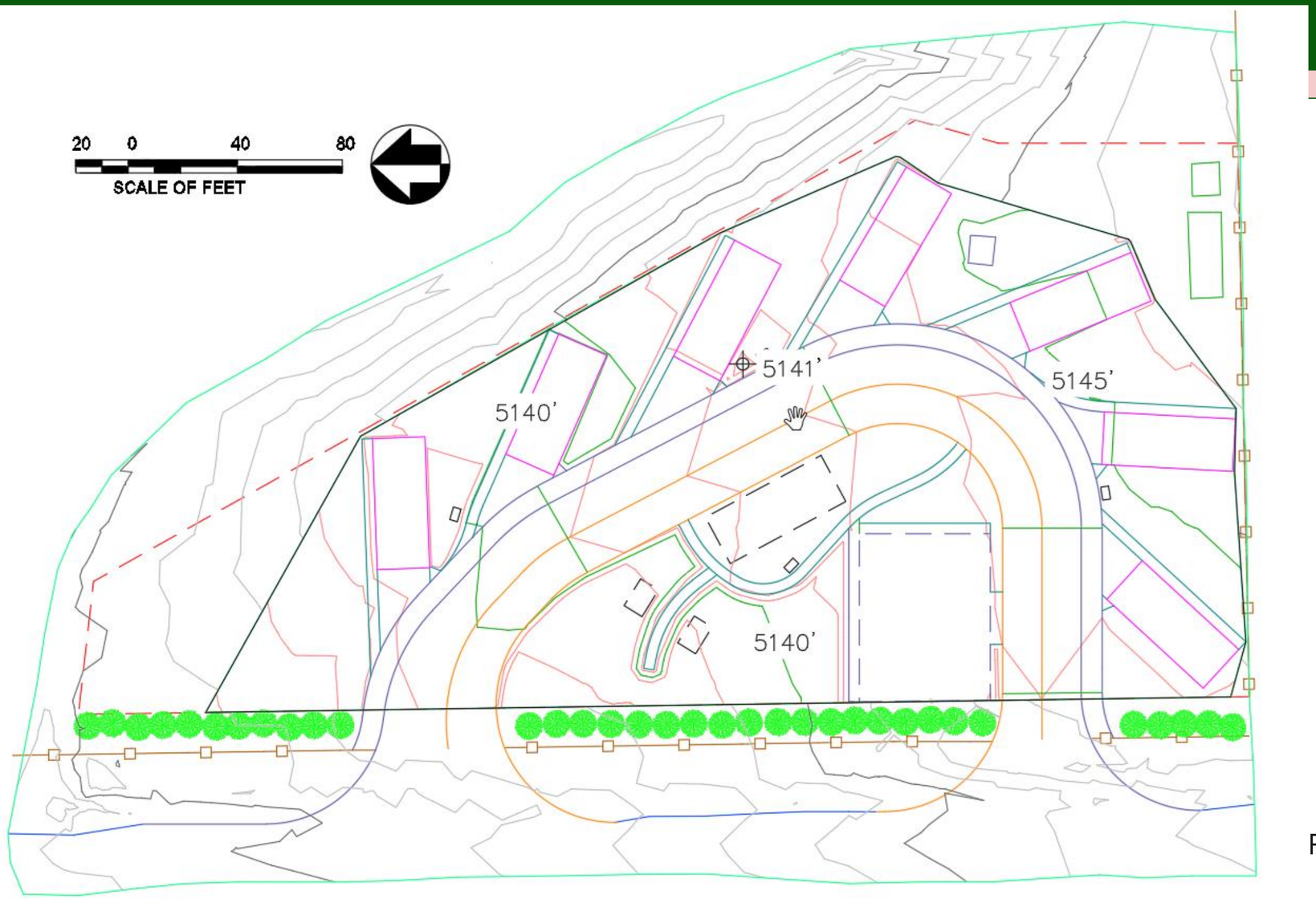


Figure 19: Final Alternative

Grading and Cut/Fill



- Total Cut: 90 Cu. Yd.
- Total Fill: 1315.54 Cu. Yd.
- Net: 1225.49 Cu. Yd.

Figure 20: Proposed Site Grading

Roadway Design

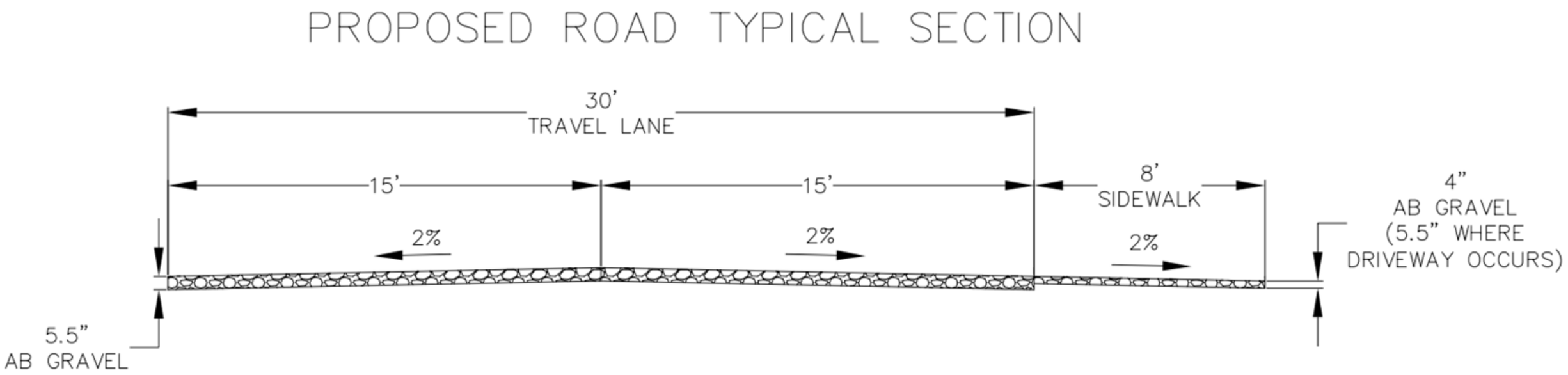
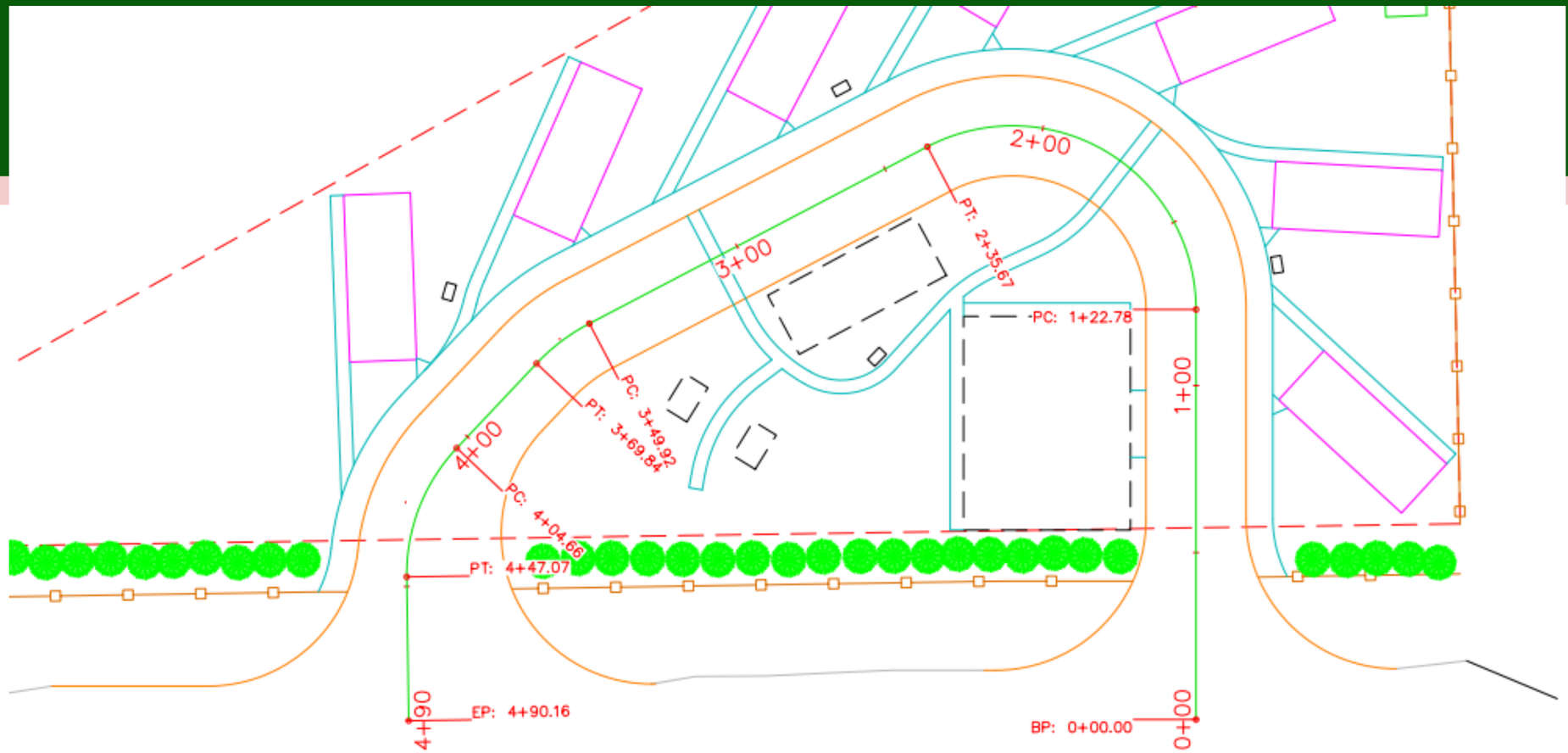


Figure 21: Road Cross Section

Roadway Design (con)



PROPOSED ROAD								
LINE/CURVE	START STA.	END STA.	P.I. STA.	LENGTH	RADIUS	TANGENT LENGTH	AZIMUTH (LINE) / DELTA (CURVE)	DELTA/2
L1	0+00.00	1+22.78		122.78'			90°00'00"	
C1	1+22.78	2+35.67	2+13.60	112.89'	55'	90.83'	117°36'18"	58° 48' 09"
L2	2+35.67	3+49.92		114.25'			332°23'42"	
C2	3+49.92	3+69.84	3+59.97	19.92'	60'	10.05'	19°01'32"	9° 30' 46"
L3	3+69.84	4+04.66		34.82'			313°22'10"	
C3	4+04.66	4+47.07	4+26.98	42.41'	55'	22.33"	44°11'18"	5° 22' 39"
L4	4+47.07	4+90.16		43.09'			269°10'52"	

Figure 22: Proposed Road Plan

Roadway Design (con)

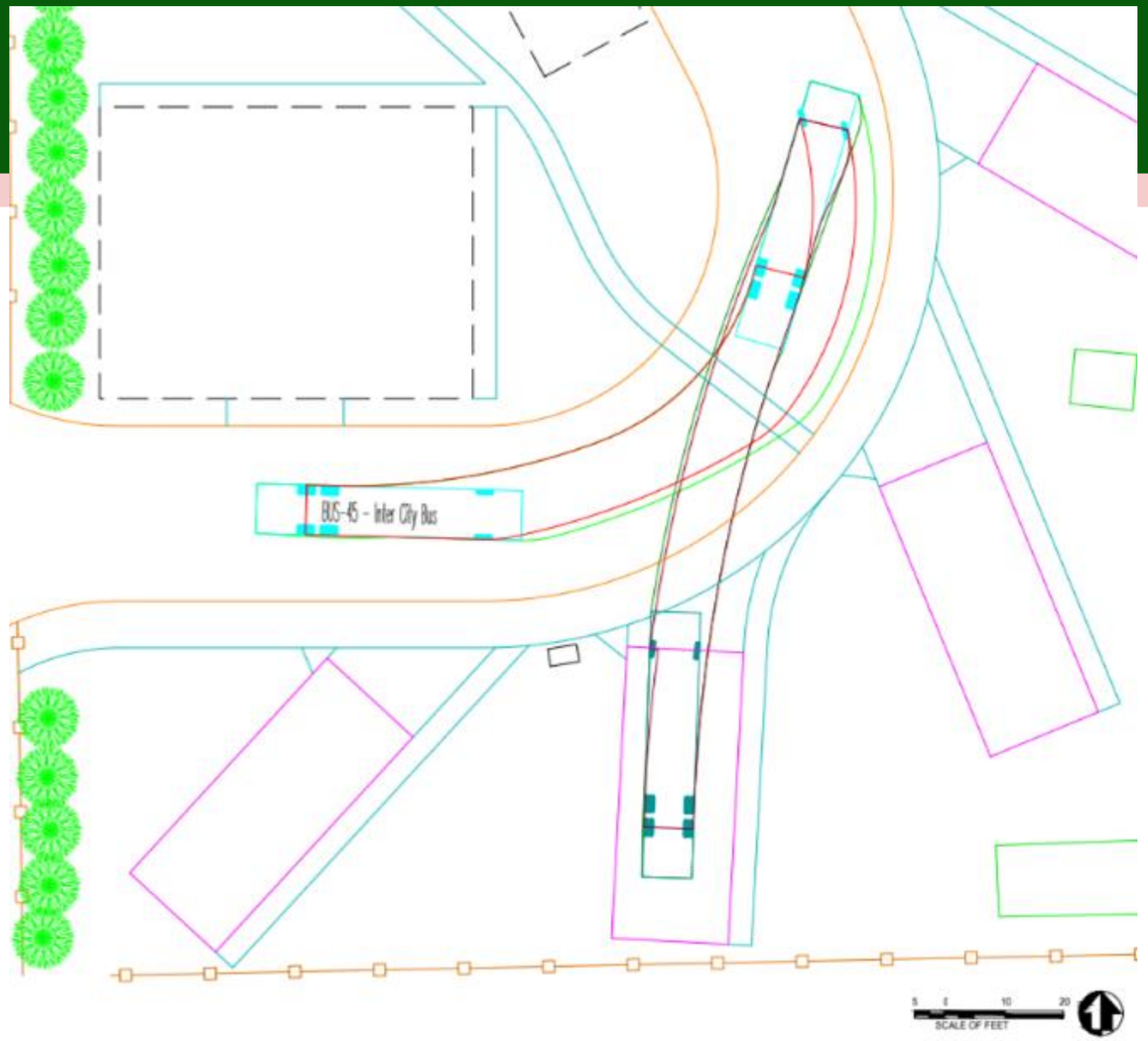


Figure 23: Pad 2 Turning Movement

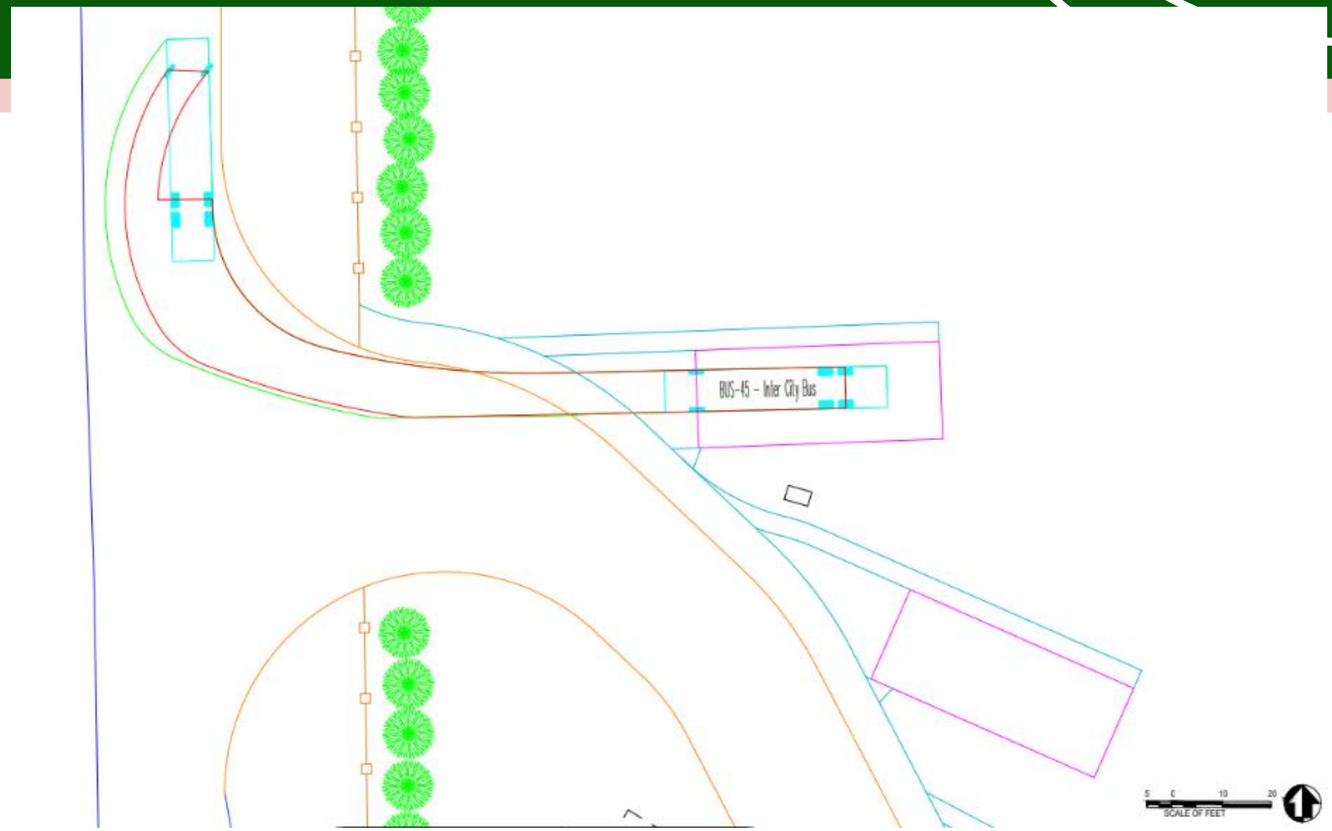


Figure 24: Pad 7 Turning Movement

Roadway Design (con)

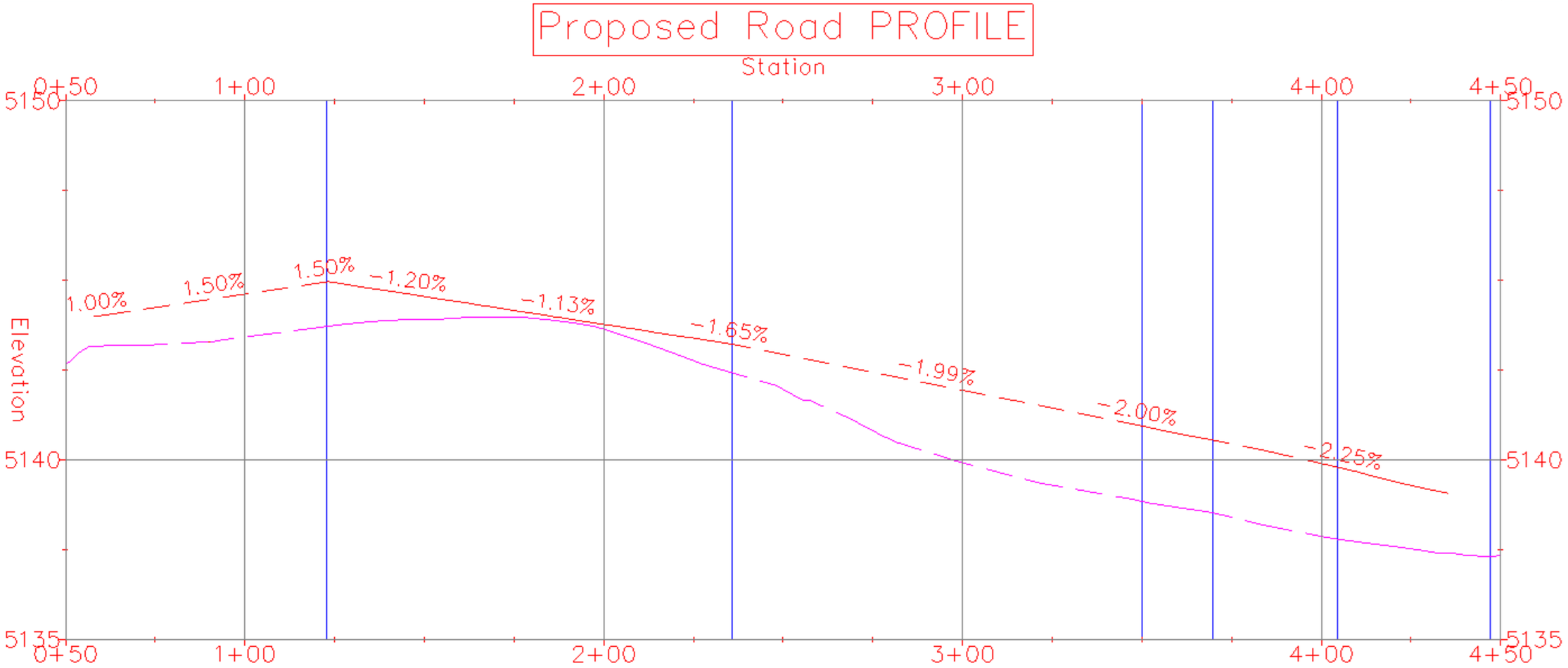


Figure 25: Proposed Road Profile

RV Pads and Concrete

RV Pads

- 50’ x 20’ concrete pad
- Full utility hookups on driver side
- Less than 2% longitudinal slope, less than 1% cross slope
- Crown of 0.5% slope designed for drainage
- 9” depth on edges, 9.5” depth at tip of crown
- 10” aggregate below concrete

Concrete

- MAG AA, 1” machine with AEA (air-entraining agent)
- Rated for 4000 psi

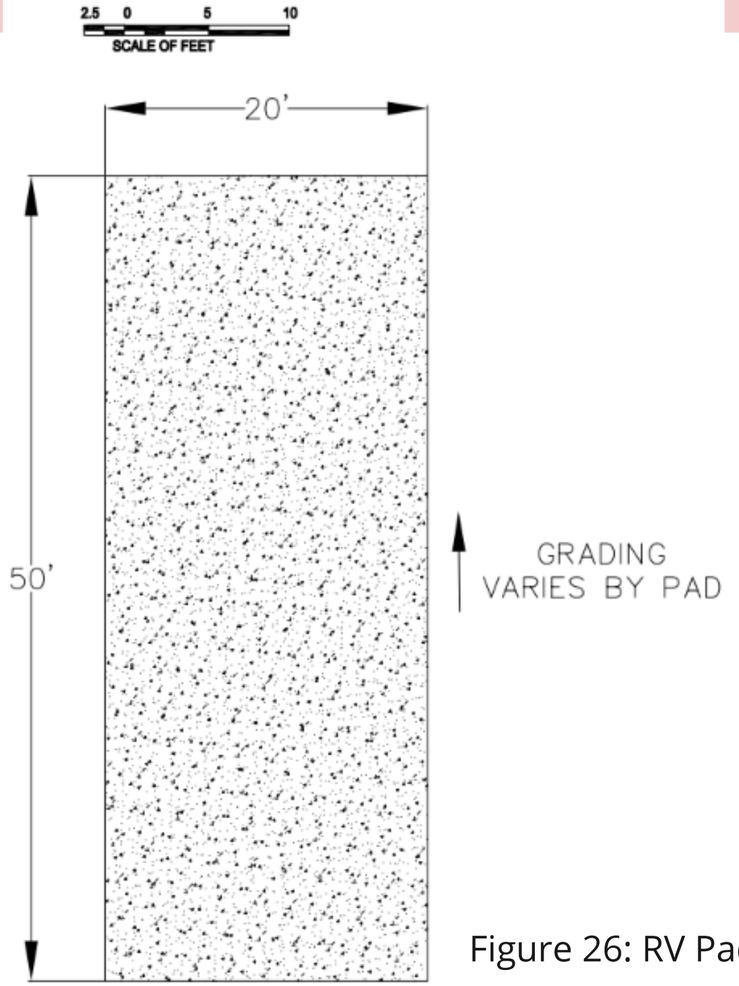


Figure 26: RV Pad Top Down

RV Pad Cross Section

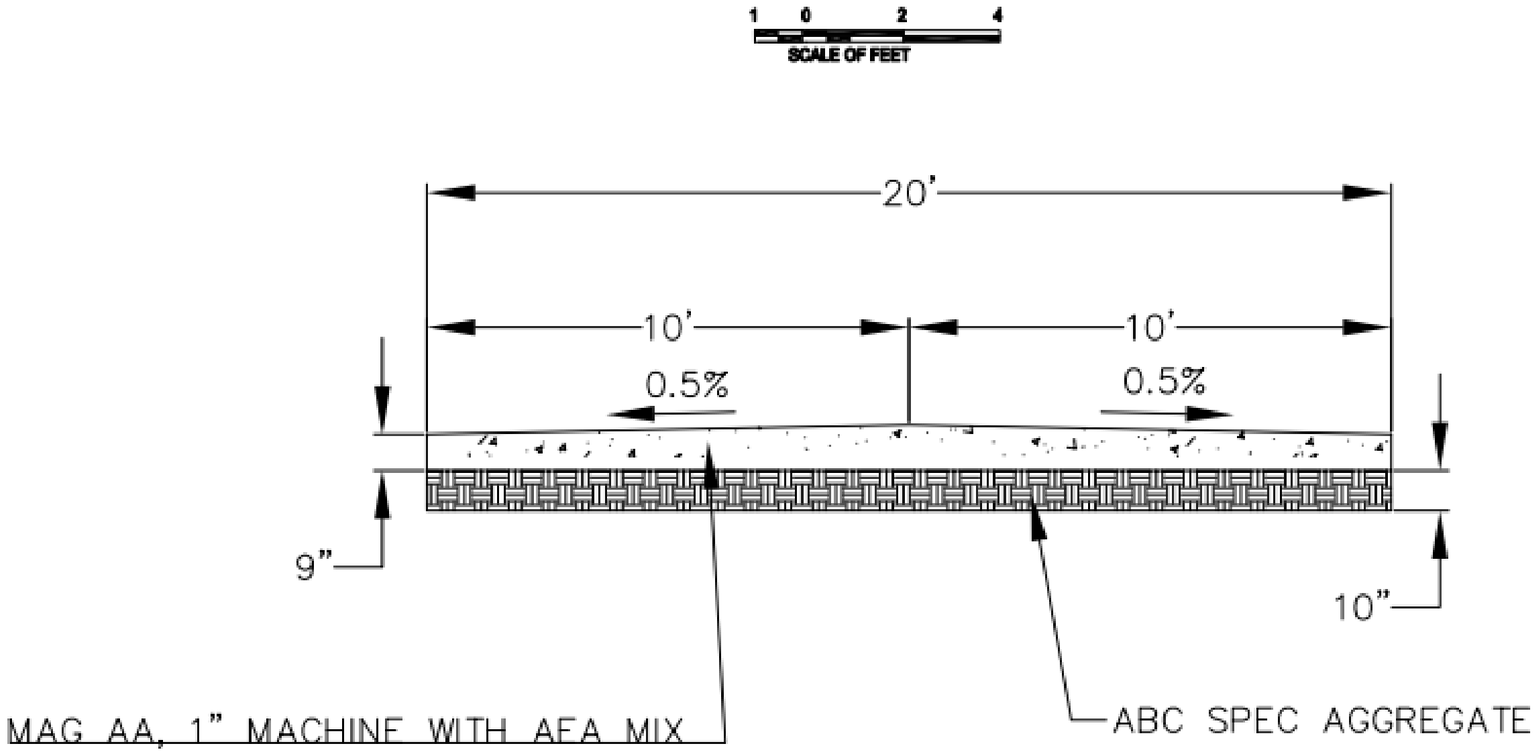


Figure 27: RV Pad Typical Cross Section

RV Pad Rebar Details

- ASTM A-615 grade 60 rebar
- #4 rebar
- across 50 foot side: 136 rebar 19.5ft long
- Across 20 foot side: 54 rebar 49.5ft long
- ACI 360R-10 and NPS Structural Engineering Standards

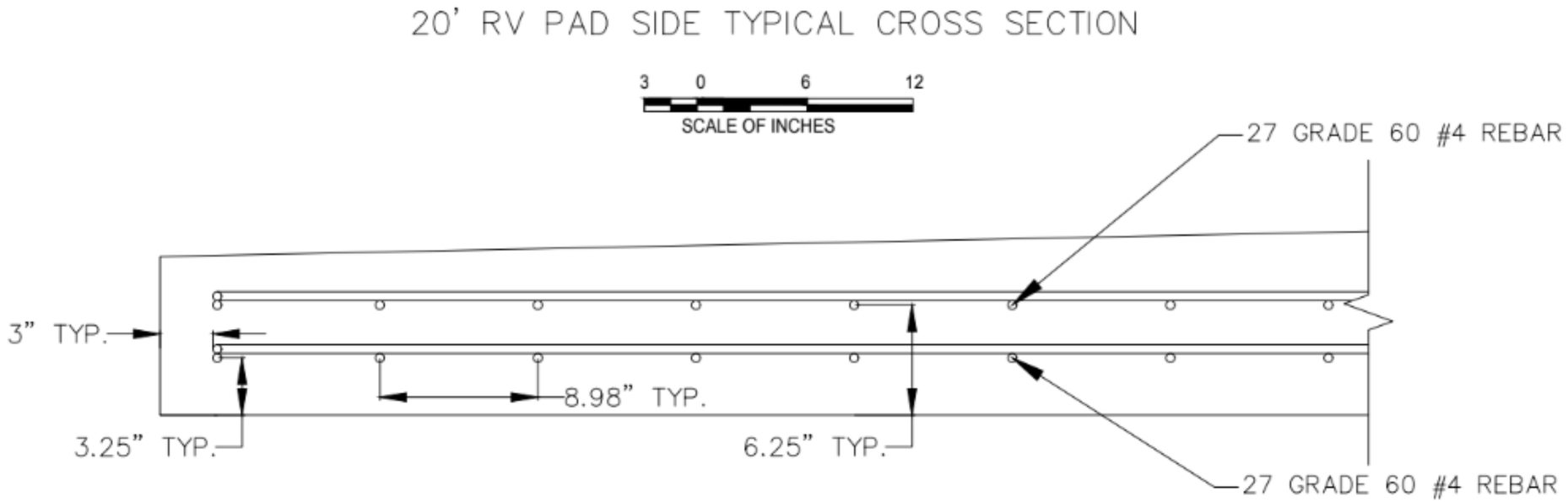


Figure 28: RV Pad 20' side Rebar Cross Section

Site Amenities and Improvements

- Solar Panels on roofs
- Outdoor Gazebos with benches
- Amber low-effect lighting
- Privacy Treeline (west of site)
- ADA accessible
- Sidewalks
- Animal Proof Trash cans
- Covered Parking lot for vehicles (by someone else)
- Left room for future design of laundry/bathroom

Figure 29: Example Gazebo

Post-Development Hydrological Analysis

Parameters

- Watershed Area: 0.41mi²/ 262.4 acres
- Watershed Type: Undeveloped Foothills
- Length of Longest Watercourse: 6869ft
- Impervious Cover: 0.12%
- NRC-SCS Soil Type: B
- Soil Percentage: 100%
- Veg. Type: Herbaceous
- Veg. Percentage: 9%
- NOAA's Rainfall Data

Results

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

Cost of Implementing Design

Cost of Construction

	Cost of Construction
Category	Cost
Site Amenities	$83,845.30
Green Improvements	$105,162.00
Concrete	$231,977.52
Roads/Sidewalk	$262,630.41
Earthwork	$45,057.38
Equipment	$39,000.00
Project Total	**$767,672.61**

Estimated Annual O&M Costs

	Estimated O&M Costs
Category	Cost
Site Amenities	$1,425.37
Green Improvements	$1,577.43
Concrete	$4,639.55
Roads/Sidewalk	$13,788.10
Earthwork	$1,892.41
Project Total	**$23,322.86**

Impacts Analysis

	Economic	Environmental	Social
Pros	Improves local economy through tourism, job creation, and economic growth	Adding a roadside treeline and solar on every roof; Uses gravel/AB binder and temporary structures for everything but the pads	Repurposes unused land into on-site housing for volunteers/employees; Common area/centralized amenities; Supports effort for National Park recognition
Cons	Local infrastructure may need costly upgrades; Costs to construct project	Removes natural vegetation on site; Risk of environmental degradation (e.g. littering)	Seasonal downtime may lead to underutilized facilities and job insecurity

References

[1] M. Co., *Microsoft Excel,* Microsoft Corporation, 2024.

[2] A. International, "Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft3 (2,700 kN-m/m3))," 05 07 2021. [Online]. Available: https://www.astm.org/d1557-12r21.html. [Accessed 21 03 2024].

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QUESTIONS?

ELEVATION ENGINEERING