ATTACHMENT 3

Access Road Drainage Calculations

Falls Village/Canaan
8 Barnes Road
Town of Canaan
Litchfield County, Connecticut

Prepared for:

SAI Communications
500 Enterprise Drive
Rocky Hill, CT 06067

Prepared by:

CHA

2139 Silas Deane Highway
Suite 212
Rocky Hill, Connecticut 06067-2336
(518) 257-4557

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INTRODUCTION

The proposed tower site is located in the Town of Canaan, Litchfield County in northwest Connecticut. The Town is bounded by the town of Salisbury to the west, North Canaan to the north, Norfolk to the east, and Cornwall to the south. The project site is located about 35 miles northwest of Hartford, the State's capital.

The entrance to the existing gravel access drive at 8 Barnes Road is located at the base of Cobble Hill, approximately 1.75 miles east of Falls Village. The gravel access drive ascends Cobble Hill on a northwest to southeast oriented ridge that begins immediately at the Barnes Road entrance (Elevation 664 feet) and climbs steeply up to the ridge of Cobble Hill and terminates at elevation 1203 after passing over the Cobble Hill crest which is approximately 1000 feet west of the proposed tower. (See Figure 1 – Site Location Map and Figures 3A-3E – Existing Site).

The proposed gravel access drive to the cell site will consist of approximately 5,200 feet of re-graded 12 foot wide gravel road that will generally follow the existing alignment up and over the crest of Cobble Hill (Elevation 1270). Some improvements to the drive alignment are proposed to maintain the road on the parcel with the perpetual easement right-of-way. Several sections of cut and fill slopes will be constructed to support the proposed vertical alignment. Encounters with bedrock and rock outcrops are anticipated; therefore, rock cutting activities are expected during construction.

This report addresses the design of drainage swales to protect the access road from washout, safely convey stormwater flows, and protect outfall locations from erosion. This report does not address the design of groundwater controls, or slope stabilization, as geotechnical information was not available at the time of this report.

HYDROLOGIC EVALUATION

The steepness of the terrain subjects the gravel access road alignment to sheet flow and high velocity shallow concentrated flows that will concentrate on adjacent sides of the road subjecting it to erosion. (See Figures 4A through 4F - Drainage Areas). The maximum drainage area upstream of the access road is 2.2 acres (DA-E) and is located approximately 1,500 feet west of the Cobble Hill crest.
Aerial photos of the watershed show that the primary terrain cover is composed of forested area with pockets of exposed rock outcrops. The Connecticut USGS South Canaan Quadrangle Map indicates that

the predominant landform consists of moderately to steeply sloped forested knobs and ridges divided by flat valleys marked by mixed forested swampy terrain. Existing elevations range from 640± feet along the Hollenbeck River and Wangum Lake Brook watershed plains to an elevation of 1962 feet at Bradford Mountain in the Housatonic State Forest located 3 miles northeast of Cobble Hill.

The onsite soils on Cobble Hill consist of:

- Hydrologic Soil Group B (Copake Fine Sandy Loam) located at the base of the hill.
- Hydrologic Soil Group D (Hollis-Chatfield Rock Outcrop Complex soils) located on the top section of the hill.
- Hydrologic Soil Group D (Hollis-Chatfield Rock Outcrop Complex soils /Rock Outcrop - Hollis Complex) located on the steep sides of the hill.

A summary of these soils can be found in Table 1 (below). See Figure 2 for a map of the onsite soils.

Table 1 - Soil Analysis Summary

Soil Name	**Hydrologic Soil Group**
31A – Copake fine sandy loam, 0-3% Slopes	B
75C – Hollis-Chatfield Rock Outcrop Complex, 3-15% Slopes	D
75E – Hollis-Chatfield Rock Outcrop Complex, 15-45% Slopes	D
76F – Rock Outcrop - Hollis Complex, 45-60% Slopes	D

Hollis-Chatfield Rock Outcrop Complex soils consist of gravely fine sandy loams with organic material, and cobbles and boulders at the surface. Depth to bedrock is shallow, ranging from 0 to 20 inches. These soils are situated on steep slopes, which can create excessive drainage. A high variability in permeability exists, and is dependent on the shallow, restrictive layer of rock (0.0 to 6.0 in / hr).

Copake fine sandy loams consist of gravely fine sandy loams. Depth to bedrock is deep (greater than 80 inches). These soils are situated on flat outwash plains and terraces, and are well drained. They have moderately high to high permeability (0.6 to 6.0 in / hr.).

No development other than the cell tower facilities (monopole, fenced compound with equipment shelter, gravel access road, and drainage improvements) is expected to occur in the watershed area that would influence the access road, so existing conditions have been used for design.

In order to determine the swale and rip rap apron end design for the access road of the site, peak flows were generated using the Rational Method. Rainfall intensities (I) for the 10-year and 25-year design storms were referenced from Chapter 6 - Appendix B of the Connecticut Department of Transportation (ConnDOT) Drainage Manual dated October 2000. Composite runoff coefficients (C) were developed from an analysis of existing land use and typical C-values provided in the ConnDOT Drainage Manual. Times of concentration (Tc) were computed using standard NRCS TR-55 Methodology. A frequency factor (Cf) was used to refine the calculated peak flow for the 25-year design storm as prescribed in Section 6.9.5 of the ConnDOT Drainage Manual.

The results of the hydrologic analysis are presented in Table 2 (below) and detailed calculations are included in Appendix H.

Table 2 – Hydrologic Analysis Summary

Design Point	Watershed Area (acres)	Peak Discharge (ft^3/sec)	
		10-year	25-year
DA A	1.76	3.5	4.5
DA B	0.27	0.6	0.8
DA C	1.25	2.6	3.3
DA D	3.28	1.6	2.1
DA E	2.16	4.4	5.6
SDA E1 (Culvert 1)	0.05	0.1	0.2
SDA E2 (Culvert 2)	0.10	0.2	0.3
DA F	0.56	1.3	1.6
DA G	1.33	2.4	3.0

HYDRAULIC EVALUATION

Swales

Basis of Design

In accordance with the design criteria and procedures set forth in Sections 7.3 and 7.6 of the ConnDOT Drainage Manual, roadway swales shall be designed:

- to safely convey the 10-year frequency design storm peak flow without causing erosive damage.
- with a lining that is sufficient to resist the shear forces created from the transportation of storm flows (The permissible or critical shear stress in a swale defines the force required to initiate movement of the channel bed or lining).

Additionally, in accordance with Chapter 5, Section 6, Permanent Lined Waterway, of the 2002 Connecticut Guidelines for Soil Erosion and Sediment Control by The Connecticut Council on Soil and Water Conservation in Cooperation with the Connecticut Department of Environmental Protection (CTDEP), swales shall be designed with a minimum freeboard of 3 inches if no out-of-bank damage would be expected.

Design Methodology

Flow capacity of the swales was determined from the following:

- Velocity (V) – Equation 7.6 of the ConnDOT Drainage Manual (Manning's Equation)
- Flow capacity (Q) – Equation 7.5 of the ConnDOT Drainage Manual (The Continuity Equation).

See Appendix E for swale sizing calculations.

Swale lining was determined by the following:

- Average Shear Stress (τ) – Equation 7.11 of the ConnDOT Drainage Manual
- Maximum Shear Stress (τ_d) – Equation 7.12 of the ConnDOT Drainage Manual
- Lining Category (Material) and Type– Table 7-4 of the ConnDOT Drainage Manual and Manufacturers data regarding turf reinforcement mats (TRM).

See Appendix F for shear stress calculations.

Design Summary

Swale geometry and design varies and was based on existing topography and spacing constraints associated with an existing 30 f oot easement. Where possible the swales were graded to have a trapezoidal cross section that is 1-foot deep, has a 1-foot flat bottom, and 2:1 side slopes. Where space was constrained v-shaped swales were used and were generally 1-2 feet deep, with 2:1 side slopes. Due to this condition, multiple sections were analyzed, where necessary, for flow capacity, shear, and freeboard to ensure the swales would function properly.

See Table 3 below for a summary of the results of the swale analysis.

Table 3 – Swale Hydraulic Analysis Summary

Swale	Slope (ft/ft)	Manning's n[1] (unitless)	Velocity (ft/s)	10-yr Peak Design Flow (cfs)	Provided Flow Capacity (cfs)	Depth of Flow (in)	Provided Freeboard @ 10-year Peak Flow (in)
DA A	0.110	0.035	5.65	3.5	29.9	6.8	11.2
	0.250	0.035	9.80		20.6	3.2	8.8
DA B	0.300	0.035	4.64	0.6	24.9	1.3	10.7
DA C	0.100	0.035	4.71	2.6	11.4	5.3	6.7
	0.255	0.035	9.11		23.5	2.0	10.0
DA D	0.145	0.035	5.12	1.6	34.3	4.8	13.2
	0.225	0.035	10.56		34.8	1.2	10.8
DA E	0.110	0.035	4.48	4.4	11.9	6.2	5.8
	0.190	0.035	6.16		31.1	7.3	10.7
SDA E1	0.013	0.035	0.97	0.1	5.2	1.3	10.7
SDA E2	0.009	0.035	1.03	0.2	4.3	2.0	10.0
DA F	0.030	0.035	2.60	1.3	7.9	3.7	8.3
	0.200	0.035	5.14		20.3	2.3	9.7
DA G	0.015	0.035	2.47	2.4	5.6	6.1	5.9
	0.100	0.035	2.53		14.4	3.8	8.2

[1]Manning's n based on TR-55 guidelines for channels classified as earth/dense weeds.

To determine the type of swale lining necessary to amour the swales and protect against erosive forces imparted by stormwater flows, shear stresses were calculated. A vegetated turf reinforcement mat (TRM) lining was chosen to amour the swales and was selected because it can withstand the calculated shear stresses in all swales. See Table 4 (on the following page) for a summary of the results of the shear stress analysis.

Table 4 – Shear Stress Analysis

Swale	Slope (ft/ft)	Design Shear Stress (lb/ft^2)	Vegetated Turf Reinforcement Mat	
			Permissible Shear Stress[1] (lb/ft^2)	Classification
DA A	0.11	3.91	8.00	Landlock TRM 450
	0.25	4.90	8.00	Landlock TRM 450
DA B	0.30	2.06	8.00	Landlock TRM 450
DA C	0.10	2.75	8.00	Landlock TRM 450
	0.26	4.42	8.00	Landlock TRM 450
DA D	0.15	3.62	8.00	Landlock TRM 450
	0.23	5.34	8.00	Landlock TRM 450
DA E	0.11	3.57	8.00	Landlock TRM 450
	0.19	7.23	8.00	Landlock TRM 450
SDA E1	0.01	0.09	8.00	Landlock TRM 450
SDA E2	0.01	0.10	8.00	Landlock TRM 450
DA F	0.03	0.58	8.00	Landlock TRM 450
	0.20	2.37	8.00	Landlock TRM 450
DA G	0.02	0.48	8.00	Landlock TRM 450
	0.10	2.00	8.00	Landlock TRM 450

[1]Determined from information provided by the manufacturer.

Based on the analyses, each of these swales will be capable of safely conveying the 10-year peak storm flows calculated for their respective Drainage Area, provide the required 3 inches of freeboard, and withstand calculated shear stresses.

Culverts

Basis of Design

In accordance with the design criteria and procedures set forth in Section 8.3 of the ConnDOT Drainage Manual, roadway culverts shall be designed to:

- Safely convey the 25-year design storm peak flow.
- Have a HW/D ratio less than 1.5 (The hydraulic performance of a culvert is commonly expressed as a ratio of headwater depth (HW), which equals the depth of water measured from the invert of the culvert, to the culvert diameter (D) as HW/D).
- Have a minimum diameter of 18 inches.

Design Methodology

The proposed culvert was analyzed using Haestad Methods CulvertMaster Computer Software (Version 3.1). This program was utilized to compute the headwater elevation and discharge velocity of the culvert (evaluating both inlet and outlet control equations) (See Appendix C for CulvertMaster output data).

The pipe flow capacity was calculated using:

- Velocity (V) – Equation 7.6 of the ConnDOT Drainage Manual (Manning's Equation)
- Flow capacity (Q) – Equation 7.5 of the ConnDOT Drainage Manual (The Continuity Equation).

See Appendix D for culvert capacity calculations.

Design Summary

The access road design requires two (2) culverts (Culvert 1 and Culvert 2) for stormwater conveyance (See Figure 5 for location). The culverts will be 18" diameter HDPE (See Figure 6 for drainage details). See Table 5 below for a summary of the results of the culvert analysis.

Table 5 – Culvert Analysis

Culvert	Length (ft)	Slope (ft/ft)	Diameter (in)	Manning's n[1] (unitless)	25-year Peak Design Flow (cfs)	Provided Flow Capacity (cfs)	Computed HW (in)	HW/D Ratio (ft/ft)
Culvert 1	28.5	0.0175	18	0.012	0.17	15.1	1.7	0.10
Culvert 2	27	0.0185	18	0.012	0.30	15.5	8.0	0.45

Based on the analysis, the 18-inch diameter HDPE culverts will safely convey peak flows from the 25-year frequency design storm, with a calculated HW/D ratio less than 1.5.

Outlet Protection

Basis of Design

In accordance with the engineering guidelines established by the ConnDOT Drainage Manual, swale outlets must be protected to minimize scour and to provide downstream erosion protection.

Design Methodology and Summary

Due to the steep terrain onsite, high approach velocities with scour potential exist in the swales. The high flow velocities can result in downstream erosion such as scour holes and rills. As a protective measure in the design of the swale outlets, rip rap apron ends are proposed at the discharge points of the swales DA F and DA G. According to Chapter 11 – Section 13 of the ConnDOT Drainage Manual, rip rap apron ends are sufficient to dissipate energy at the swale outlets if the outlet velocities are less than or equal to 14 feet per second. Based on the hydraulic analysis results (Table 4), hydraulic conditions in swales DA F and DA G meet this criterion.

The remaining swale outlets all occur within the existing 30' easement, off the subject lot(s). In these areas, the easement must be respected, and there is not sufficient room to install rip rap apron ends as a means of outlet project. In these areas, a geosynthetic Pyramat® will be installed to help dissipate velocity, spread flows and minimize scour. A minimum length for the Pyramat has been established based on the existing and proposed topography, and available space within the existing easement (See Figures 5B-5C). The width of the Pyramat will be variable and determined in the field based upon available room between the proposed limits of grading and the existing 30 foot wide easement. Per the manufacturers provided information, this product is sufficient to dissipate energy at the swale outlets for outlet velocities up to 25 feet per second. Based on the hydraulic analysis results (Table 4), hydraulic conditions in all swales meet this criterion.

See Figures 5A through 5E – Proposed Access Drive Drainage for swales, riprap apron end, Pyamat® and culvert locations and Figure 6 – Drainage Details for swale, riprap apron end, and culvert design details. See Appendix G for outlet protection calculations. See Table 6 (on the following page) for the results of the outlet protection analysis.

Table 6 – Outlet Protection Analysis

Outlet	Outlet Velocity (ft/sec)	Outlet Structure Type	Required Dimensions[5]			
			L_a (ft)	W_1[2] (ft)	W_2[3] (ft)	Lining Specification
Swale DA A	9.80	Vegetated High Performance Turf Reinforcement Mat	30	Sized in field based on grading and easement constraints		Pyramat ® by SI Geosolutions
Swale DA B	4.64		20			
Swale DA C	9.11		30			
Swale DA D	10.56		20			
Swale DA E	6.16		50			
Swale DA F	2.60	Type A Riprap Apron	10[1]	3	10	Modified Rip Rap[4]
Swale DA G	2.40		10[1]	3	10	Modified Rip Rap[4]

[1] L_a values determined using Table 11-12.1 and 11-13.1 of the ConnDOT Drainage Manual.
[2] W_1 = width of apron at pipe outlet
[3] W_2 = width of apron at terminus
[4] Riprap specification selected from Table 11.11 of the ConnDOT Drainage Manual
[5] Dimensions represent minimum acceptable parameters based on calculations. Actual dimensions selected for use may differ.

CONCLUSIONS

Based on the hydraulic analysis, the graded drainage swales are sufficient in size to safely convey the 10-year frequency design storm with a proposed lining that is sufficient to resist the shear forces imparted by the anticipated design flows. For outlet protection, riprap aprons and Pyramat® geosynthetic mats are proposed at all swale discharge points. I n addition, both required drainage culverts will meet the ConnDOT requirements of safely conveying the 25-year design storm peak flows with an HW/D ratio of less than 1.5.

APPENDICES

Appendix A

Composite Runoff Coefficient Calculations

Drainage Area	Area (Acres)														Average C
	HSG A			HSG B			HSG C			HSG D			Gravel	Total	
	F	A	S	F	A	S	F	A	S	F	A	S			
DA A	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	1.61	0.14	1.76	0.42
DA B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.05	0.27	0.47
DA C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.12	0.13	1.25	0.43
DA D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.71	0.08	3.28	0.10
DA E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.93	0.22	2.16	0.43
SDA E1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.02	0.05	0.53
SDA E2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.02	0.10	0.47
DA F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.11	0.56	0.47
DA G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.26	0.07	1.33	0.40

Surface Type	Runoff Coefficient (C)[3]		
	Flat (F) 0 - 1%	Average (A) 2 - 6%	Steep (S) > 6%
HSG A	0.09	0.14	0.18
HSG B	0.12	0.17	0.24
HSG C	0.16	0.21	0.31
HSG D	0.2	0.25	0.38
Gravel	0.85		

[3]C-values obtained from Tables 6-3 and 6-5 of the ConnDOT Drainage Manual

Appendix B

Time of Concentration Calculations

CHA, Inc.

Worksheet 3: Time of Concentration (Tc)

Project:	FALLS VILLAGE	Job No.	18301-1026	By	JDM	Date	4/12/2013
Location:	Falls Village, CT			Checked		Date	

Proposed

Subarea: DA A Outfall

		High	Low	Run	Slope
Sheet	AB	860	851	36	0.250
Shallow	BC	851	722	468	0.276
Channel	CD	722	673	268	0.183

1. Sheet Flow

	Unit	Segment ID: A-B			
1. Surface Description (table 3-1)		WOODS			
2. Manning's roughness coeff., 'n' (table 3-1)		0.400			
3. Flow length, L (total L ≤ 150 ft	ft	36			
4. Two-year 24-hour rainfall, P_2	in	3.2			
5. Land Slope, s	ft/ft	0.250			
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}}$	hr	0.058	0.000	0.000	0.058

2. Shallow Concentrated Flow

	Unit	Segment ID: B-C			
7. Surface description (Paved or Unpaved)		U			
8. Flow length, L	ft	468			
9. Watercourse slope, s	ft/ft	0.276			
10. Average velocity, V (figure 3-1)	ft/s	8.471			
11. $T_t = \frac{L}{3600\,V}$	hr	0.015	0.000	0.000	0.015

3. Channel Flow

	Unit	Segment ID: C-D			
12. Cross sectional flow area, a	ft^2	4.50			
13. Wetted perimeter, p_w	ft	6.7			
14. Hydraulic radius, $r = a/p_w$	ft	0.67			
15. Channel slope, s	ft/ft	0.183			
16. Manning's roughness coefficient, n		0.035			
17. $V = \frac{1.49\,r^{2/3}\,s^{1/2}}{n}$	ft/s	13.961			
18. Flow Length, L	ft	268			
19. $T_t = \frac{L}{3600\,V}$	hr	0.005	0.000	0.000	0.005

20. Total Tc For Watershed or Subarea (Add Steps 6, 11, and 19)

hr = 0.08

min = 4.69

CHA, Inc.

Worksheet 3: Time of Concentration (Tc)

Project:	FALLS VILLAGE	Job No.	18301-1026	By	JDM	Date	4/12/2013
Location:	Falls Village, CT			Checked		Date	

Proposed

Subarea: DA B Outfall

		High	Low	Run	Slope
Sheet	AB	865.5	838	100	0.275
Shallow	BC	838	759	181	0.436
Channel	CD	0	0	800	0.000

1. Sheet Flow

	Units	Segment ID A-B			
1. Surface Description (table 3-1)		WOODS			
2. Manning's roughness coeff., 'n' (table 3-1)		0.400			
3. Flow length, L (total L ≤ 150 ft	ft	100			
4. Two-year 24-hour rainfall, P_2	in	3.2			
5. Land Slope, s	ft/ft	0.275			
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}}$	hr	0.125	0.000	0.000	0.125

2. Shallow Concentrated Flow

	Units	Segment ID B-C			
7. Surface description (Paved or Unpaved)		U			
8. Flow length, L	ft	181			
9. Watercourse slope, s	ft/ft	0.436			
10. Average velocity, V (figure 3-1)	ft/s	10.659			
11. $T_t = \frac{L}{3600\,V}$	hr	0.005	0.000	0.000	0.005

3. Channel Flow

	Units	Segment ID C-D			
12. Cross sectional flow area, a	ft^2	3.00			
13. Wetted perimeter, p_w	ft	5.5			
14. Hydraulic radius, $r = a/p_w$	ft	0.55			
15. Channel slope, s	ft/ft	0.000			
16. Manning's roughness coefficient, n		0.035			
17. $V = \frac{1.49\,r^{2/3}\,s^{1/2}}{n}$	ft/s	0.000			
18. Flow Length, L	ft	800			
19. $T_t = \frac{L}{3600\,V}$	hr	0.000	0.000	0.000	0.000

20. Total Tc For Watershed or Subarea (Add Steps 6, 11, and 19)

hr = 0.13

min = 7.81

CHA, Inc.

Worksheet 3: Time of Concentration (Tc)

Project:	FALLS VILLAGE	Job No.	18301-1026	By	JDM	Date	4/12/2013
Location:	Falls Village, CT			Checked		Date	
	Proposed			Subarea:	DA C Outfall		

		High	Low	Run	Slope
Sheet	AB	1036	1023	56	0.232
Shallow	BC			1	0.000
Channel	CD	1023	862	761	0.212

1. Sheet Flow

	Unit				
Segment ID		**A-B**			
1. Surface Description (table 3-1)		WOODS			
2. Manning's roughness coeff., 'n' (table 3-1)		0.400			
3. Flow length, L (total L $\leq$ 150 ft	ft	56			
4. Two-year 24-hour rainfall, P_2	in	3.2			
5. Land Slope, s	ft/ft	0.232			
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}}$	hr	0.084	0.000	0.000	0.084

2. Shallow Concentrated Flow

	Unit				
Segment ID		**B-C**			
7. Surface description (Paved or Unpaved)		U			
8. Flow length, L	ft	1			
9. Watercourse slope, s	ft/ft	0.000			
10. Average velocity, V (figure 3-1)	ft/s	0.000			
11. $T_t = \frac{L}{3600\,V}$	hr	0.000	0.000	0.000	0.000

3. Channel Flow

	Unit				
Segment ID		**C-D**			
12. Cross sectional flow area, a	ft^2	3.00			
13. Wetted perimeter, p_w	ft	6.3			
14. Hydraulic radius, $r = a/p_w$	ft	0.48			
15. Channel slope, s	ft/ft	0.212			
16. Manning's roughness coefficient, n		0.035			
17. $V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n}$	ft/s	11.941			
18. Flow Length, L	ft	761			
19. $T_t = \frac{L}{3600\,V}$	hr	0.018	0.000	0.000	0.018

20. Total Tc For Watershed or Subarea (Add Steps 6, 11, and 19)

hr =	**0.10**
min =	**6.13**

CHA, Inc.

Worksheet 3: Time of Concentration (Tc)

Project:	FALLS VILLAGE	Job No.	18301-1026	By	JDM	Date	4/12/2013
Location:	Falls Village, CT			Checked		Date	

Proposed

Subarea: DA D Outfall

		High	Low	Run	Slope
Sheet	AB	1015	981	100	0.340
Shallow	BC	981	928	158	0.335
Channel	CD	928	913	86	0.174

1. Sheet Flow

		Segment ID	A-B			
1. Surface Description (table 3-1)			WOODS			
2. Manning's roughness coeff., 'n' (table 3-1)			0.400			
3. Flow length, L (total L ≤ 150 ft		ft	100			
4. Two-year 24-hour rainfall, P_2		in	3.2			
5. Land Slope, s		ft/ft	0.340			
6. T_t =	$\frac{0.007\ (nL)^{0.8}}{P_2^{0.5}\ s^{0.4}}$	hr	0.115	0.000	0.000	0.115

2. Shallow Concentrated Flow

		Segment ID	B-C			
7. Surface description (Paved or Unpaved)			U			
8. Flow length, L		ft	158			
9. Watercourse slope, s		ft/ft	0.335			
10. Average velocity, V (figure 3-1)		ft/s	9.345			
11. T_t =	$\frac{L}{3600\ V}$	hr	0.005	0.000	0.000	0.005

3. Channel Flow

		Segment ID	C-D			
12. Cross sectional flow area, a		ft^2	4.50			
13. Wetted perimeter, p_w		ft	6.7			
14. Hydraulic radius, $r = a/p_w$		ft	0.67			
15. Channel slope, s		ft/ft	0.174			
16. Manning's roughness coefficient, n			0.035			
17. V =	$\frac{1.49\ r^{2/3}\ s^{1/2}}{n}$	ft/s	13.636			
18. Flow Length, L		ft	86			
19. T_t =	$\frac{L}{3600\ V}$	hr	0.002	0.000	0.000	0.002

20. Total Tc For Watershed or Subarea (Add Steps 6, 11, and 19)

hr = 0.12

min = 7.30

CHA, Inc.

Worksheet 3: Time of Concentration (Tc)

Project:	FALLS VILLAGE	Job No.	18301-1026	By	JDM	Date	4/12/2013
Location:	Falls Village, CT			Checked		Date	

Proposed

Subarea: SDA E1 - Culvert 1

		High	Low	Run	Slope
Sheet	AB	1228	1212.5	73	0.212
Shallow	BC	0	0	1	0.000
Channel	CD	1212.5	1207	41	0.134

1. Sheet Flow

		Segment ID	A-B			
1. Surface Description (table 3-1)			WOODS			
2. Manning's roughness coeff., 'n' (table 3-1)			0.400			
3. Flow length, L (total L $\leq$ 150 ft		ft	73			
4. Two-year 24-hour rainfall, P_2		in	3.2			
5. Land Slope, s		ft/ft	0.212			
6. T_t =	$\frac{0.007\ (nL)^{0.8}}{P_2^{0.5}\ s^{0.4}}$	hr	0.108	0.000	0.000	0.108

2. Shallow Concentrated Flow

		Segment ID	B-C			
7. Surface description (Paved or Unpaved)			U			
8. Flow length, L		ft	1			
9. Watercourse slope, s		ft/ft	0.000			
10. Average velocity, V (figure 3-1)		ft/s	0.000			
11. T_t =	$\frac{L}{3600\ V}$	hr	0.000	0.000	0.000	0.000

3. Channel Flow

		Segment ID	C-D			
12. Cross sectional flow area, a		ft^2	3.00			
13. Wetted perimeter, p_w		ft	5.5			
14. Hydraulic radius, r = a/p_w		ft	0.55			
15. Channel slope, s		ft/ft	0.134			
16. Manning's roughness coefficient, n			0.035			
17. V =	$\frac{1.49\ r^{2/3}\ s^{1/2}}{n}$	ft/s	10.409			
18. Flow Length, L		ft	41			
19. T_t =	$\frac{L}{3600\ V}$	hr	0.001	0.000	0.000	0.001

20. Total Tc For Watershed or Subarea (Add Steps 6, 11, and 19)

hr = 0.11

min = 6.55

CHA, Inc.

Worksheet 3: Time of Concentration (Tc)

Project:	FALLS VILLAGE	Job No.	18301-1026	By	JDM	Date	4/12/2013
Location:	Falls Village, CT			Checked		Date	

Proposed

Subarea: SDA E2 - Culvert 2

		High	Low	Run	Slope
Sheet	AB	1228	1212.5	73	0.212
Shallow	BC	0	0	1	0.000
Channel	CD	1212.5	1201	206	0.056

1. Sheet Flow

	Unit	Segment ID A-B			
1. Surface Description (table 3-1)		WOODS			
2. Manning's roughness coeff., 'n' (table 3-1)		0.400			
3. Flow length, L (total L ≤ 150 ft	ft	73			
4. Two-year 24-hour rainfall, P_2	in	3.2			
5. Land Slope, s	ft/ft	0.212			
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\, s^{0.4}}$	hr	0.108	0.000	0.000	0.108

2. Shallow Concentrated Flow

	Unit	Segment ID B-C			
7. Surface description (Paved or Unpaved)		U			
8. Flow length, L	ft	1			
9. Watercourse slope, s	ft/ft	0.000			
10. Average velocity, V (figure 3-1)	ft/s	0.000			
11. $T_t = \frac{L}{3600\,V}$	hr	0.000	0.000	0.000	0.000

3. Channel Flow

	Unit	Segment ID C-D			
12. Cross sectional flow area, a	ft^2	3.00			
13. Wetted perimeter, p_w	ft	5.5			
14. Hydraulic radius, $r = a/p_w$	ft	0.55			
15. Channel slope, s	ft/ft	0.056			
16. Manning's roughness coefficient, n		0.035			
17. $V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n}$	ft/s	6.715			
18. Flow Length, L	ft	206			
19. $T_t = \frac{L}{3600\,V}$	hr	0.009	0.000	0.000	0.009

20. Total Tc For Watershed or Subarea (Add Steps 6, 11, and 19)

hr = 0.12

min = 7.00

CHA, Inc.

Worksheet 3: Time of Concentration (Tc)

Project:	FALLS VILLAGE	Job No.	18301-1026	By	JDM	Date	4/12/2013
Location:	Falls Village, CT			Checked		Date	

Proposed

Subarea: DA E Outfall

		High	Low	Run	Slope
Sheet	AB	1228	1212.5	73	0.212
Shallow	BC	0	0	1	0.000
Channel	CD	1212.5	1049	1377	0.119

1. Sheet Flow

	Unit				
Segment ID		**A-B**			
1. Surface Description (table 3-1)		WOODS			
2. Manning's roughness coeff., 'n' (table 3-1)		0.400			
3. Flow length, L (total L $\leq$ 150 ft	ft	73			
4. Two-year 24-hour rainfall, P_2	in	3.2			
5. Land Slope, s	ft/ft	0.212			
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}}$	hr	0.108	0.000	0.000	0.108

2. Shallow Concentrated Flow

	Unit				
Segment ID		**B-C**			
7. Surface description (Paved or Unpaved)		U			
8. Flow length, L	ft	1			
9. Watercourse slope, s	ft/ft	0.000			
10. Average velocity, V (figure 3-1)	ft/s	0.000			
11. $T_t = \frac{L}{3600\,V}$	hr	0.000	0.000	0.000	0.000

3. Channel Flow

	Unit				
Segment ID		**C-D**			
12. Cross sectional flow area, a	ft^2	3.00			
13. Wetted perimeter, p_w	ft	6.3			
14. Hydraulic radius, $r = a/p_w$	ft	0.48			
15. Channel slope, s	ft/ft	0.119			
16. Manning's roughness coefficient, n		0.035			
17. $V = \frac{1.49\,r^{2/3}\,s^{1/2}}{n}$	ft/s	8.945			
18. Flow Length, L	ft	1377			
19. $T_t = \frac{L}{3600\,V}$	hr	0.043	0.000	0.000	0.043

20. Total Tc For Watershed or Subarea (Add Steps 6, 11, and 19)

hr = 0.15

min = 9.05

CHA, Inc.

Worksheet 3: Time of Concentration (Tc)

Project:	FALLS VILLAGE	Job No.	18301-1026	By	JDM	Date	4/12/2013
Location:	Falls Village, CT			Checked		Date	
	Proposed			Subarea:	DA F Outfall		

		High	Low	Run	Slope
Sheet	AB	1270	1269	12	0.083
Shallow	BC			1	0.000
Channel	CD	1269	1201	790	0.086

1. Sheet Flow

Segment ID		**A-B**			
1. Surface Description (table 3-1)		WOODS			
2. Manning's roughness coeff., 'n' (table 3-1)		0.400			
3. Flow length, L (total L ≤ 150 ft	ft	12			
4. Two-year 24-hour rainfall, P_2	in	3.2			
5. Land Slope, s	ft/ft	0.083			
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}}$	hr	0.037	0.000	0.000	0.037

2. Shallow Concentrated Flow

Segment ID		**B-C**			
7. Surface description (Paved or Unpaved)		U			
8. Flow length, L	ft	1			
9. Watercourse slope, s	ft/ft	0.000			
10. Average velocity, V (figure 3-1)	ft/s	0.000			
11. $T_t = \frac{L}{3600\,V}$	hr	0.000	0.000	0.000	0.000

3. Channel Flow

Segment ID		**C-D**			
12. Cross sectional flow area, a	ft^2	3.00			
13. Wetted perimeter, p_w	ft	5.5			
14. Hydraulic radius, $r = a/p_w$	ft	0.55			
15. Channel slope, s	ft/ft	0.086			
16. Manning's roughness coefficient, n		0.035			
17. $V = \frac{1.49\,r^{2/3}\,s^{1/2}}{n}$	ft/s	8.338			
18. Flow Length, L	ft	790			
19. $T_t = \frac{L}{3600\,V}$	hr	0.026	0.000	0.000	0.026

20. Total Tc For Watershed or Subarea (Add Steps 6, 11, and 19)

hr = 0.06

min = 3.80

CHA, Inc.

Worksheet 3: Time of Concentration (Tc)

Project:	FALLS VILLAGE	Job No.	18301-1026	By	JDM	Date	4/12/2013
Location:	Falls Village, CT			Checked		Date	

Proposed

Subarea: DA G Outfall

		High	Low	Run	Slope
Sheet	AB	1249	1240	100	0.090
Shallow	BC	1240	1202.25	293	0.129
Channel	CD	1202.25	1200	66	0.034

1. Sheet Flow

	Unit				
Segment ID		**A-B**			
1. Surface Description (table 3-1)		WOODS			
2. Manning's roughness coeff., 'n' (table 3-1)		0.400			
3. Flow length, L (total L $\le$ 150 ft	ft	100			
4. Two-year 24-hour rainfall, P_2	in	3.2			
5. Land Slope, s	ft/ft	0.090			
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\, s^{0.4}}$	hr	0.196	0.000	0.000	0.196

2. Shallow Concentrated Flow

	Unit				
Segment ID		**B-C**			
7. Surface description (Paved or Unpaved)		U			
8. Flow length, L	ft	293			
9. Watercourse slope, s	ft/ft	0.129			
10. Average velocity, V (figure 3-1)	ft/s	5.791			
11. $T_t = \frac{L}{3600\,V}$	hr	0.014	0.000	0.000	0.014

3. Channel Flow

	Unit				
Segment ID		**C-D**			
12. Cross sectional flow area, a	ft^2	3.00			
13. Wetted perimeter, p_w	ft	5.5			
14. Hydraulic radius, $r = a/p_w$	ft	0.55			
15. Channel slope, s	ft/ft	0.034			
16. Manning's roughness coefficient, n		0.035			
17. $V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n}$	ft/s	5.247			
18. Flow Length, L	ft	66			
19. $T_t = \frac{L}{3600\,V}$	hr	0.003	0.000	0.000	0.003

20. Total Tc For Watershed or Subarea (Add Steps 6, 11, and 19)

hr = 0.21

min = 12.82

Appendix C

CulvertMaster Output Data

Culvert Calculator Report
Culvert 1 (SDA E1)

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	1,208.50 ft	Headwater Depth/Height	0.14
Computed Headwater Elevation	1,206.71 ft	Discharge	0.17 cfs
Inlet Control HW Elev.	1,206.69 ft	Tailwater Elevation	0.00 ft
Outlet Control HW Elev.	1,206.71 ft	Control Type	Entrance Control

Grades			
Upstream Invert	1,206.50 ft	Downstream Invert	1,206.00 ft
Length	28.50 ft	Constructed Slope	0.017544 ft/ft

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.11 ft
Slope Type	Steep	Normal Depth	0.11 ft
Flow Regime	Supercritical	Critical Depth	0.15 ft
Velocity Downstream	2.84 ft/s	Critical Slope	0.004933 ft/ft

Section			
Section Shape	Circular	Mannings Coefficient	0.012
Section Material	Corrugated HDPE (Smooth Interior)	Span	1.50 ft
Section Size	18 inch	Rise	1.50 ft
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	1,206.71 ft	Upstream Velocity Head	0.05 ft
Ke	0.20	Entrance Loss	0.01 ft

Inlet Control Properties			
Inlet Control HW Elev.	1,206.69 ft	Flow Control	N/A
Inlet Type	Beveled ring, 33.7° bevels	Area Full	1.8 ft²
K	0.00180	HDS 5 Chart	3
M	2.50000	HDS 5 Scale	B
C	0.02430	Equation Form	1
Y	0.83000		

Culvert Calculator Report
Culvert 2 (SDA E2)

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	1,203.00	ft	Headwater Depth/Height	0.67	
Computed Headwater Elevation	1,201.50	ft	Discharge	0.30	cfs
Inlet Control HW Elev.	1,201.50	ft	Tailwater Elevation	1,201.50	ft
Outlet Control HW Elev.	1,201.50	ft	Control Type	Outlet Control	

Grades					
Upstream Invert	1,200.50	ft	Downstream Invert	1,200.00	ft
Length	27.00	ft	Constructed Slope	0.018519	ft/ft

Hydraulic Profile					
Profile	S1		Depth, Downstream	1.50	ft
Slope Type	Steep		Normal Depth	0.14	ft
Flow Regime	Subcritical		Critical Depth	0.20	ft
Velocity Downstream	0.17	ft/s	Critical Slope	0.004607	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.012	
Section Material	Corrugated HDPE (Smooth Interior)		Span	1.50	ft
Section Size	18 inch		Rise	1.50	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	1,201.50	ft	Upstream Velocity Head	0.00	ft
Ke	0.20		Entrance Loss	0.00	ft

Inlet Control Properties					
Inlet Control HW Elev.	1,201.50	ft	Flow Control	N/A	
Inlet Type	Beveled ring, 33.7° bevels		Area Full	1.8	ft²
K	0.00180		HDS 5 Chart	3	
M	2.50000		HDS 5 Scale	B	
C	0.02430		Equation Form	1	
Y	0.83000				

Appendix D

Culvert Capacity Calculations

CULVERT CAPACITY
By CHA Inc.

JOB DATA

Project:	SAI - Falls Village
Calc. by:	JDM
Date:	4/1/13
Pipe at:	SDA E1 - Culvert 1

EQUATIONS:

Manning's Equation, $V = (1.49/n)R^{2/3}S^{1/2}$
$Q = VA$
Froude Number = $V/(gd)^{1/2}$

INPUT:

Diameter (D) =	1.50	ft	
Depth of flow (d) =	1.50	ft	
Manning's n =	0.012		from CulvertMaster
Slope of pipe (s) =	0.0175	ft/ft	

OUTPUT:

Angle (a) =	0.00	radians						
Wet Perimeter (P) =	4.71	ft						
Area of Flow (A) =	1.77	sq. ft.						
Hydr. Radius (R) =	0.38	ft						
Velocity of Flow (V) =	8.5	fps						
Flow Capacity (Q) =	15.06	cfs	=	9,734,385	gpd	=	**6760.0**	gpm
Froude Number (F) =	1.23	>1, supercritical flow						

CULVERT CAPACITY
By CHA Inc.

JOB DATA

Project:	SAI - Falls Village
Calc. by:	JDM
Date:	4/1/13
Pipe at:	SDA E2 - Culvert 2

EQUATIONS:

Manning's Equation, $V = (1.49/n)R^{2/3}S^{1/2}$
$Q = VA$
Froude Number $= V/(gd)^{1/2}$

INPUT:

Diameter (D) =	1.50	ft	
Depth of flow (d) =	1.50	ft	
Manning's n =	0.012		from CulvertMaster
Slope of pipe (s) =	0.0185	ft/ft	

OUTPUT:

Angle (a) =	0.00	radians						
Wet Perimeter (P) =	4.71	ft						
Area of Flow (A) =	1.77	sq. ft.						
Hydr. Radius (R) =	0.38	ft						
Velocity of Flow (V) =	8.8	fps						
Flow Capacity (Q) =	15.48	cfs	=	10,002,360	gpd	=	**6946.1**	gpm
Froude Number (F) =	1.26	>1, supercritical flow						

Appendix E

Swale Sizing Calculations

TRAPEZOIDAL/V-SHAPE SWALE CAPACITY
CHA, Inc.

PROJECT DATA:

Project:	18301-1015
Calc. by:	JDM
Date:	March 2013
Swale ID:	DA A - Min

EQUATIONS:

Manning's Equation, $V = (1.49/n)R^{2/3}S^{1/2}$
Froude number, $F = V/(gd)^{1/2}$
$Q = VA$
$d75 = 12(118QS_b^{13/6}R/P)^{2/5}$

INPUT:

Base width (b) =	0.0	ft	
Sideslope (z) =	2	on 1	
Depth of flow (d) =	1.25	ft	
Swale Depth=	1.50	ft	
Manning's n =	0.035		TRM
Slope of ditch (s) =	0.1100	ft/ft	

OUTPUT:

Wet Perimeter (P) =	5.59	ft
Area of Flow (A) =	3.13	sq. ft.
Hydr. Radius (R) =	0.56	ft
Freeboard =	0.25	ft
Velocity of Flow (V) =	9.56	fps
Flow Capacity (Q) =	29.88	cfs
Froude number, F =	1.51	>1, supercritical flow

TRAPEZOIDAL/V-SHAPE SWALE CAPACITY
CHA, Inc.

PROJECT DATA:

Project:	18301-1015
Calc. by:	JDM
Date:	March 2013
Swale ID:	DA A - Max

EQUATIONS:

Manning's Equation, $V = (1.49/n)R^{2/3}S^{1/2}$

Froude number, $F = V/(gd)^{1/2}$

$Q = VA$

$d75 = 12(118QS_b^{13/6}R/P)^{2/5}$

INPUT:

Base width (b) =	1.0	ft	
Sideslope (z) =	1 1/2	on 1	
Depth of flow (d) =	0.75	ft	
Swale Depth=	1.00	ft	
Manning's n =	0.035		TRM
Slope of ditch (s) =	0.2500	ft/ft	

OUTPUT:

Wet Perimeter (P) =	3.35	ft
Area of Flow (A) =	1.59	sq. ft.
Hydr. Radius (R) =	0.48	ft
Freeboard =	0.25	ft
Velocity of Flow (V) =	12.93	fps
Flow Capacity (Q) =	20.61	cfs
Froude number, F =	2.63	>1, supercritical flow

TRAPEZOIDAL/V-SHAPE SWALE CAPACITY
CHA, Inc.

PROJECT DATA:

Project:	18301-1015
Calc. by:	JDM
Date:	March 2013
Swale ID:	DA B

EQUATIONS:

Manning's Equation, $V = (1.49/n)R^{2/3}S^{1/2}$

Froude number, $F = V/(gd)^{1/2}$

$Q = VA$

$d75 = 12(118QS_b^{13/6}R/P)^{2/5}$

INPUT:

Base width (b) =	1.0	ft	
Sideslope (z) =	2	on 1	
Depth of flow (d) =	0.75	ft	
Swale Depth=	1.00	ft	
Manning's n =	0.035		TRM
Slope of ditch (s) =	0.3000	ft/ft	

OUTPUT:

Wet Perimeter (P) =	4.35	ft
Area of Flow (A) =	1.88	sq. ft.
Hydr. Radius (R) =	0.43	ft
Freeboard =	0.25	ft
Velocity of Flow (V) =	13.26	fps
Flow Capacity (Q) =	24.86	cfs
Froude number, F =	2.70	>1, supercritical flow

TRAPEZOIDAL/V-SHAPE SWALE CAPACITY
CHA, Inc.

PROJECT DATA:

Project:	18301-1015
Calc. by:	JDM
Date:	March 2013
Swale ID:	DA C - Min

EQUATIONS:

Manning's Equation, $V = (1.49/n)R^{2/3}S^{1/2}$
Froude number, $F = V/(gd)^{1/2}$
$Q = VA$
$d75 = 12(118QS_b^{13/6}R/P)^{2/5}$

INPUT:

Base width (b) =	0.0	ft	
Sideslope (z) =	3	on 1	
Depth of flow (d) =	0.75	ft	
Swale Depth=	1.00	ft	
Manning's n =	0.035		TRM
Slope of ditch (s) =	0.1000	ft/ft	

OUTPUT:

Wet Perimeter (P) =	4.74	ft
Area of Flow (A) =	1.69	sq. ft.
Hydr. Radius (R) =	0.36	ft
Freeboard =	0.25	ft
Velocity of Flow (V) =	6.74	fps
Flow Capacity (Q) =	11.37	cfs
Froude number, F =	1.37	>1, supercritical flow

TRAPEZOIDAL/V-SHAPE SWALE CAPACITY
CHA, Inc.

PROJECT DATA:

Project:	18301-1015
Calc. by:	JDM
Date:	March 2013
Swale ID:	DA C - Max

EQUATIONS:

Manning's Equation, $V = (1.49/n)R^{2/3}S^{1/2}$

Froude number, $F = V/(gd)^{1/2}$

$Q = VA$

$d75 = 12(118QS_b^{13/6}R/P)^{2/5}$

INPUT:

Base width (b) =	1.5	ft	
Sideslope (z) =	1 1/2	on 1	
Depth of flow (d) =	0.75	ft	
Swale Depth=	1.00	ft	
Manning's n =	0.035		TRM
Slope of ditch (s) =	0.2550	ft/ft	

OUTPUT:

Wet Perimeter (P) =	4.74	ft
Area of Flow (A) =	1.97	sq. ft.
Hydr. Radius (R) =	0.42	ft
Freeboard =	0.25	ft
Velocity of Flow (V) =	11.93	fps
Flow Capacity (Q) =	23.48	cfs
Froude number, F =	2.43	>1, supercritical flow

TRAPEZOIDAL/V-SHAPE SWALE CAPACITY
CHA, Inc.

PROJECT DATA:

Project:	18301-1015
Calc. by:	JDM
Date:	March 2013
Swale ID:	DA D - Min

EQUATIONS:

Manning's Equation, $V = (1.49/n)R^{2/3}S^{1/2}$
Froude number, $F = V/(gd)^{1/2}$
$Q = VA$
$d75 = 12(118QS_b^{13/6}R/P)^{2/5}$

INPUT:

Base width (b) =	0.0	ft	
Sideslope (z) =	2	on 1	
Depth of flow (d) =	1.25	ft	
Swale Depth=	1.50	ft	
Manning's n =	0.035		TRM
Slope of ditch (s) =	0.1450	ft/ft	

OUTPUT:

Wet Perimeter (P) =	5.59	ft
Area of Flow (A) =	3.13	sq. ft.
Hydr. Radius (R) =	0.56	ft
Freeboard =	0.25	ft
Velocity of Flow (V) =	10.98	fps
Flow Capacity (Q) =	34.31	cfs
Froude number, F =	1.73	>1, supercritical flow

TRAPEZOIDAL/V-SHAPE SWALE CAPACITY
CHA, Inc.

PROJECT DATA:

Project:	18301-1015
Calc. by:	JDM
Date:	March 2013
Swale ID:	DA D - Max

EQUATIONS:

Manning's Equation, $V = (1.49/n)R^{2/3}S^{1/2}$
Froude number, $F = V/(gd)^{1/2}$
$Q = VA$
$d75 = 12(118QS_b^{13/6}R/P)^{2/5}$

INPUT:

Base width (b) =	1.5	ft	
Sideslope (z) =	2	on 1	
Depth of flow (d) =	0.75	ft	
Swale Depth=	1.00	ft	
Manning's n =	0.035		TRM
Slope of ditch (s) =	0.2250	ft/ft	

OUTPUT:

Wet Perimeter (P) =	3.35	ft
Area of Flow (A) =	2.25	sq. ft.
Hydr. Radius (R) =	0.67	ft
Freeboard =	0.25	ft
Velocity of Flow (V) =	15.45	fps
Flow Capacity (Q) =	34.77	cfs
Froude number, F =	3.14	>1, supercritical flow

TRAPEZOIDAL/V-SHAPE SWALE CAPACITY
CHA, Inc.

PROJECT DATA:

Project:	18301-1015
Calc. by:	JDM
Date:	March 2013
Swale ID:	DA E - Min

EQUATIONS:

Manning's Equation, $V = (1.49/n)R^{2/3}S^{1/2}$
Froude number, $F = V/(gd)^{1/2}$
$Q = VA$
$d75 = 12(118QS_b^{13/6}R/P)^{2/5}$

INPUT:

Base width (b) =	0.0	ft	
Sideslope (z) =	3	on 1	
Depth of flow (d) =	0.75	ft	
Swale Depth=	1.00	ft	
Manning's n =	0.035		TRM
Slope of ditch (s) =	0.1100	ft/ft	

OUTPUT:

Wet Perimeter (P) =	4.74	ft
Area of Flow (A) =	1.69	sq. ft.
Hydr. Radius (R) =	0.36	ft
Freeboard =	0.25	ft
Velocity of Flow (V) =	7.06	fps
Flow Capacity (Q) =	11.92	cfs
Froude number, F =	1.44	>1, supercritical flow

TRAPEZOIDAL RIPRAP SWALE CAPACITY
CHA, Inc.

PROJECT DATA:

Project:	18301-1015
Calc. by:	JDM
Date:	March 2013
Swale ID:	DA E - Max

EQUATIONS:

Manning's Equation, $V = (1.49/n)R^{2/3}S^{1/2}$
Froude number, $F = V/(gd)^{1/2}$
$Q = VA$
$d75 = 12(118QS_b^{13/6}R/P)^{2/5}$

INPUT:

Base width (b) =	0.0	ft	
Sideslope (z) =	2	on 1	
Depth of flow (d) =	1.25	ft	
Swale Depth=	1.50	ft	
Manning's n =	0.035		TRM
Slope of ditch (s) =	0.1900	ft/ft	

OUTPUT:

Wet Perimeter (P) =	7.91	ft
Area of Flow (A) =	3.13	sq. ft.
Hydr. Radius (R) =	0.40	ft
Freeboard =	0.25	ft
Velocity of Flow (V) =	9.96	fps
Flow Capacity (Q) =	31.14	cfs
Froude number, F =	1.57	>1, supercritical flow

TRAPEZOIDAL/V-SHAPE SWALE CAPACITY
CHA, Inc.

PROJECT DATA:

Project:	18301-1015
Calc. by:	JDM
Date:	March 2013
Swale ID:	DA F - Min

EQUATIONS:

Manning's Equation, $V = (1.49/n)R^{2/3}S^{1/2}$

Froude number, $F = V/(gd)^{1/2}$

$Q = VA$

$d75 = 12(118QS_b^{13/6}R/P)^{2/5}$

INPUT:

Base width (b) =	1.0	ft	
Sideslope (z) =	2	on 1	
Depth of flow (d) =	0.75	ft	
Swale Depth=	1.00	ft	
Manning's n =	0.035		TRM
Slope of ditch (s) =	0.0300	ft/ft	

OUTPUT:

Wet Perimeter (P) =	4.35	ft
Area of Flow (A) =	1.88	sq. ft.
Hydr. Radius (R) =	0.43	ft
Freeboard =	0.25	ft
Velocity of Flow (V) =	4.19	fps
Flow Capacity (Q) =	7.86	cfs
Froude number, F =	0.85	<1, subcritical flow

<u>TRAPEZOIDAL/V-SHAPE SWALE CAPACITY</u>
CHA, Inc.

PROJECT DATA:

Project:	18301-1015
Calc. by:	JDM
Date:	March 2013
Swale ID:	DA F - Max

EQUATIONS:

Manning's Equation, $V = (1.49/n)R^{2/3}S^{1/2}$
Froude number, $F = V/(gd)^{1/2}$
$Q = VA$
$d75 = 12(118QS_b^{13/6}R/P)^{2/5}$

INPUT:

Base width (b) =	1.0	ft	
Sideslope (z) =	2	on 1	
Depth of flow (d) =	0.75	ft	
Swale Depth=	1.00	ft	
Manning's n =	0.035		TRM
Slope of ditch (s) =	0.2000	ft/ft	

OUTPUT:

Wet Perimeter (P) =	4.35	ft
Area of Flow (A) =	1.88	sq. ft.
Hydr. Radius (R) =	0.43	ft
Freeboard =	0.25	ft
Velocity of Flow (V) =	10.83	fps
Flow Capacity (Q) =	20.30	cfs
Froude number, F =	2.20	>1, supercritical flow

TRAPEZOIDAL/V-SHAPE SWALE CAPACITY
CHA, Inc.

PROJECT DATA:

Project:	18301-1015
Calc. by:	JDM
Date:	March 2013
Swale ID:	DA G - Min

EQUATIONS:

Manning's Equation, $V = (1.49/n)R^{2/3}S^{1/2}$

Froude number, $F = V/(gd)^{1/2}$

$Q = VA$

$d75 = 12(118QS_b^{13/6}R/P)^{2/5}$

INPUT:

Base width (b) =	1.0	ft	
Sideslope (z) =	2	on 1	
Depth of flow (d) =	0.75	ft	
Swale Depth=	1.00	ft	
Manning's n =	0.035		TRM
Slope of ditch (s) =	0.0150	ft/ft	

OUTPUT:

Wet Perimeter (P) =	4.35	ft
Area of Flow (A) =	1.88	sq. ft.
Hydr. Radius (R) =	0.43	ft
Freeboard =	0.25	ft
Velocity of Flow (V) =	2.96	fps
Flow Capacity (Q) =	5.56	cfs
Froude number, F =	0.60	<1, subcritical flow

<u>TRAPEZOIDAL/V-SHAPE SWALE CAPACITY</u>
CHA, Inc.

PROJECT DATA:

Project:	18301-1015
Calc. by:	JDM
Date:	March 2013
Swale ID:	DA G - Max

EQUATIONS:

Manning's Equation, $V = (1.49/n)R^{2/3}S^{1/2}$

Froude number, $F = V/(gd)^{1/2}$

$Q = VA$

$d75 = 12(118QS_b^{13/6}R/P)^{2/5}$

INPUT:

Base width (b) =	1.0	ft	
Sideslope (z) =	2	on 1	
Depth of flow (d) =	0.75	ft	
Swale Depth=	1.00	ft	
Manning's n =	0.035		TRM
Slope of ditch (s) =	0.1000	ft/ft	

OUTPUT:

Wet Perimeter (P) =	4.35	ft
Area of Flow (A) =	1.88	sq. ft.
Hydr. Radius (R) =	0.43	ft
Freeboard =	0.25	ft
Velocity of Flow (V) =	7.66	fps
Flow Capacity (Q) =	14.35	cfs
Froude number, F =	1.56	>1, supercritical flow

<u>TRAPEZOIDAL/V-SHAPE SWALE CAPACITY</u>
CHA, Inc.

PROJECT DATA:

Project:	18301-1015
Calc. by:	JDM
Date:	March 2013
Swale ID:	Culvert 1 Outlet Swale

EQUATIONS:

Manning's Equation, $V = (1.49/n)R^{2/3}S^{1/2}$

Froude number, $F = V/(gd)^{1/2}$

$Q = VA$

$d75 = 12(118QS_b^{13/6}R/P)^{2/5}$

INPUT:

Base width (b) =	1.0	ft	
Sideslope (z) =	2	on 1	
Depth of flow (d) =	0.75	ft	
Swale Depth=	1.00	ft	
Manning's n =	0.035		Rip-Rap
Slope of ditch (s) =	0.0130	ft/ft	

OUTPUT:

Wet Perimeter (P) =	4.35	ft
Area of Flow (A) =	1.88	sq. ft.
Hydr. Radius (R) =	0.43	ft
Freeboard =	0.25	ft
Velocity of Flow (V) =	2.76	fps
Flow Capacity (Q) =	5.18	cfs
Froude number, F =	0.56	<1, subcritical flow

<u>TRAPEZOIDAL/V-SHAPE SWALE CAPACITY</u>

PROJECT DATA:

Project:	18301-1015
Calc. by:	JDM
Date:	March 2013
Swale ID:	Culvert 2 Outlet Swale

EQUATIONS:

Manning's Equation, $V = (1.49/n)R^{2/3}S^{1/2}$

Froude number, $F = V/(gd)^{1/2}$

$Q = VA$

$d75 = 12(118QS_b^{13/6}R/P)^{2/5}$

INPUT:

Base width (b) =	1.0	ft	
Sideslope (z) =	2	on 1	
Depth of flow (d) =	0.75	ft	
Swale Depth=	1.00	ft	
Manning's n =	0.035		Rip-Rap
Slope of ditch (s) =	0.0090	ft/ft	

OUTPUT:

Wet Perimeter (P) =	4.35	ft
Area of Flow (A) =	1.88	sq. ft.
Hydr. Radius (R) =	0.43	ft
Freeboard =	0.25	ft
Velocity of Flow (V) =	2.30	fps
Flow Capacity (Q) =	4.31	cfs
Froude number, F =	0.47	<1, subcritical flow

Appendix F

Shear Stress Calculations

Swale	ID	Slope (ft/ft)	Hydraulic Radius (ft)	Max Flow Depth[1] (ft)	Average Shear Stress (lb/ft^2)	Max. Shear Stress (lb/ft^2)	Design Shear Stress[2] (lb/ft^2)	Vegetated Turf Reinforcement Mat	
								Permissible Shear Stress (lb/ft^2)	Classification
DA A	1	0.11	0.25	0.57	1.75	3.91	3.91	8.00	Landlock TRM 450
	2	0.25	0.31	0.27	4.90	4.21	4.90	8.00	Landlock TRM 450
DA B	3	0.30	0.09	0.11	1.68	2.06	2.06	8.00	Landlock TRM 450
DA C	4	0.10	0.21	0.44	1.30	2.75	2.75	8.00	Landlock TRM 450
	5	0.26	0.28	0.17	4.42	2.71	4.42	8.00	Landlock TRM 450
DA D	6	0.15	0.18	0.40	1.62	3.62	3.62	8.00	Landlock TRM 450
	8	0.23	0.38	0.10	5.34	1.40	5.34	8.00	Landlock TRM 450
DA E	9	0.11	0.25	0.52	1.69	3.57	3.57	8.00	Landlock TRM 450
	11	0.19	0.19	0.61	2.29	7.23	7.23	8.00	Landlock TRM 450
DA F	12	0.03	0.21	0.31	0.39	0.58	0.58	8.00	Landlock TRM 450
	13	0.20	0.14	0.19	1.77	2.37	2.37	8.00	Landlock TRM 450
DA G	14	0.02	0.31	0.51	0.29	0.48	0.48	8.00	Landlock TRM 450
	15	0.10	0.22	0.32	1.35	2.00	2.00	8.00	Landlock TRM 450
Culvert 1	16	0.01	0.09	0.11	0.07	0.09	0.09	8.00	Landlock TRM 450
Culvert 2	17	0.01	0.13	0.17	0.07	0.10	0.10	8.00	Landlock TRM 450

[1]Max flow depth based on 10-year design storm

[2]Shear stress used to design swale armoring. Largest value among the average and maximum shear stresses.

Unit Weight of Water=	62.4	lb/ft^3

Appendix G

Outlet Protection Calculations

Design Point	Discharging Structure	Outlet Velocity (ft/sec)	10-year Peak Discharge (ft^3/sec)	Outlet Structure Type	Min. Required Dimensions[5]			
					L_a[1] (ft)	W_1[2] (ft)	W_2[3] (ft)	Lining Specification
DA A	Swale	9.80	3.53	Vegetated High Performance Turf Reinforcement Mat	30	Sized in field based on grading and easement constraints		Pyramat ® by SI Geosolutions
DA B		4.64	0.61		20			
DA C		9.11	2.58		30			
DA D		10.56	1.64		20			
DA E		6.16	4.43		50			
DA F		2.60	1.28	Type A Riprap Apron	10	3	10	Modified Rip Rap[4]
DA G		2.40	2.43		10	3	10	Modified Rip Rap[4]

[1]L_a values determined using Table 11-12.1 and 11-13.1 of the ConnDOT Drainage Manual.

[2]W_1 = width of apron at pipe outlet

[3]W_2 = width of apron at terminus

[4]Riprap specification selected from Table 11.11 of the ConnDOT Drainage Manual

[5]Dimensions represent minimum acceptable parameters based on calculations. Actual dimensions selected for use may differ.

Appendix H

Hydrologic Calculations

Proposed Drainage Analysis							
Drainage Area/ Design Point	Area (acres)	Composite C	T_c (min)	I (in/hr)		Q (cfs)	
				10-year	25-year	10-year	25-year[1]
DA A	1.76	0.42	10.00	4.80	5.50	3.53	4.45
DA B	0.27	0.47	10.00	4.80	5.50	0.61	0.76
DA C	1.25	0.43	10.00	4.80	5.50	2.58	3.25
DA D	3.28	0.10	10.00	4.80	5.50	1.64	2.07
DA E	2.16	0.43	10.00	4.80	5.50	4.43	5.59
SDA E1	0.05	0.53	10.00	4.80	5.50	0.13	0.17
SDA E2	0.10	0.47	10.00	4.80	5.50	0.23	0.30
DA F	0.56	0.47	10.00	4.80	5.50	1.28	1.61
DA G	1.33	0.40	12.00	4.50	5.10	2.43	3.03

[1]Frequency Factor for 25-year recurrence intervall is 1.1 (Table 6-2 of ConnDOT Drainage Manual)

C_f[1]	Recurrence Interval
1.1	25
1.2	50
1.25	100

FIGURES

Figure 1

Site Location Map

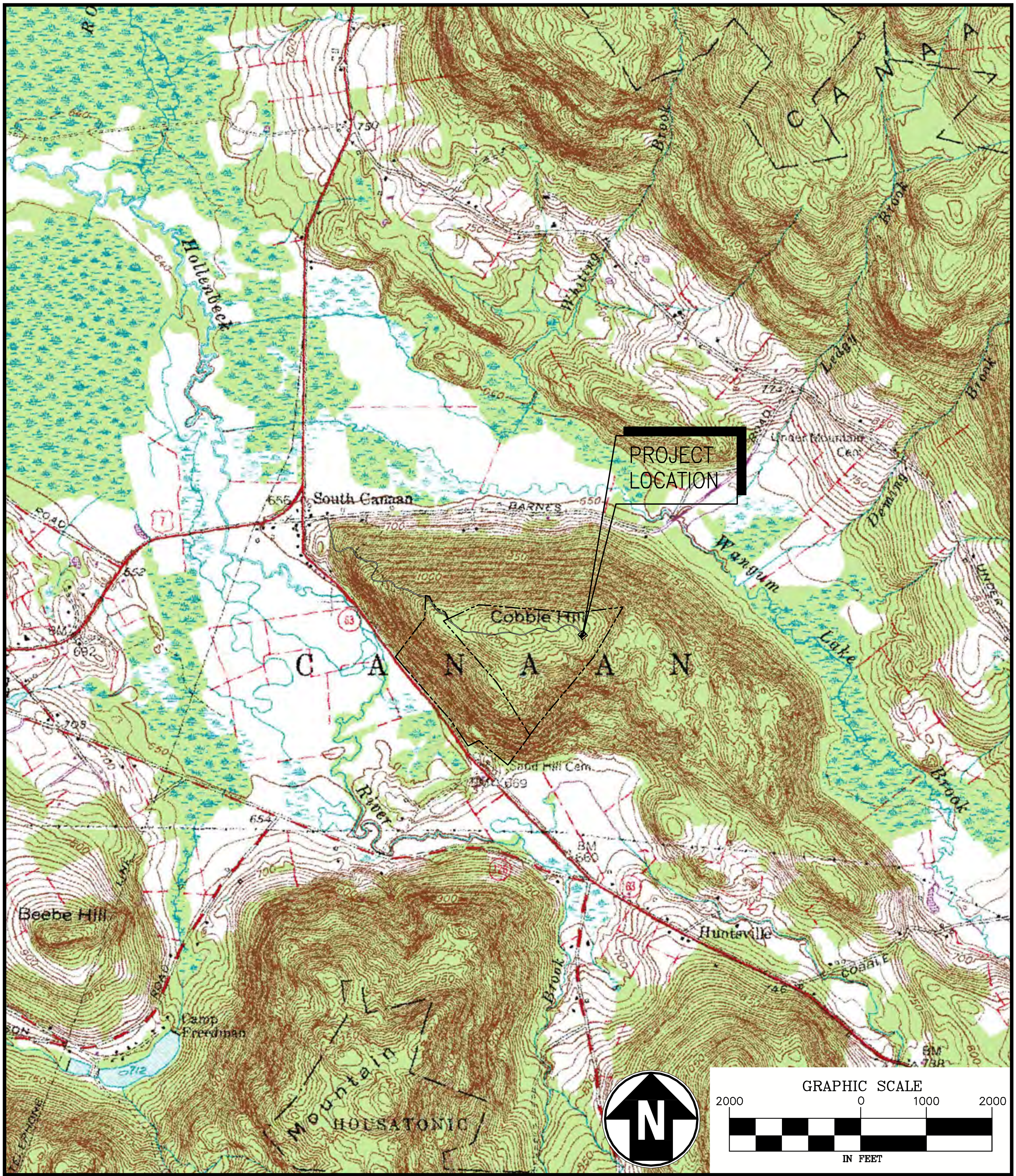

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FIGURE 1
SITE LOCATION MAP

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DATE: 4/12/2013 11:06 AM FILE: W:\SAI CINGULAR\18301\SITES\1026 FALLS VILLAGE 2413\MISC\DRAINAGE_MARCH 2013\FIGURE 1 AND 2.DWG

Figure 2

Soils Map

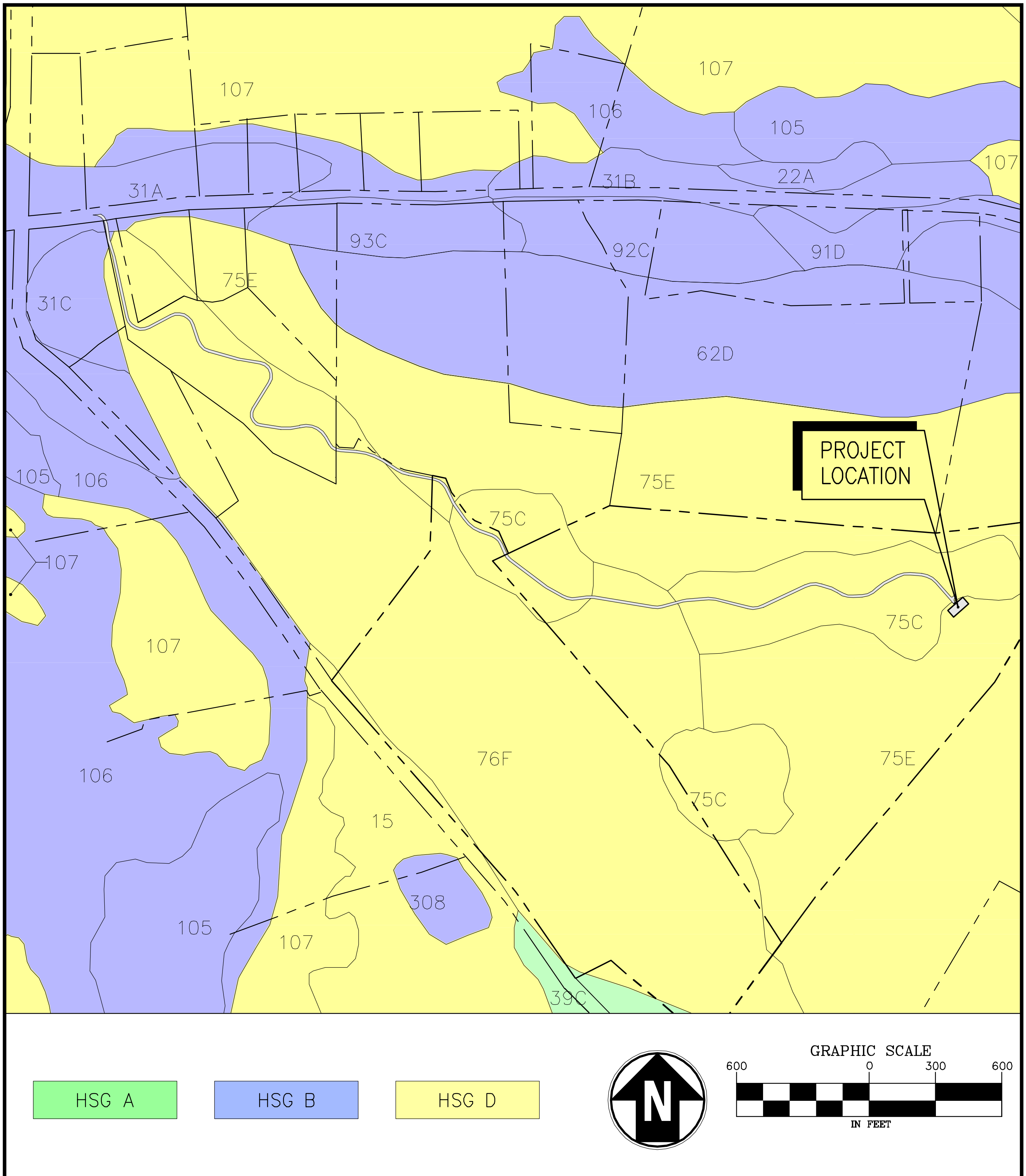

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FIGURE 2
SOILS MAP

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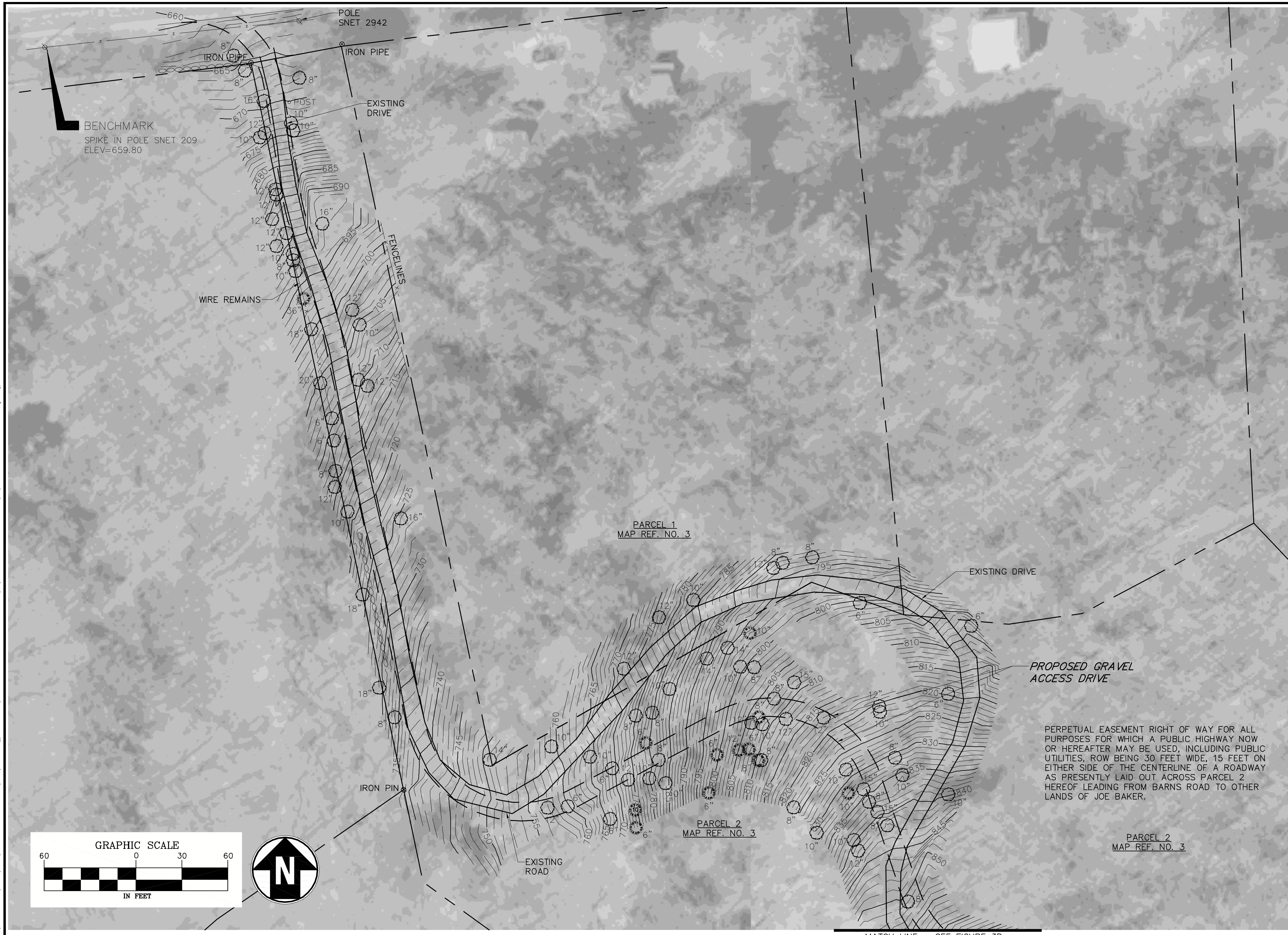
Figures 3A-3E

Existing Site



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	BY: JDM	CHK: DPA	APP'D: JPS
2	04/02/13	REPORT FIGURE	
	BY: JDM	CHK: KDT	APP'D: JPS

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FIGURE 3A

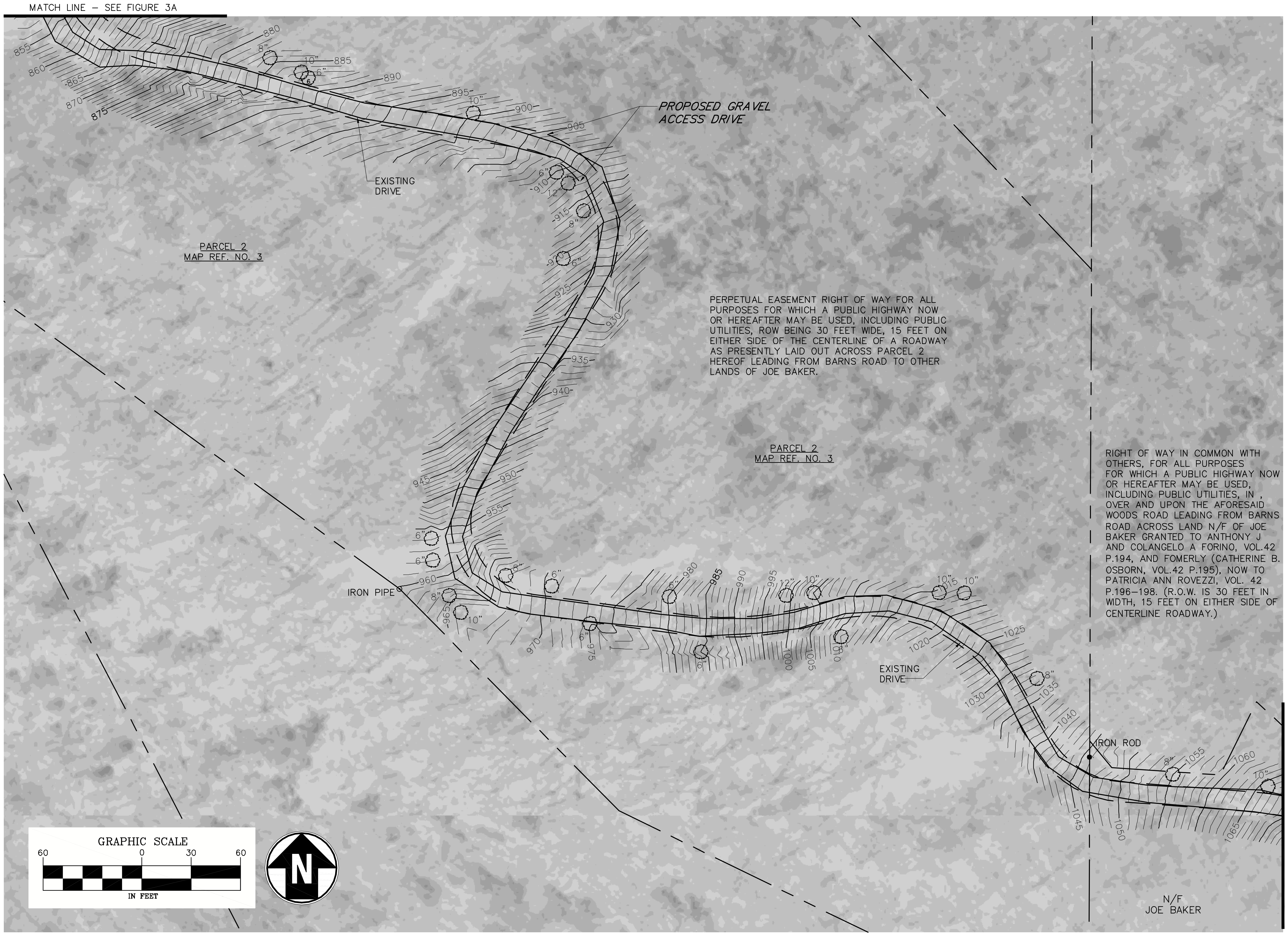

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FIGURE 3B

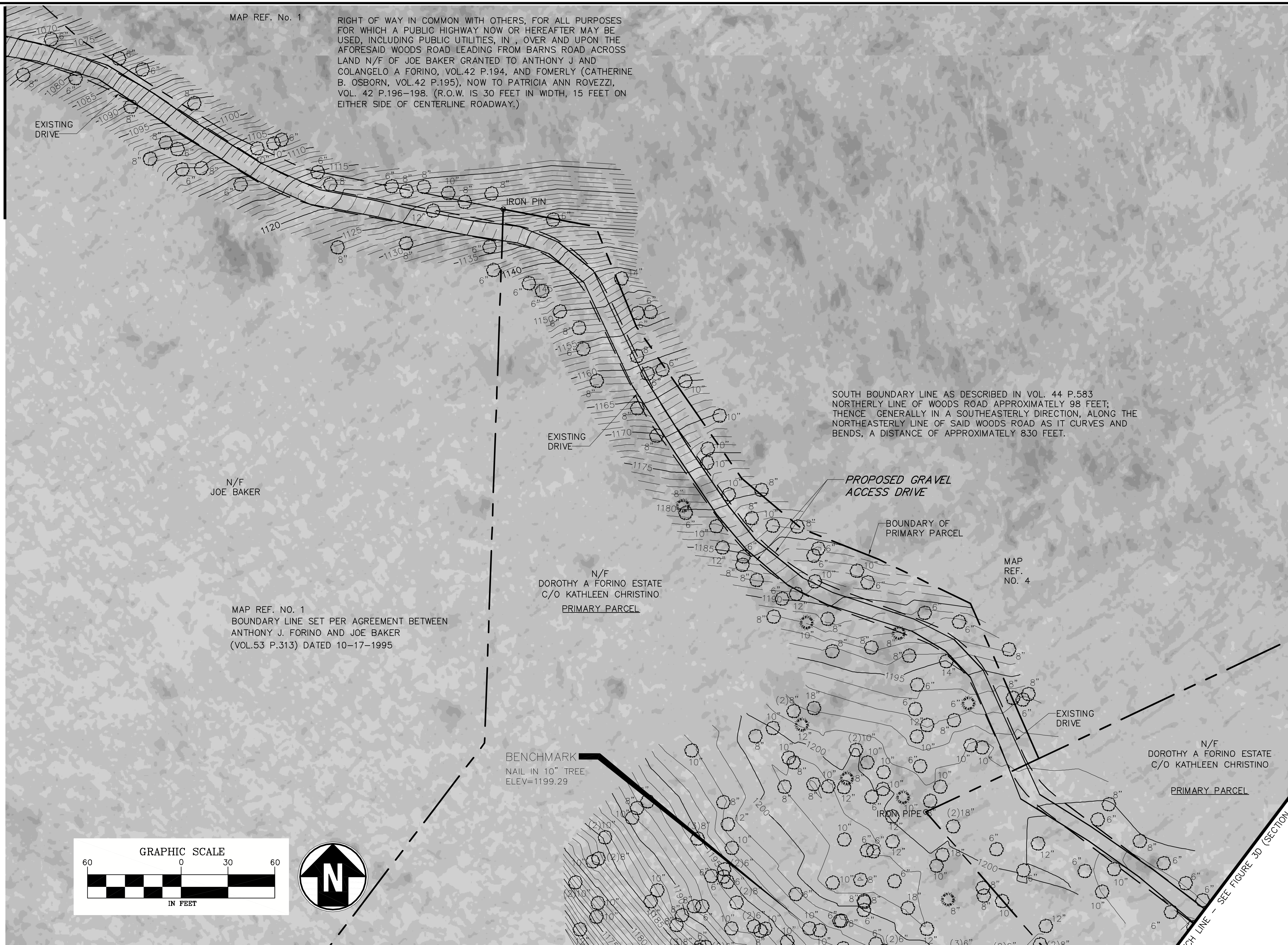

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FIGURE 3C

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FIGURE 3D – SECTION 1

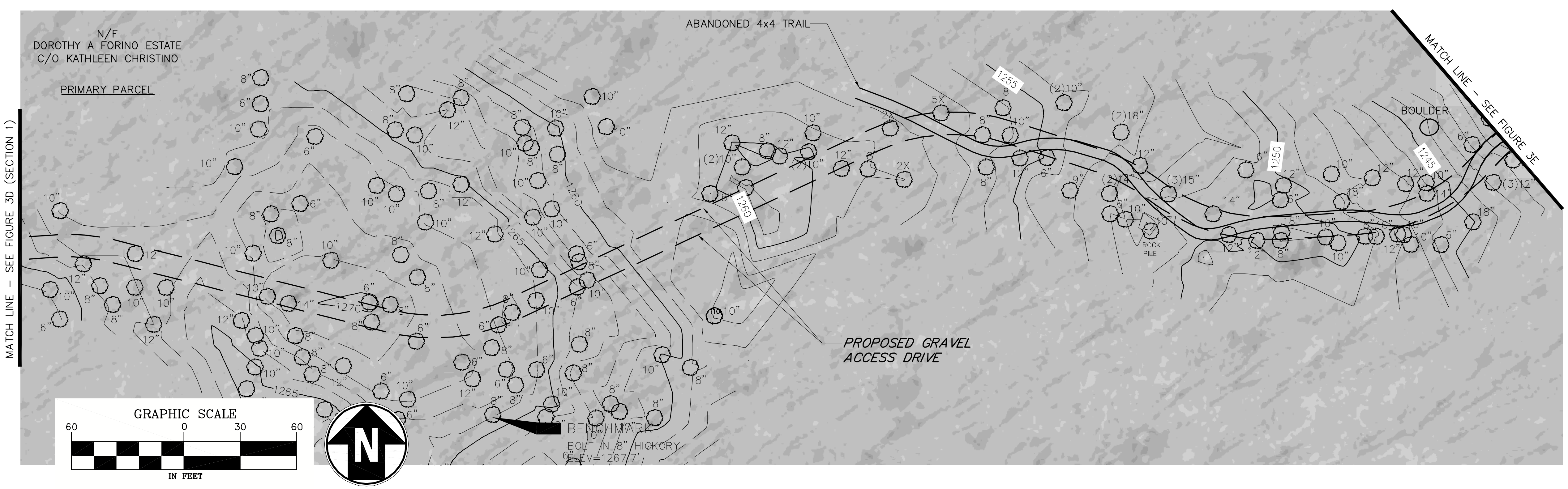

FIGURE 3D – SECTION 2

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FIGURE 3D

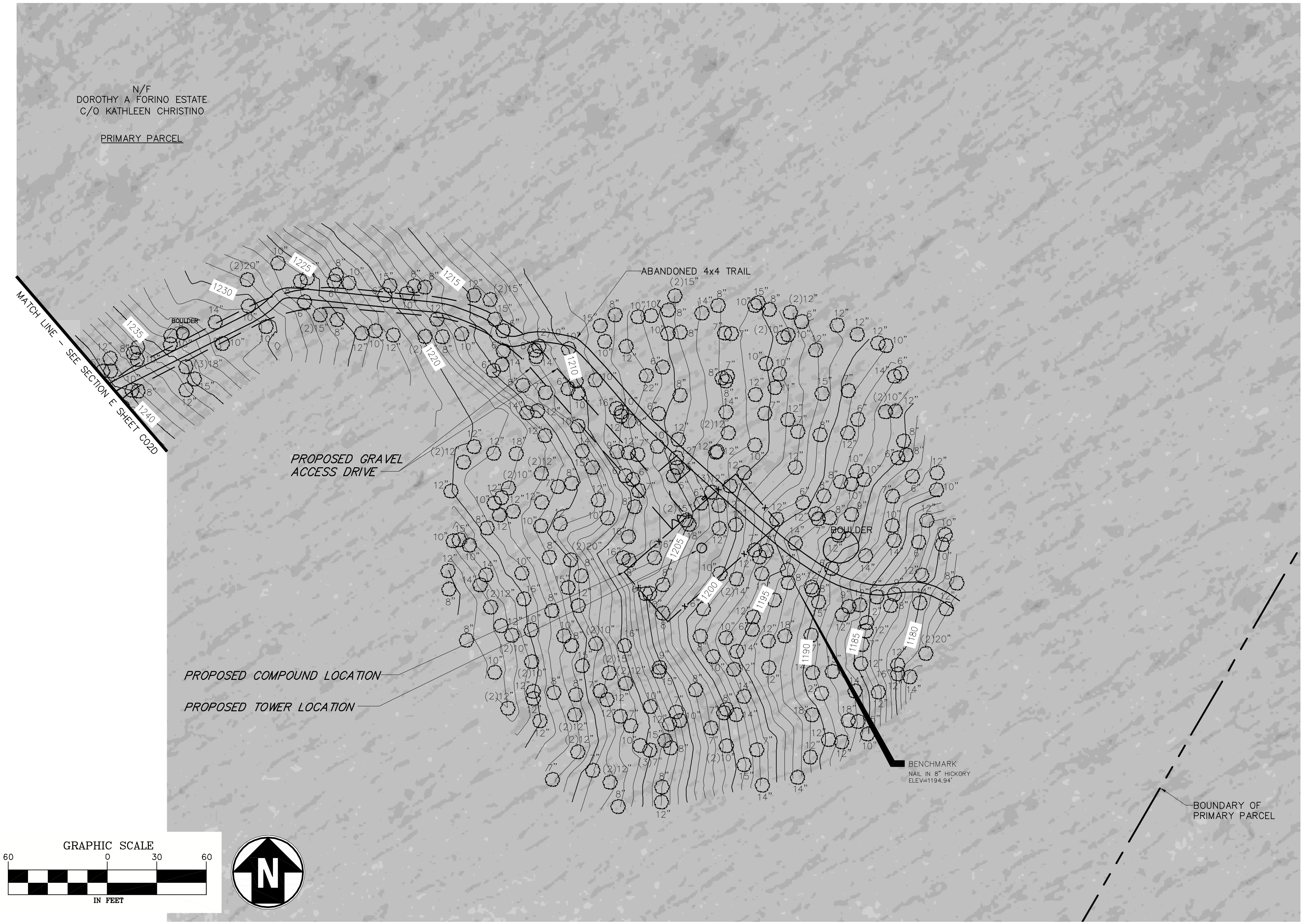

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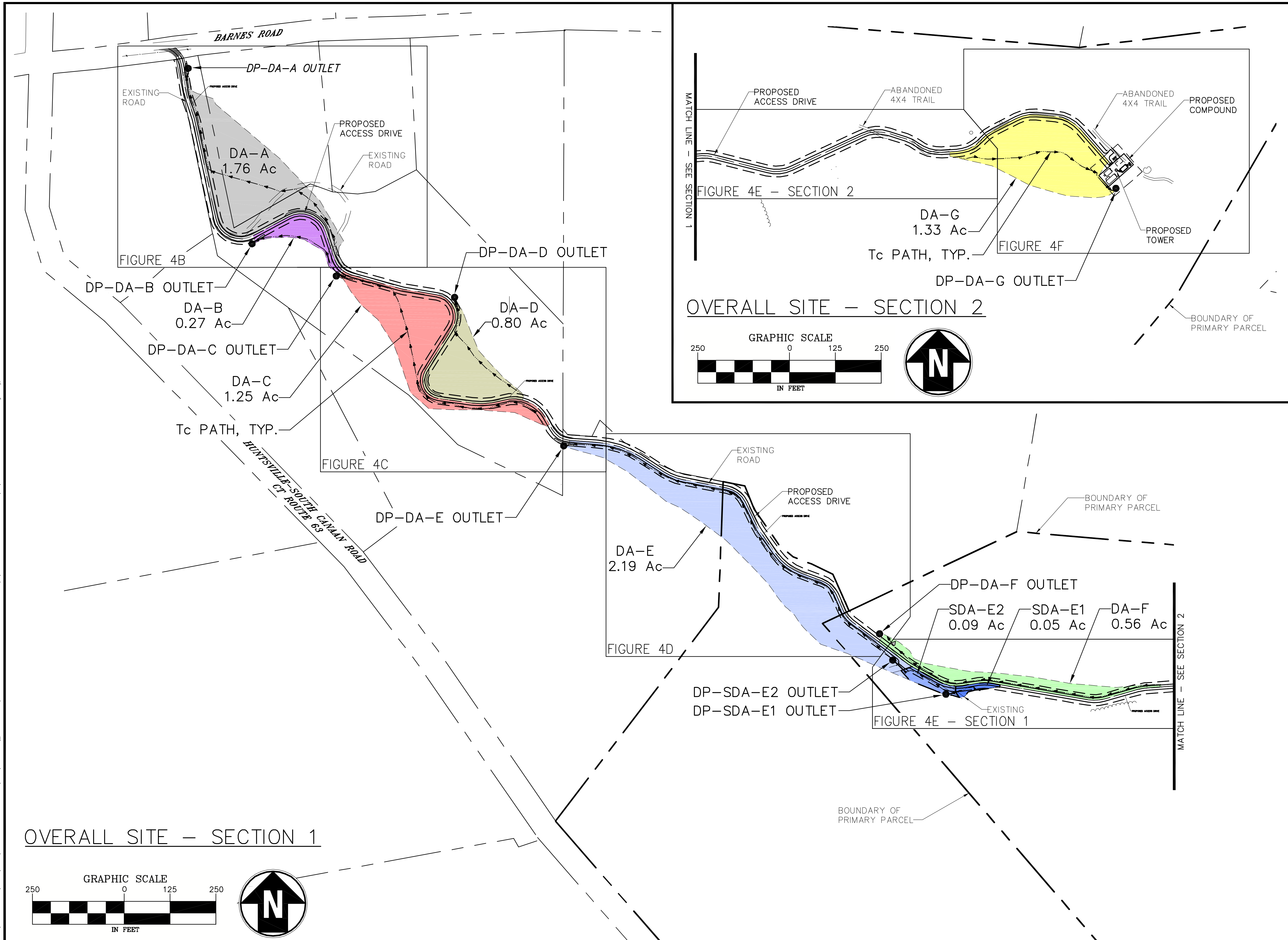
FIGURE 3E

Figures 4A-4F

Drainage Areas



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2	04/02/13	REPORT FIGURE	
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SHEET TITLE
DRAINAGE AREAS

SHEET NUMBER
FIGURE 4A

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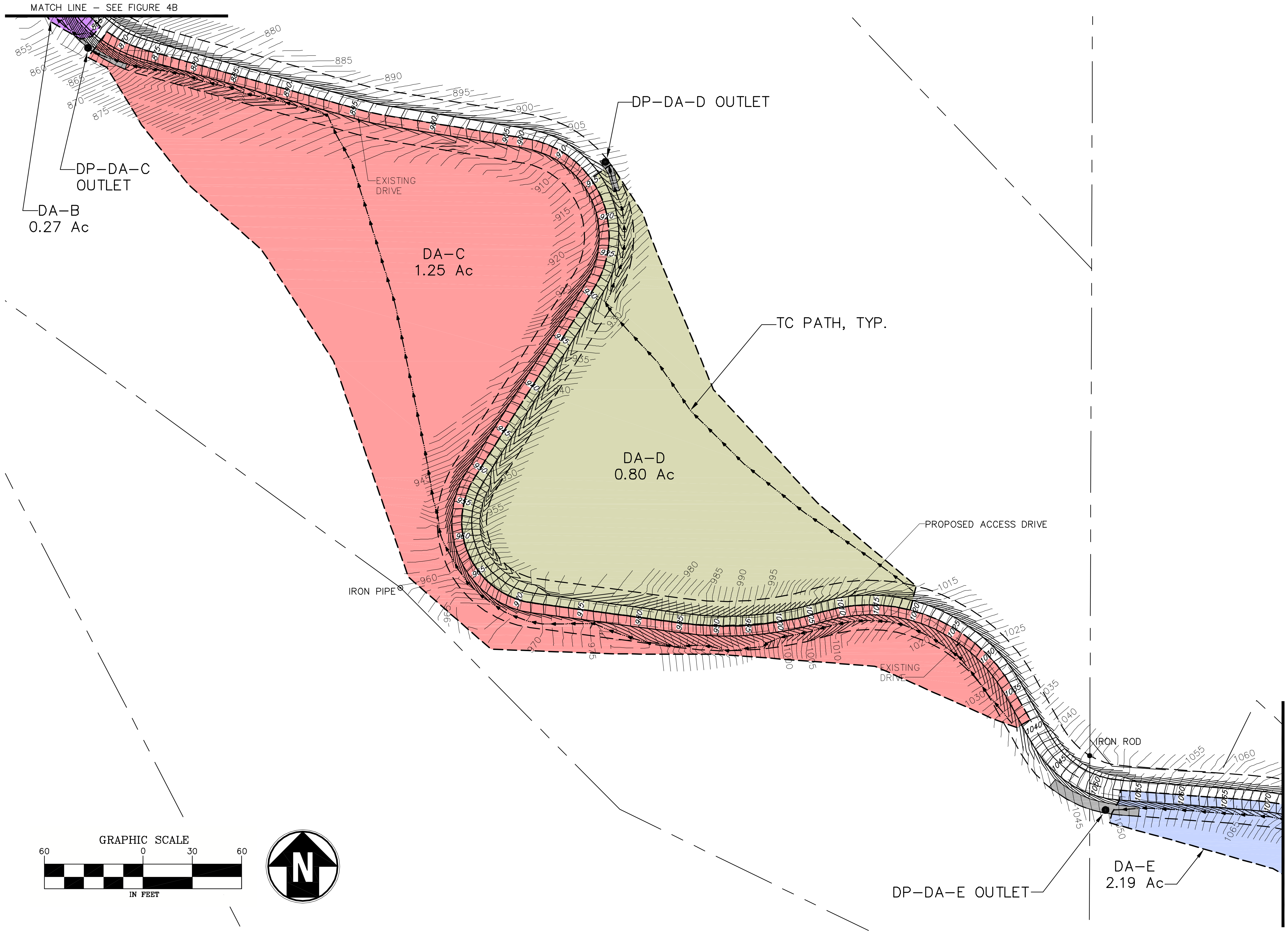
SHEET TITLE
DRAINAGE AREAS

SHEET NUMBER
FIGURE 4B



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SHEET TITLE
DRAINAGE AREAS

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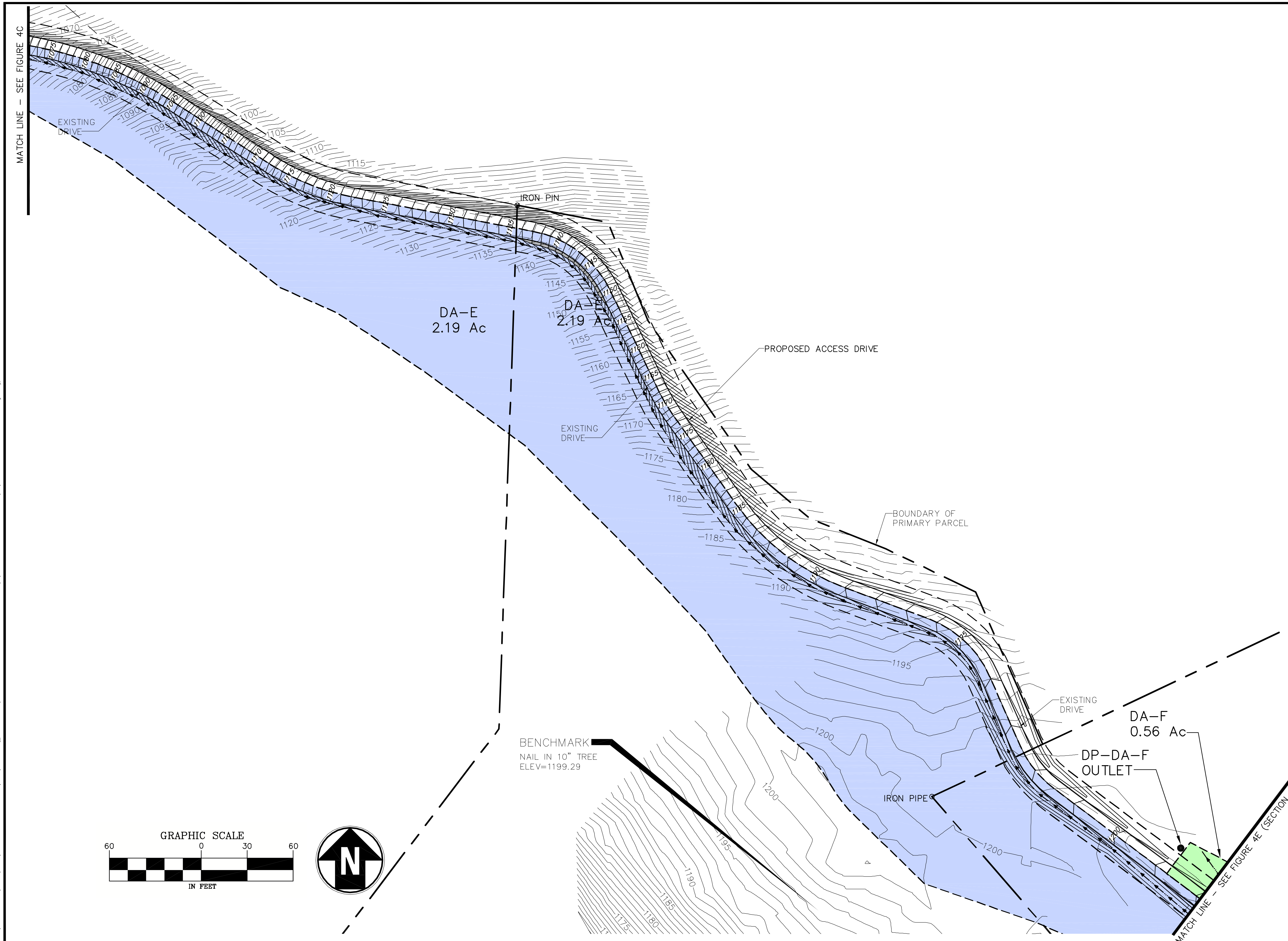
FIGURE 4C



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SHEET TITLE
DRAINAGE AREAS

SHEET NUMBER
FIGURE 4D

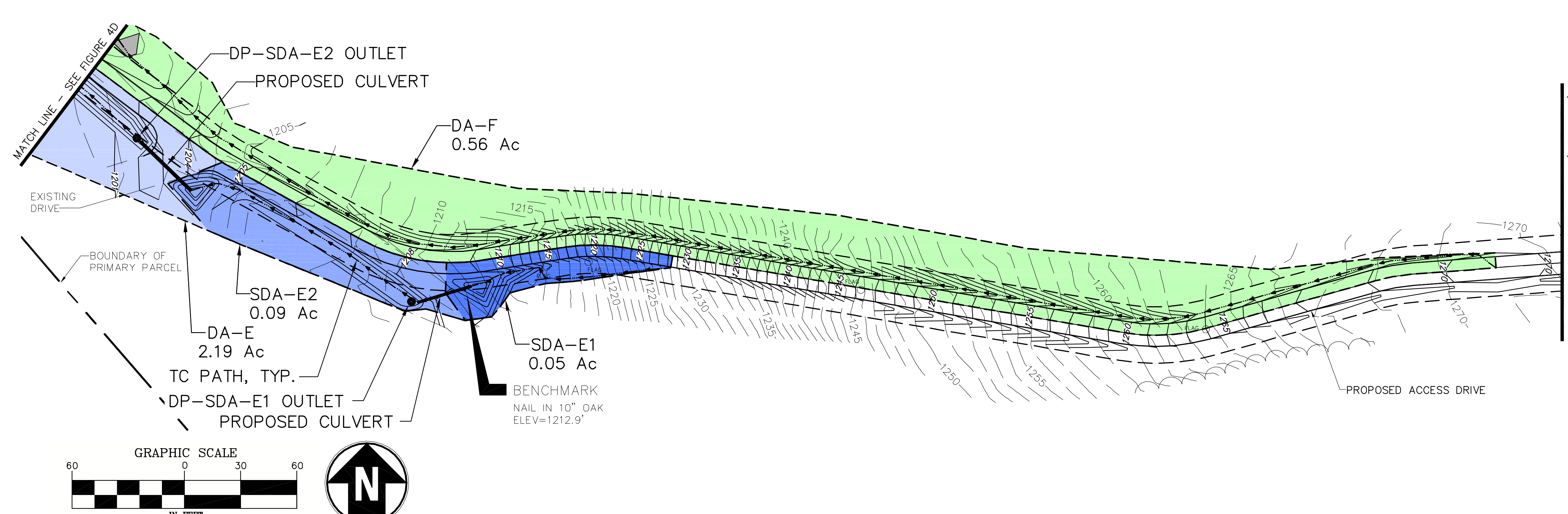

FIGURE 4E – SECTION 1

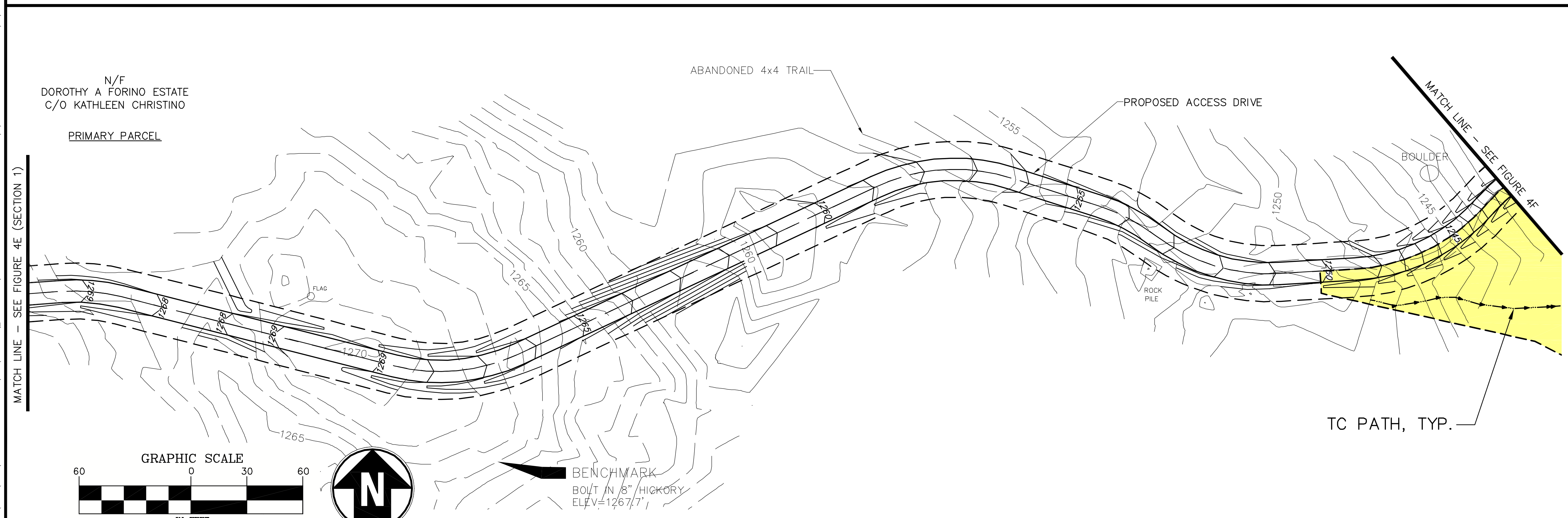

FIGURE 4E – SECTION 2

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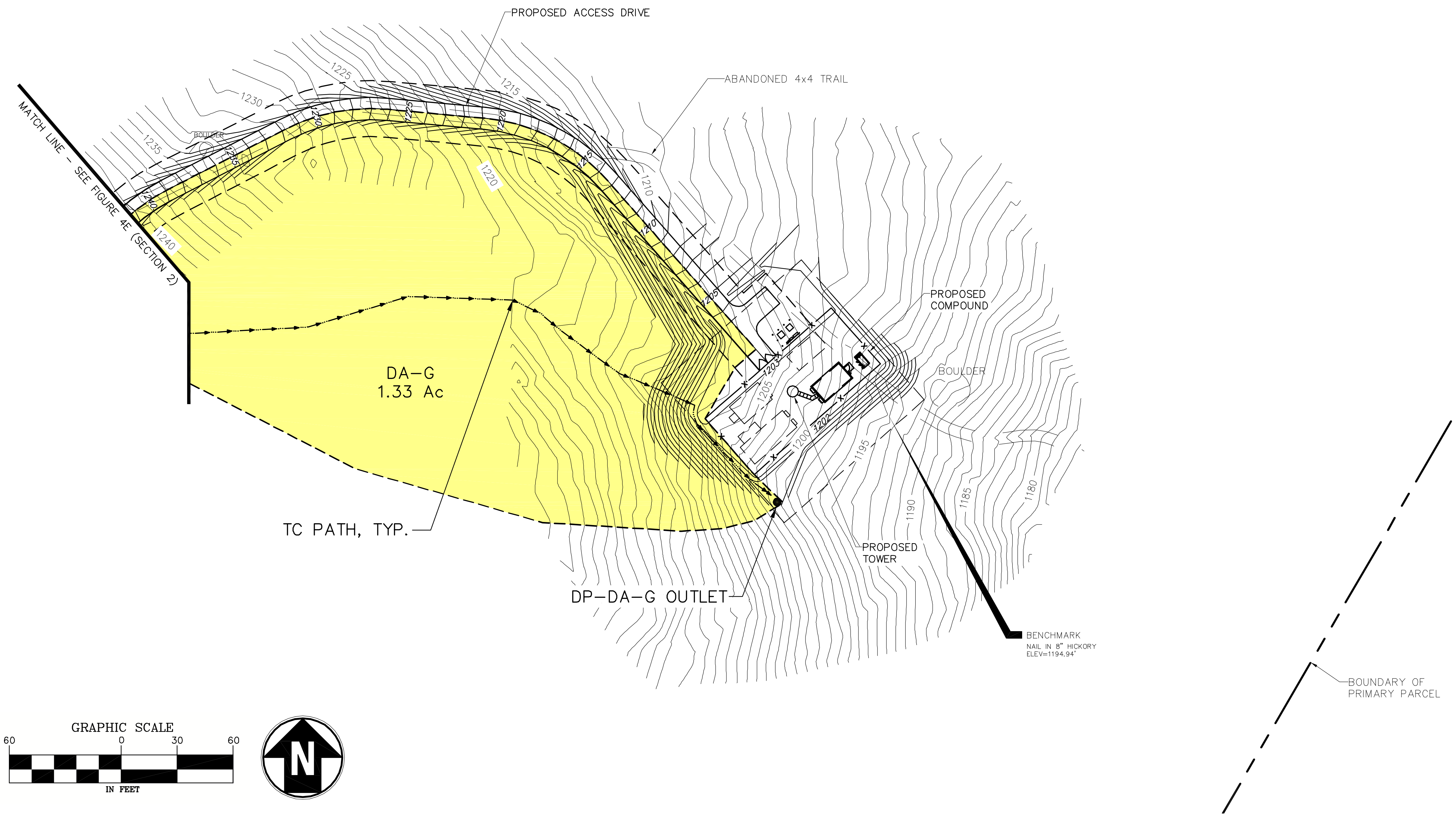
SHEET TITLE
DRAINAGE AREAS

SHEET NUMBER
FIGURE 4E

File: W:\SAI CINGULAR\18301\SITES\1026 FALLS VILLAGE 2413\MISC\DRAINAGE_MARCH 2013\FIGURE 4 - DRAINAGE AREAS.DWG Saved: 4/2/2013 4:49:15 PM Plotted: 4/12/2013 11:26:20 AM User: Montgomery, John



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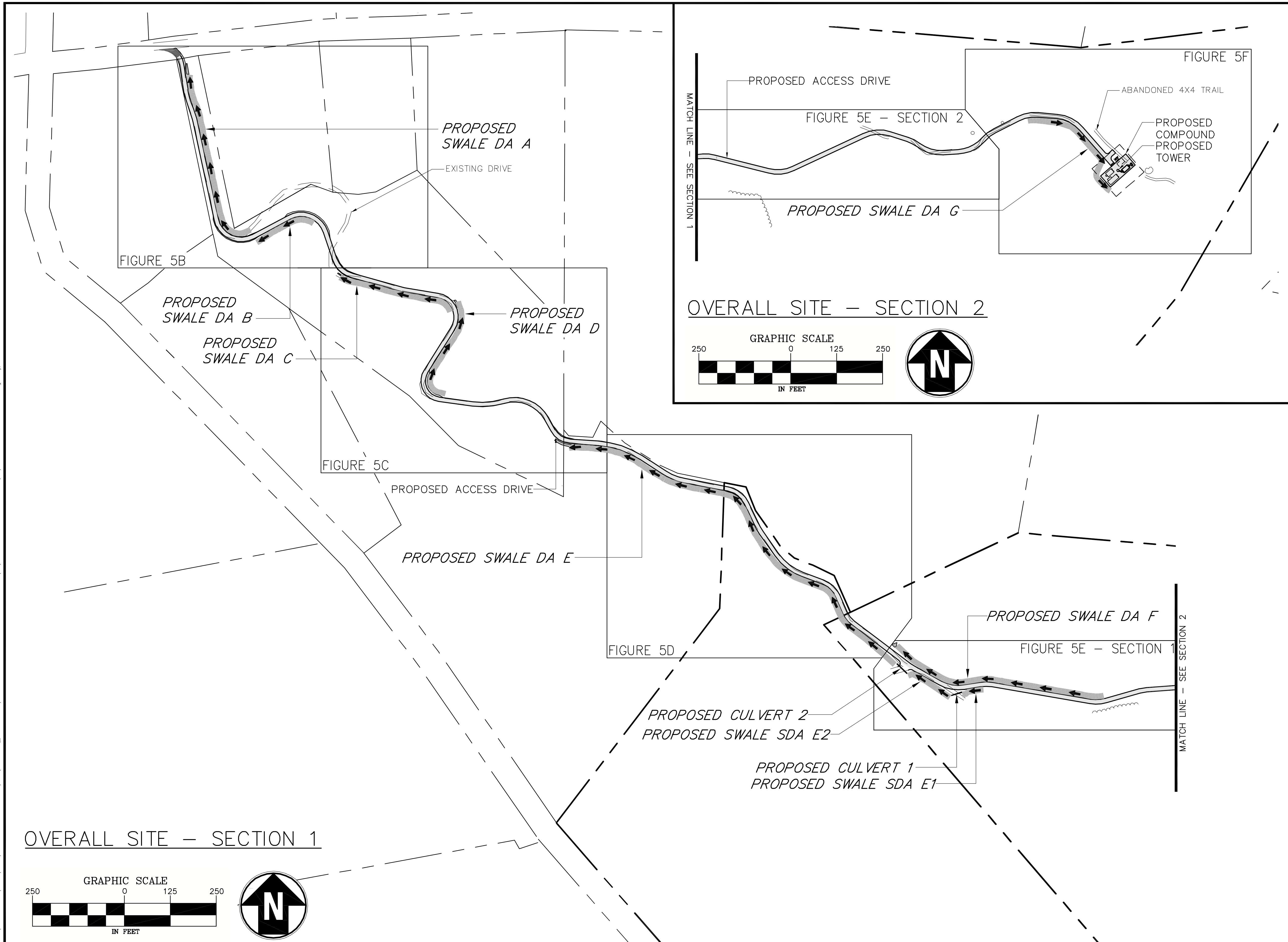
DRAINAGE AREAS

SHEET NUMBER
FIGURE 4F

Figures 5A-5F

Proposed Access Drive Drainage



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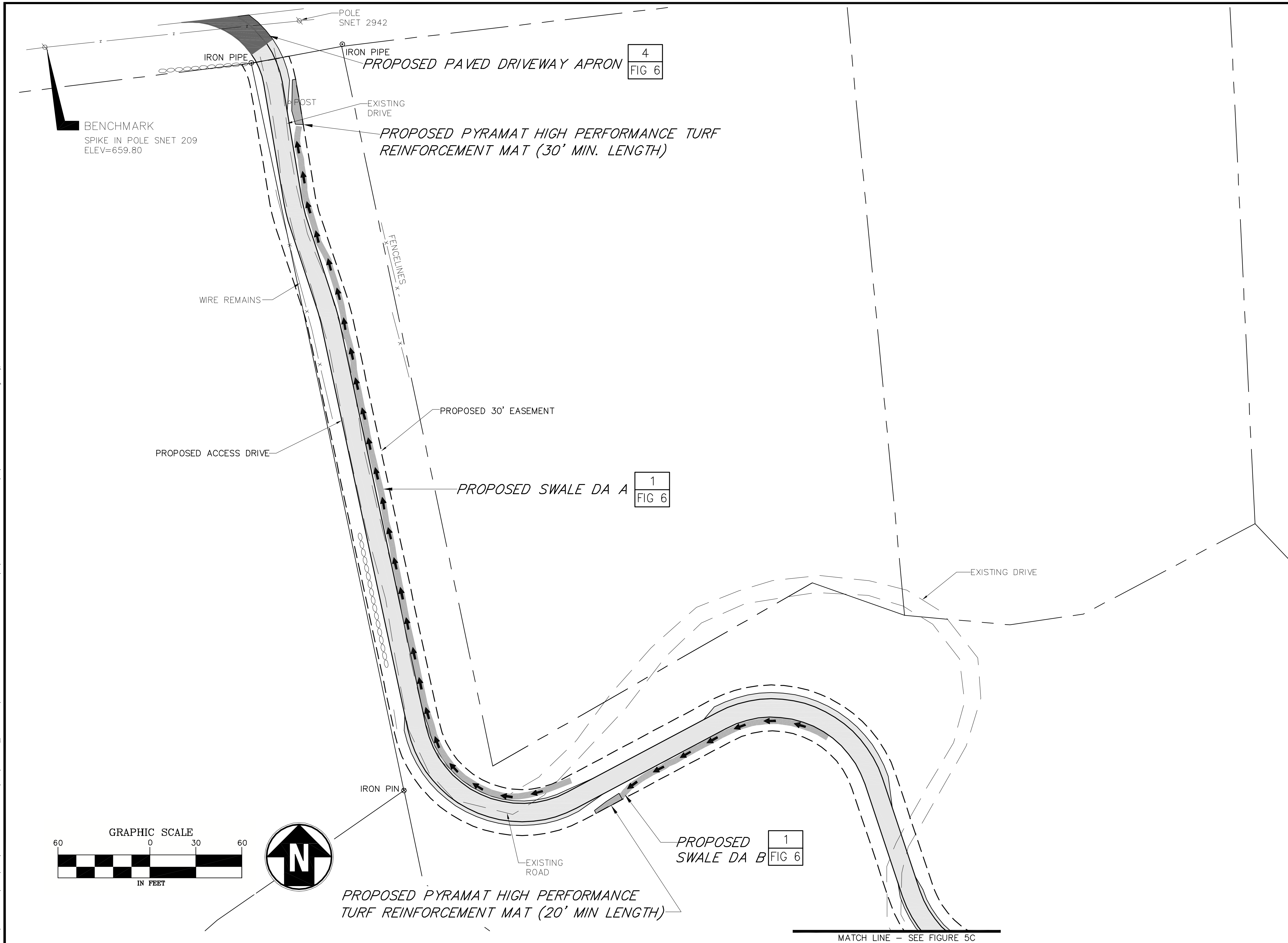
SHEET TITLE
PROPOSED ACCESS DRIVE DRAINAGE

SHEET NUMBER
FIGURE 5A



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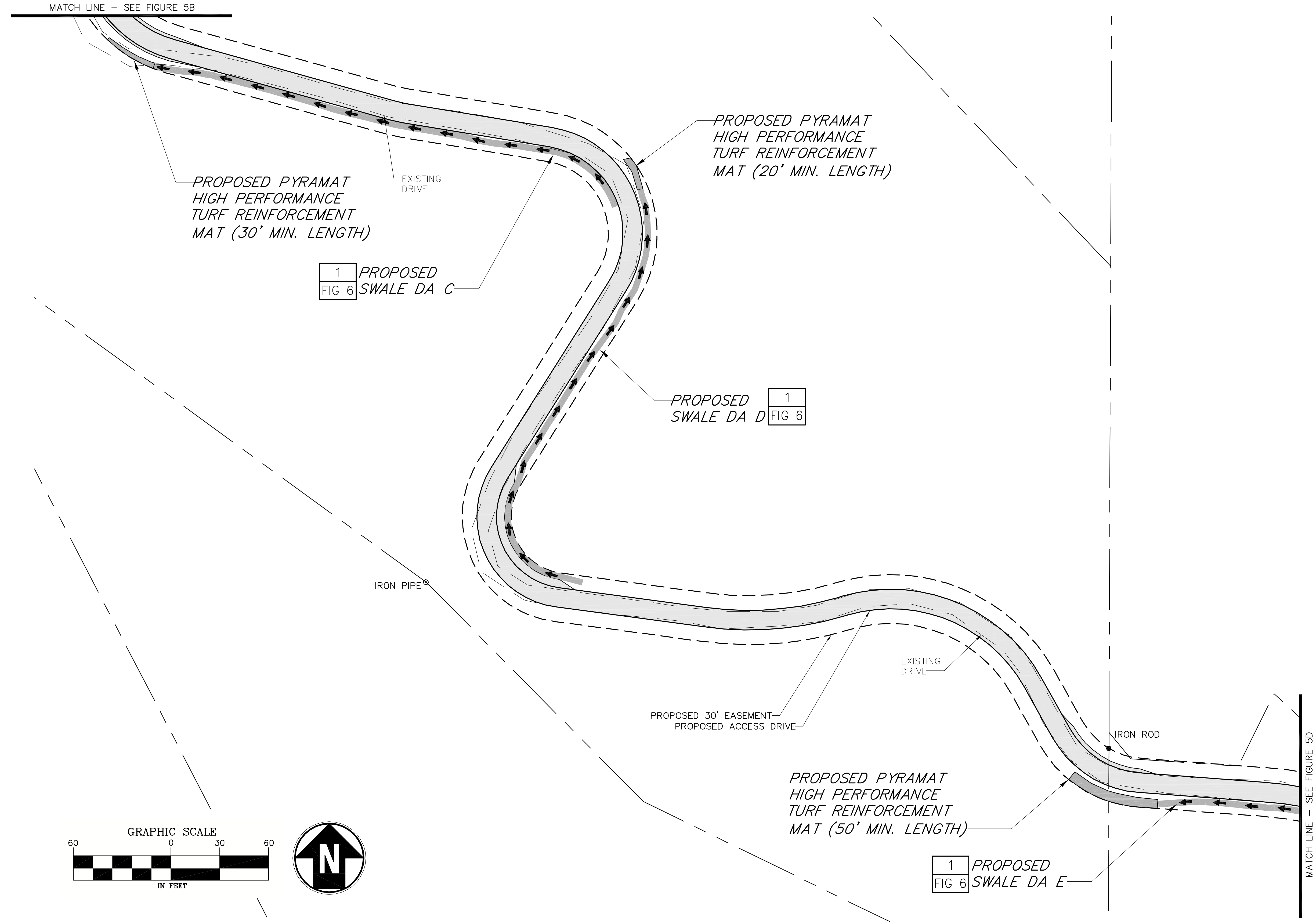
SHEET TITLE
PROPOSED ACCESS DRIVE DRAINAGE

SHEET NUMBER
FIGURE 5B



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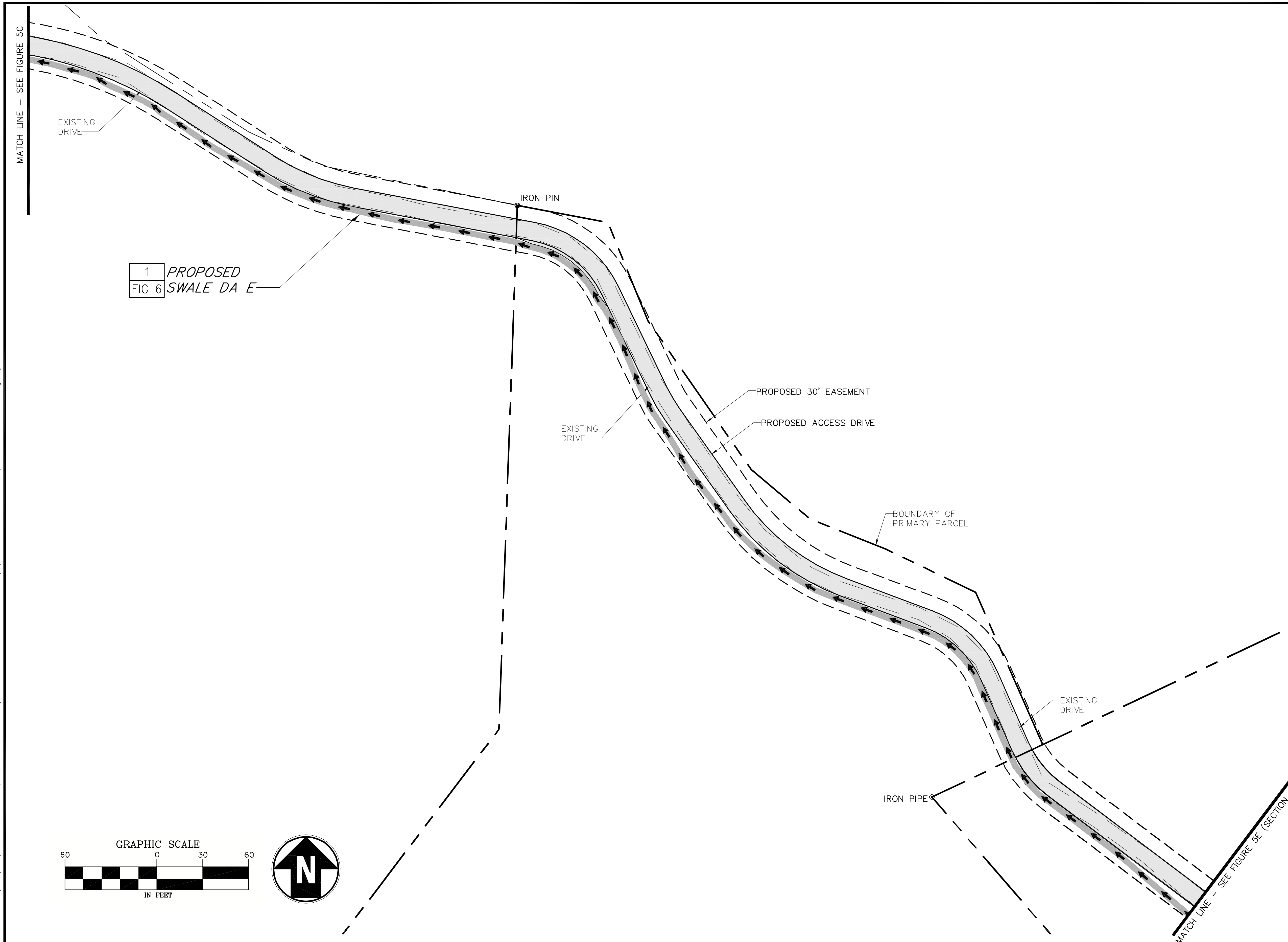
SHEET TITLE
PROPOSED ACCESS DRIVE DRAINAGE

SHEET NUMBER
FIGURE 5C



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SHEET TITLE
PROPOSED ACCESS DRIVE DRAINAGE

SHEET NUMBER
FIGURE 5D

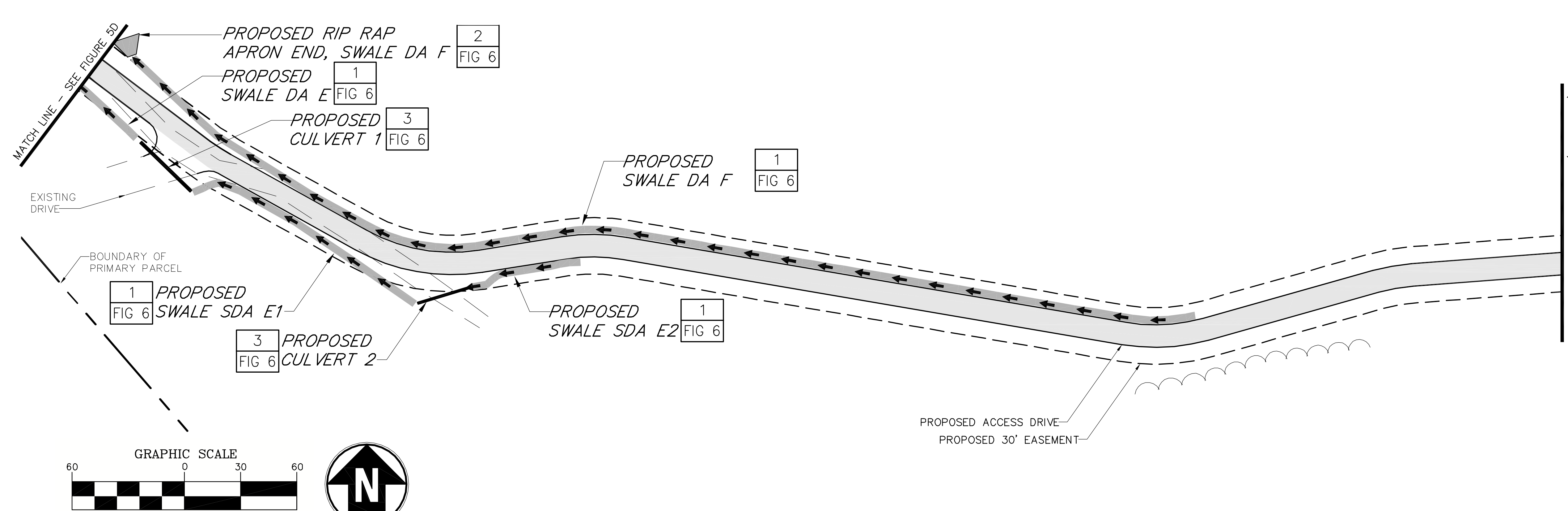

FIGURE 5E – SECTION 1

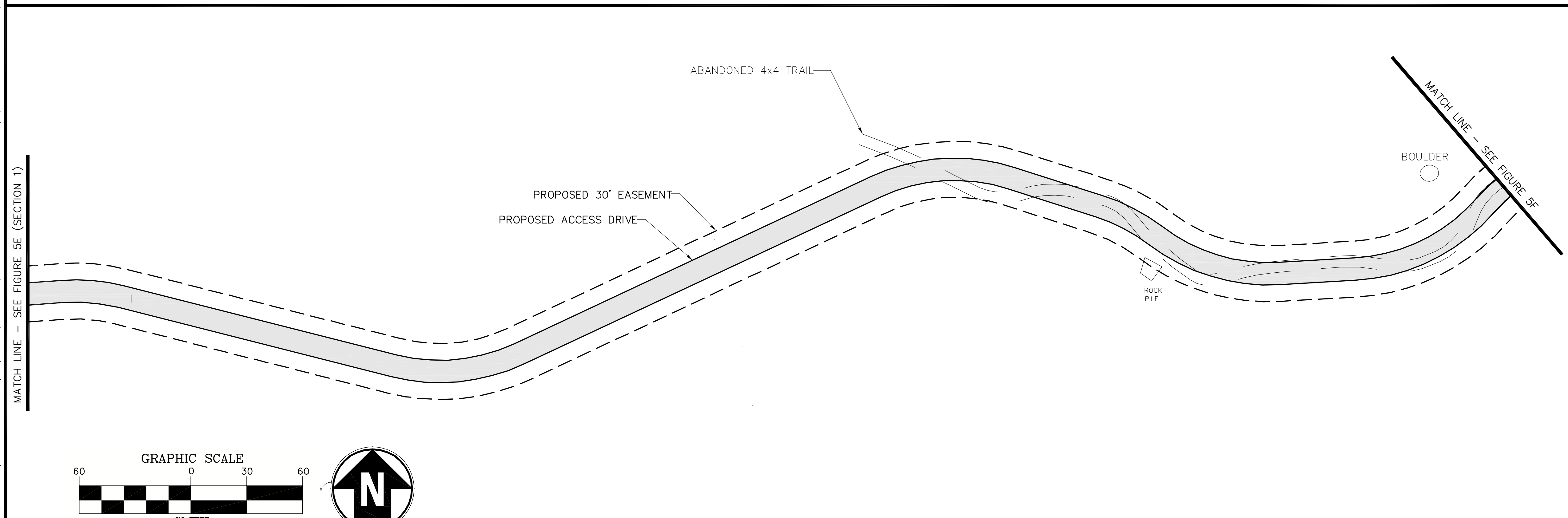

FIGURE 5E – SECTION 2

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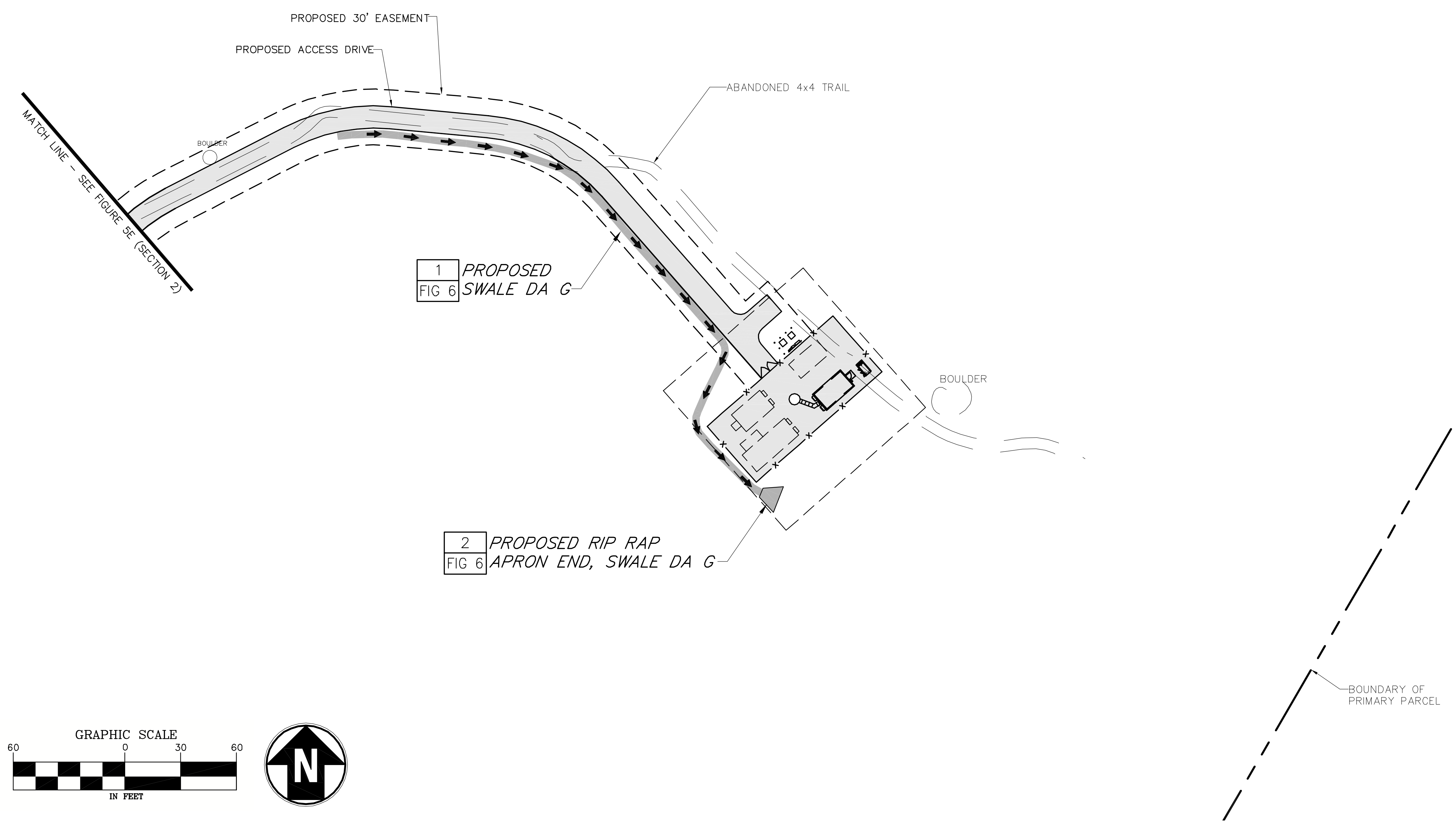
SHEET TITLE
PROPOSED ACCESS DRIVE DRAINAGE

SHEET NUMBER
FIGURE 5E



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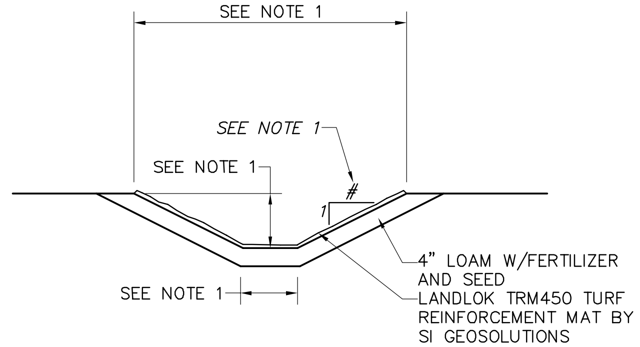
SHEET TITLE
PROPOSED ACCESS DRIVE DRAINAGE

SHEET NUMBER
FIGURE 5F

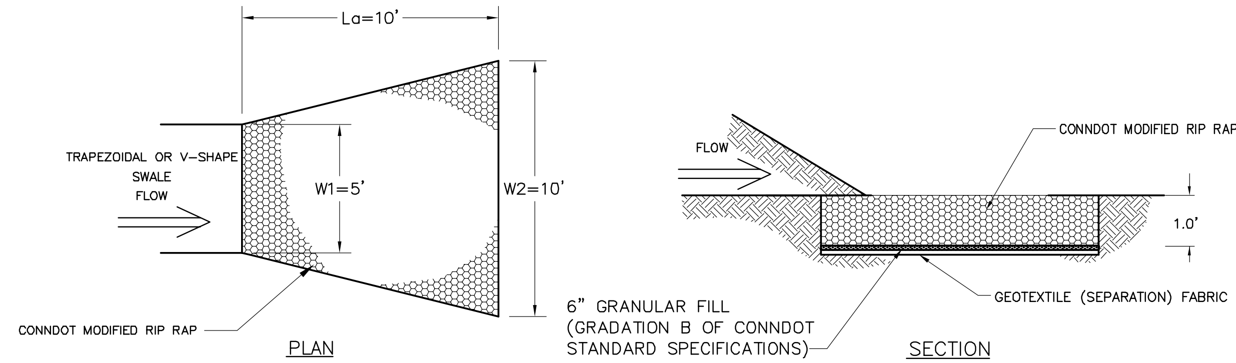
Figure 6

Drainage Detail

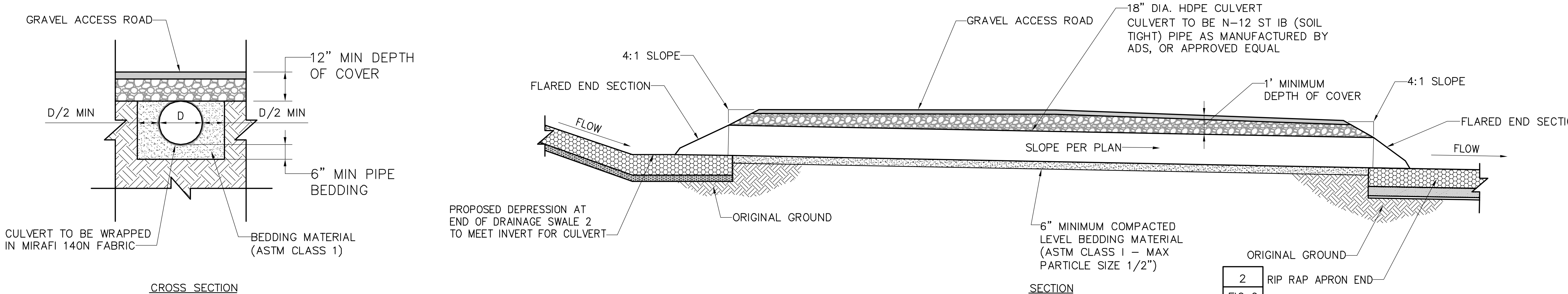


NOTES:
1. DIMENSION VARIES, REFER TO GRADING PLANS.

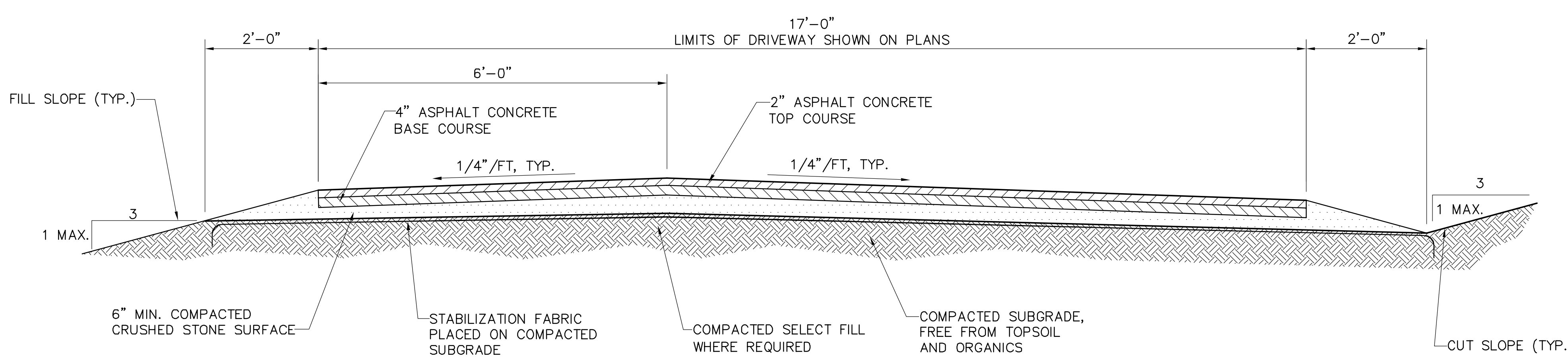
1 DRAINAGE SWALE
SCALE: N.T.S.



2 RIP RAP APRON END
SCALE: N.T.S.



3 TYPICAL CULVERT INSTALLATION
SCALE: N.T.S.



4 ASPHALT APRON SECTION
C08 NO SCALE

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SHEET TITLE
DRAINAGE DETAILS

SHEET NUMBER
FIGURE 6

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