Capstone: SR-64 Preliminary Passing Lane Addition Design

CENE486C
04/26/2019

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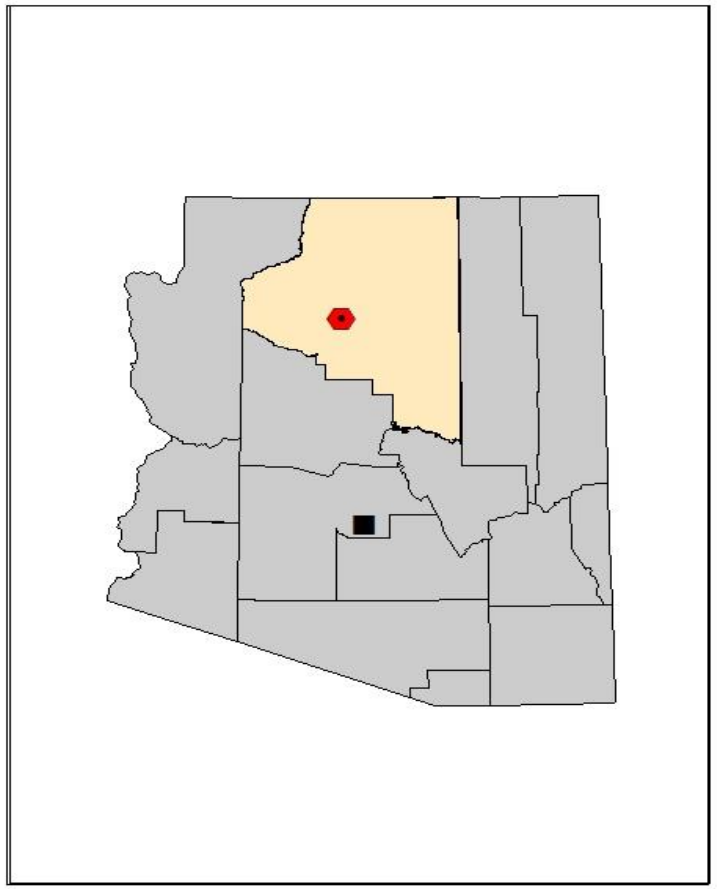
Purpose:
Design a passing lane 3 miles in length
Reduce traffic collisions
Alleviate traffic congestion

- **Client:**
- Arizona Department of Transportation (ADOT).
- **Representative:**
- Nathan Reisner P.E.
- NReisner@azdot.gov
- 1801 S. Milton Road, Flagstaff AZ, 86001
  (928) 779-7545

- Project Exclusions
  - Surveying
  - Geotechnical Analysis
  - New Culvert Design

State Location (A)



SR 64 Location (B)

N

Map (A) reprsents that SR 64 is located in the state of Arizona in the Coconino County

Map (B) representst the layout of SR 64 between Williams, and the Grand Canyon, and the location of the of the project site.

Legend

- Phoenix
- Flagstaff
- Grand Canyon Village
- Williams
- HWY64
- Maker 201 (Miles)
- Maker 204 (Miles)
- Segment of interset
- Hwy 64

0 10 20 40 60 80 Miles

Figure 1: Project location Map[1]

Impacts

- Safety
  - 0-0.35 crashes per million vehicle miles traveled between MM201-204[2]
- Time
  - Less travel time
- Economy
  - Fewer Crashes
  - Fewer Police Reports
  - Fewer Emergency Responses
  - Fewer Road Cleaning/ Fixing

Figure 2: Stuck Behind Slow Vehicle [3]

Project Milestones

1. Site Assessment (30 Percent)
2. Hydrology and Hydraulics Analysis (60 Percent)
3. Existing Highway Design (60 Percent)
4. Traffic Control Plan (90 Percent)
5. Design Plan Sets (90 Percent)
    - Typical Roadway Sections
    - Geometric Control
    - Drainage Plans and Details
    - Plan and Profile
    - Cross Sections
    - Traffic Control Plans and Quantities
    - Cost Report
    - Drainage Report
6. Project Management (90 Percent)

Site Assessment

- Existing Road Condition
- Drainage Condition
- Pavement Assessment
  - **Entering** $\boldsymbol{Taper\ Length = Lane\ Width * 25}$
  - ADOT Roadway Design Guidelines- May 2012 Edition- DOC 31-089 (Section 207-B)[4]
  - **Dropping** $\boldsymbol{Taper\ Length = Lane\ Width * Design\ Speed}$
  - ADOT Roadway Design Guidelines- May 2012 Edition- DOC 31-089 (Section 207-C)[4]
- Right of Way Assessment
  - Based on the Arizona Highway Department Right of Way Division for State Route 64 , Mile Post 200-215 have 100 feet of Right of way on each side of the centerline.[5]

Figure 3: Northbound Mile Marker 201 View

Figure 4: 78” Corrugated Metal Pipe Culvert A

Figure 5: 36” Corrugated Metal Pipe Culvert I

Figure 6: 10’x6’ Single Box Concrete Culvert H

Figure 7: 8’x4’ Doubled Box Concrete Culvert F

Culvert Analysis

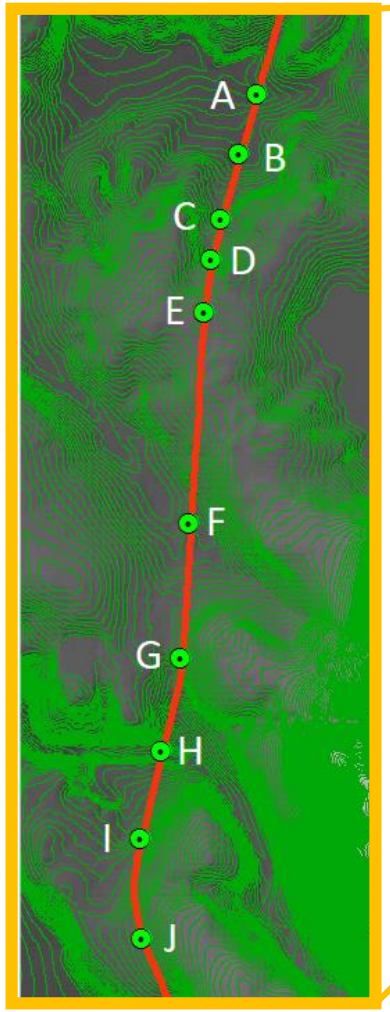


Figure 8: Culvert Naming/Location[1]

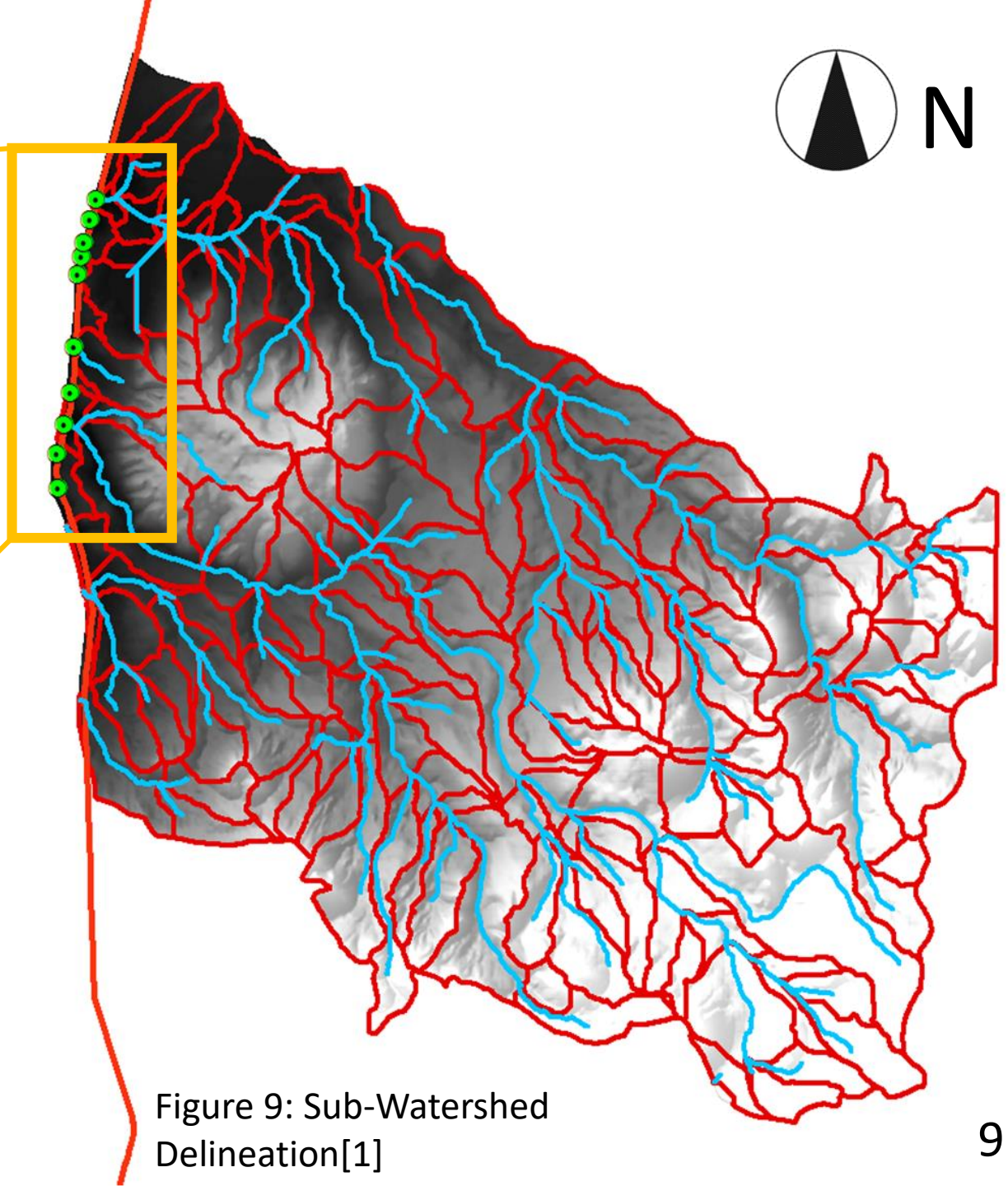


Figure 9: Sub-Watershed Delineation[1]

Culvert Analysis

Equation 1: Soil and Cover Conditions

$$S = \frac{1000}{CN} - 10$$

Equation 2: Total Losses From Soil and Cover Conditions

$$I_a = 0.2S$$

Equation 3: Runoff of Water in Inches

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

Equation 4: Flow Volume

$$Q_t = \frac{Q \times A}{t}$$

Equation 5: Rational Method

$$Q_R = CiA$$

S= Potential max retention after runoff begins

CN= Curve number [9]

I_a= Initial abstraction

Q= Runoff of water

P= Precipitation of rainfall for area of interest

Q_t= Total runoff of water, volume

A= Area of sub-watershed

t= Storm time duration

Q_R= Peak discharge

C= Runoff coefficient

i= Design storm rainfall intensity

Culvert Analysis

Table 1: Culvert Analysis for Existing Conditions

Culvert	Inputs						Outputs	
	Discharge (cfs)	Max Allowable HW (ft)	Shape	Material	Size	Length (ft)	Computed HW (ft)	
A	426.6175	8.5	Circular	CMP	78"	52.0	11.69	Fail
B	5.137906	4.0	Circular	CMP	30"	42.5	2.36	Pass
C	2.159898	8.5	Circular	CMP	30"	68.0	2.06	Pass
D	2.697454	3.8	Circular	CMP	24"	57.0	2.42	Pass
E	1.829324	3.0	Circular	CMP	24"	45.0	1.91	Pass
F	38.98193	6.5	Box	Concrete	8 x 4 ft	39.5	1.91	Pass
G	4.064084	8.0	Circular	CMP	30"	87.0	2.92	Pass
H	604.0946	14.0	Box	Concrete	10 x 6 ft	70.0	10.27	Pass
I	2.77633	5.0	Circular	CMP	36"	65.0	2.42	Pass
J	1.290884	3.0	Circular	CMP	24"	54.0	2.62	Pass

Culvert Analysis

Table 2: Culvert Analysis for Post-Construction

Culvert	Inputs						Outputs	
	Discharge (cfs)	Max Allowable HW (ft)	Shape	Material	Size	Length (ft)	Computed HW (ft)	
A	426.6175	8.5	Box	Concrete	8 x 4 ft	74.5	6.19	Pass
B	5.137906	4.0	Circular	CMP	30"	62.1	2.31	Pass
C	2.159898	8.5	Circular	CMP	30"	86.2	2.06	Pass
D	2.697454	3.8	Circular	CMP	24"	78.3	2.42	Pass
E	1.829324	3.0	Circular	CMP	24"	60.8	1.92	Pass
F	38.98193	6.5	Box	Concrete	8 x 4 ft	54.1	2.4	Pass
G	4.064084	8.0	Circular	CMP	30"	117.4	2.92	Pass
H	604.0946	14.0	Box	Concrete	10 x 6 ft	87.9	10.27	Pass
I	2.77633	5.0	Circular	CMP	36"	87.5	2.42	Pass
J	1.290884	3.0	Circular	CMP	24"	69.6	2.62	Pass

CulvertMaster Software Analysis

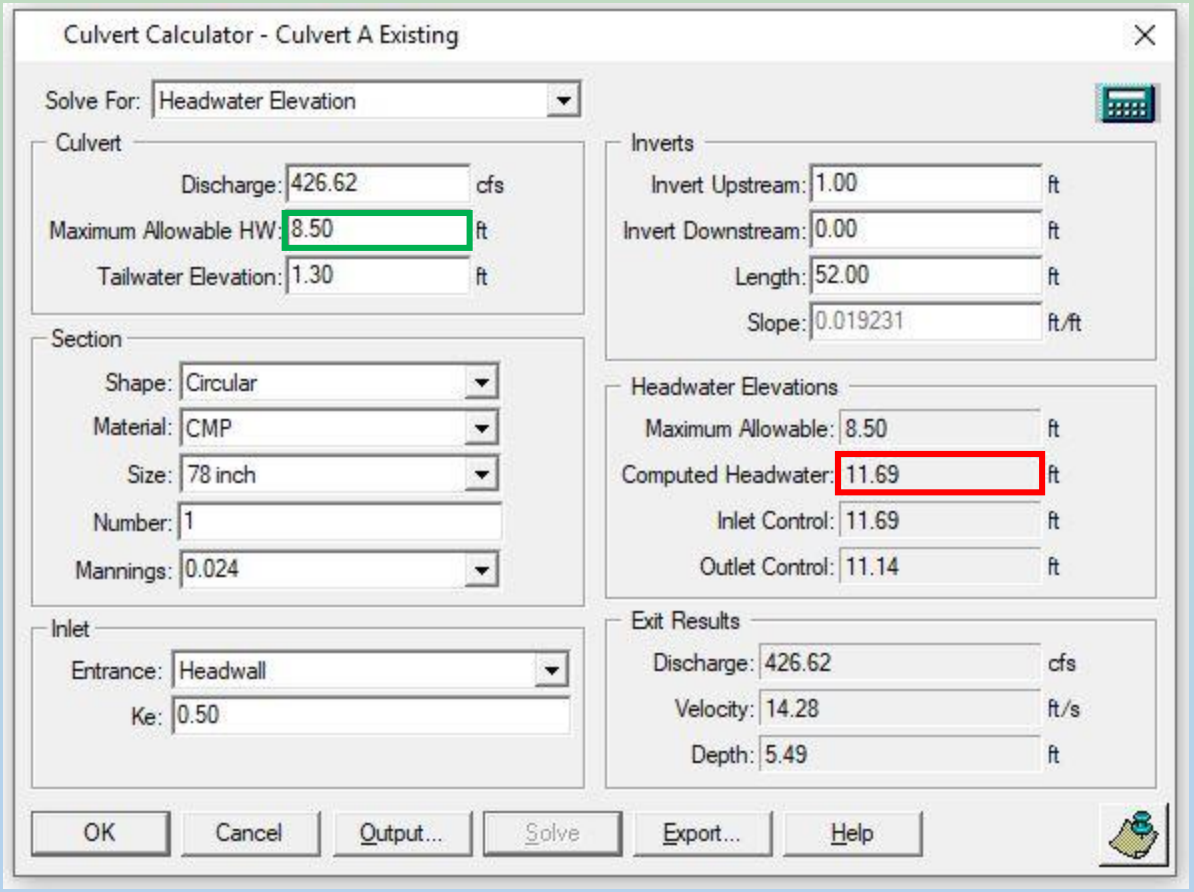


Figure 10: Culvert A CMP 78” Design

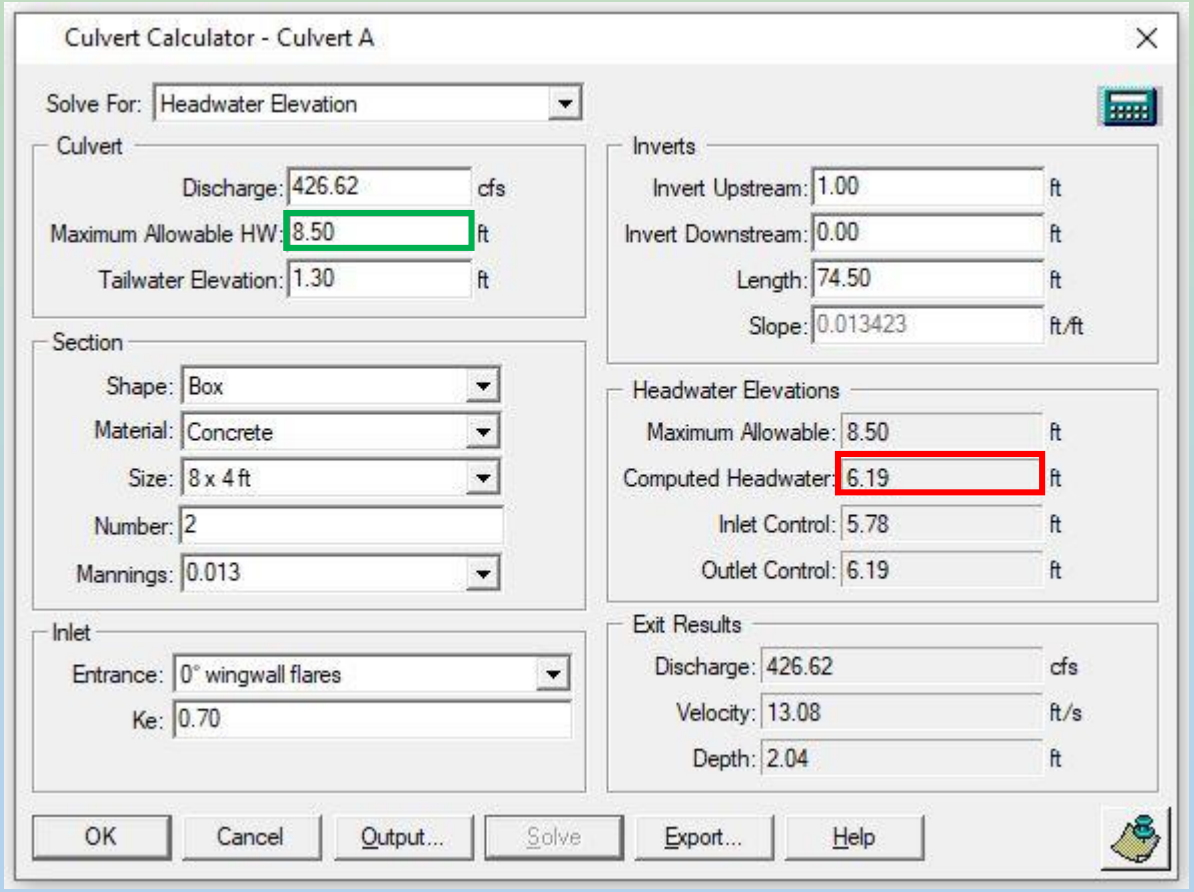
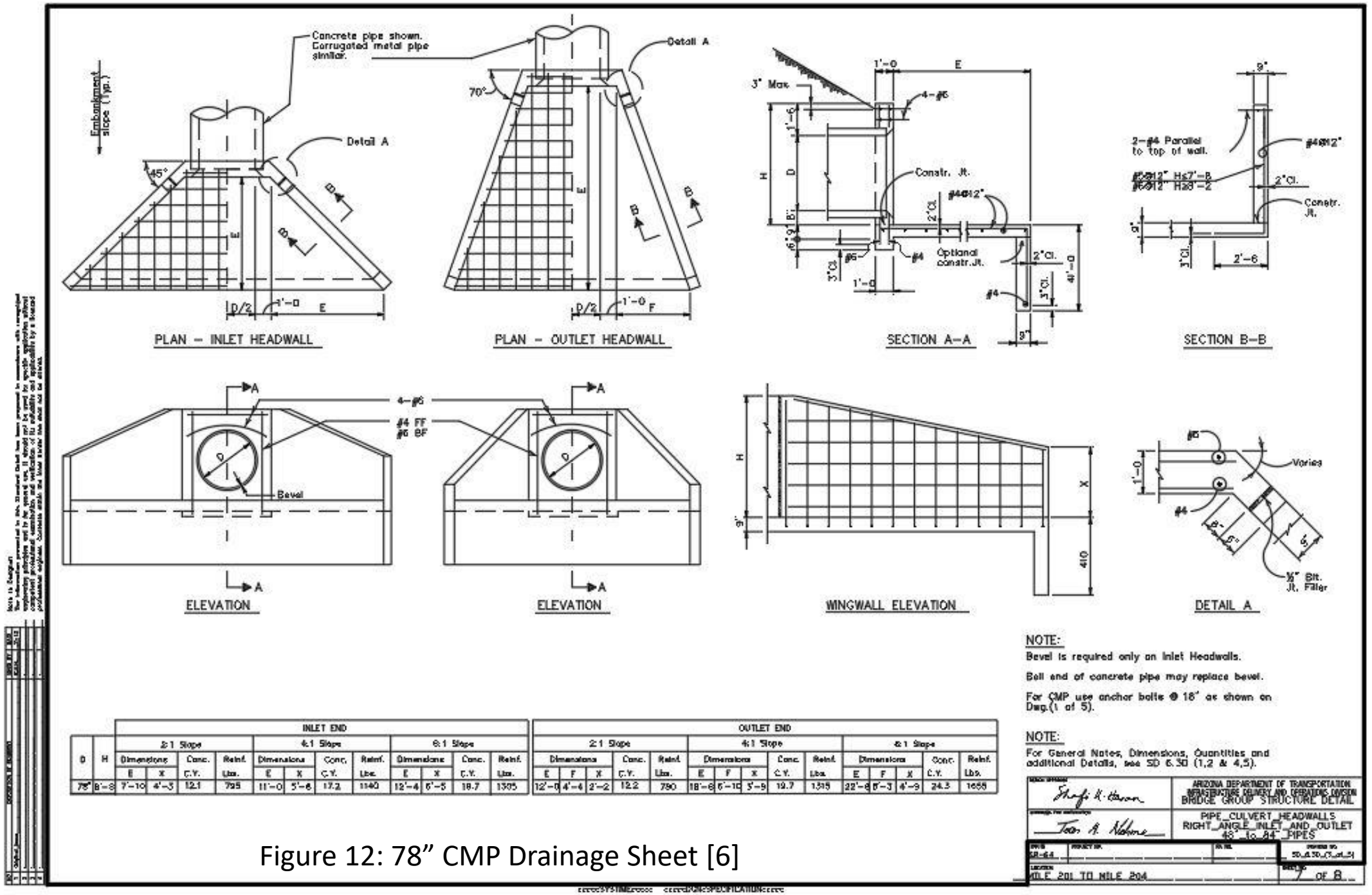


Figure 11: Culvert A Double-Box 8x4ft Design

Drainage Sheet Example



D	H	INLET END 2:1 Slope Dimensions E	X	Conc. C.Y.	Reinf. Lbs.	4:1 Slope Dimensions E	X	Conc. C.Y.	Reinf. Lbs.	6:1 Slope Dimensions E	X	Conc. C.Y.	Reinf. Lbs.
78"	8'-8	7'-10	4'-3	12.1	795	11'-0	5'-8	17.2	1140	12'-4	6'-5	18.7	1305

OUTLET END 2:1 Slope Dimensions E	F	X	Conc. C.Y.	Reinf. Lbs.	4:1 Slope Dimensions E	F	X	Conc. C.Y.	Reinf. Lbs.	6:1 Slope Dimensions E	F	X	Conc. C.Y.	Reinf. Lbs.
12'-0	4'-4	2'-2	12.2	780	18'-8	6'-10	5'-9	19.7	1315	22'-8	8'-3	4'-9	24.3	1655

Figure 12: 78” CMP Drainage Sheet [6]

Drainage Sheet Example

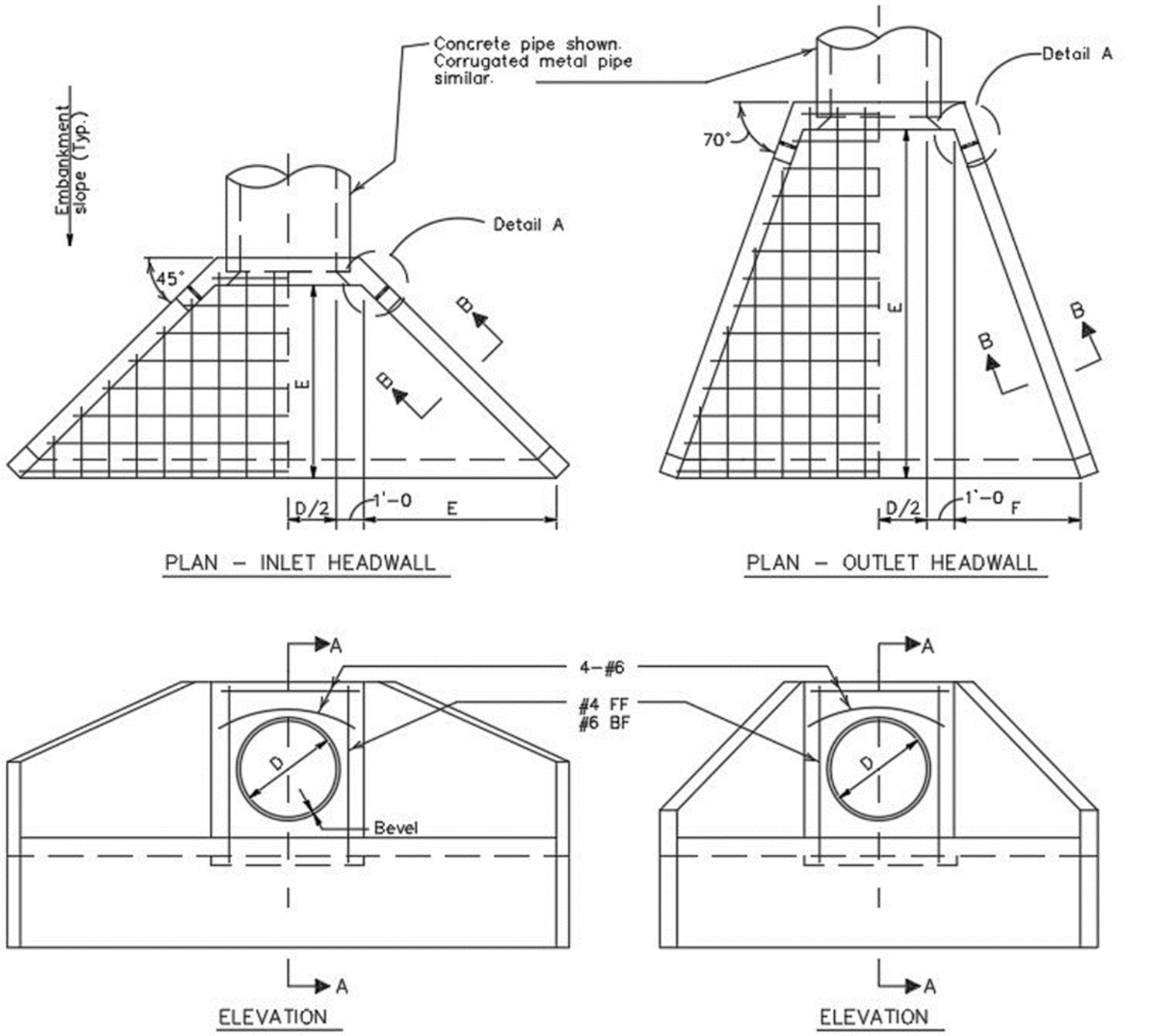


Figure 12: 78” CMP Drainage Sheet [6]

Digital Elevation Model (DEM) and Contours Using ArcGIS

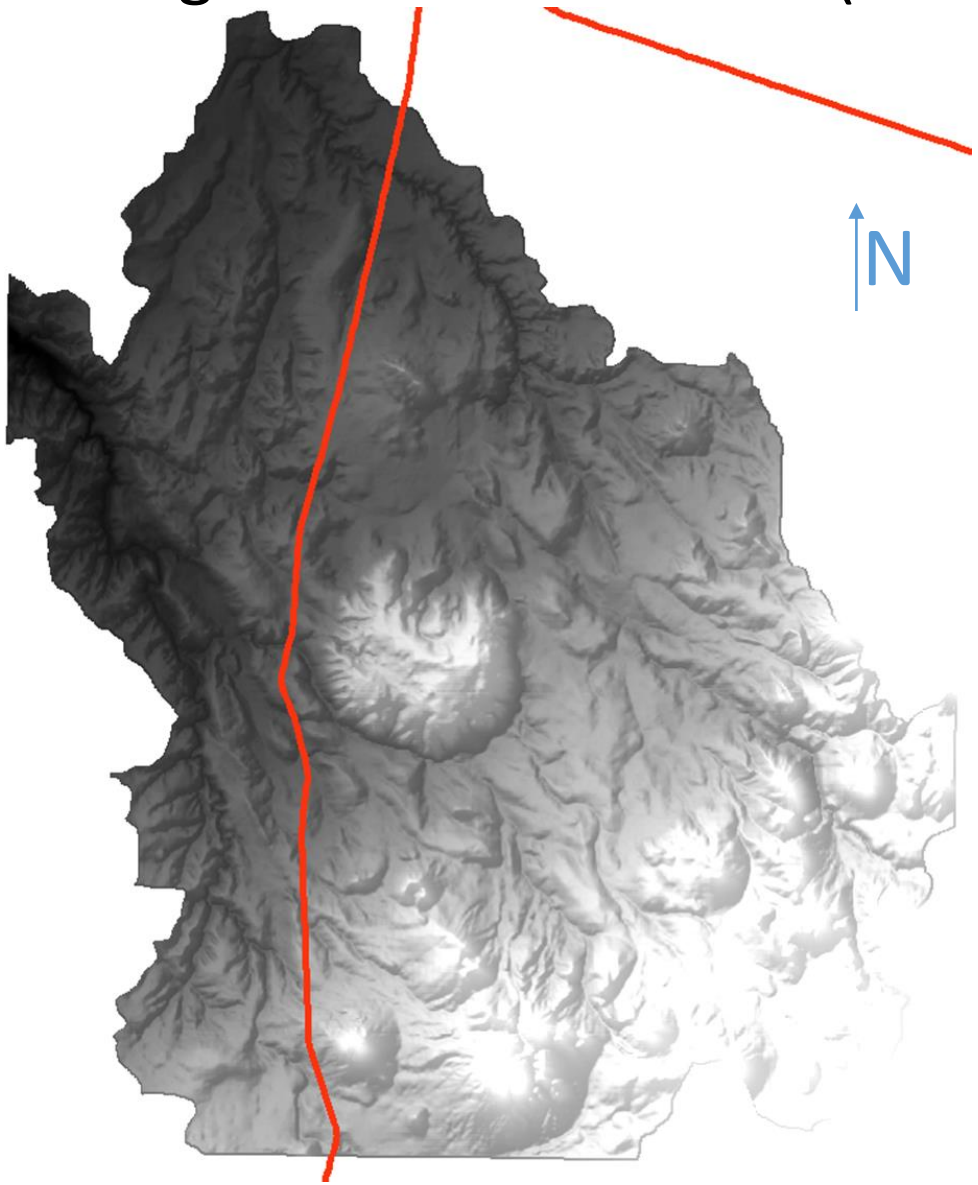


Figure 13: ArcGIS Generated DEM Map[1]

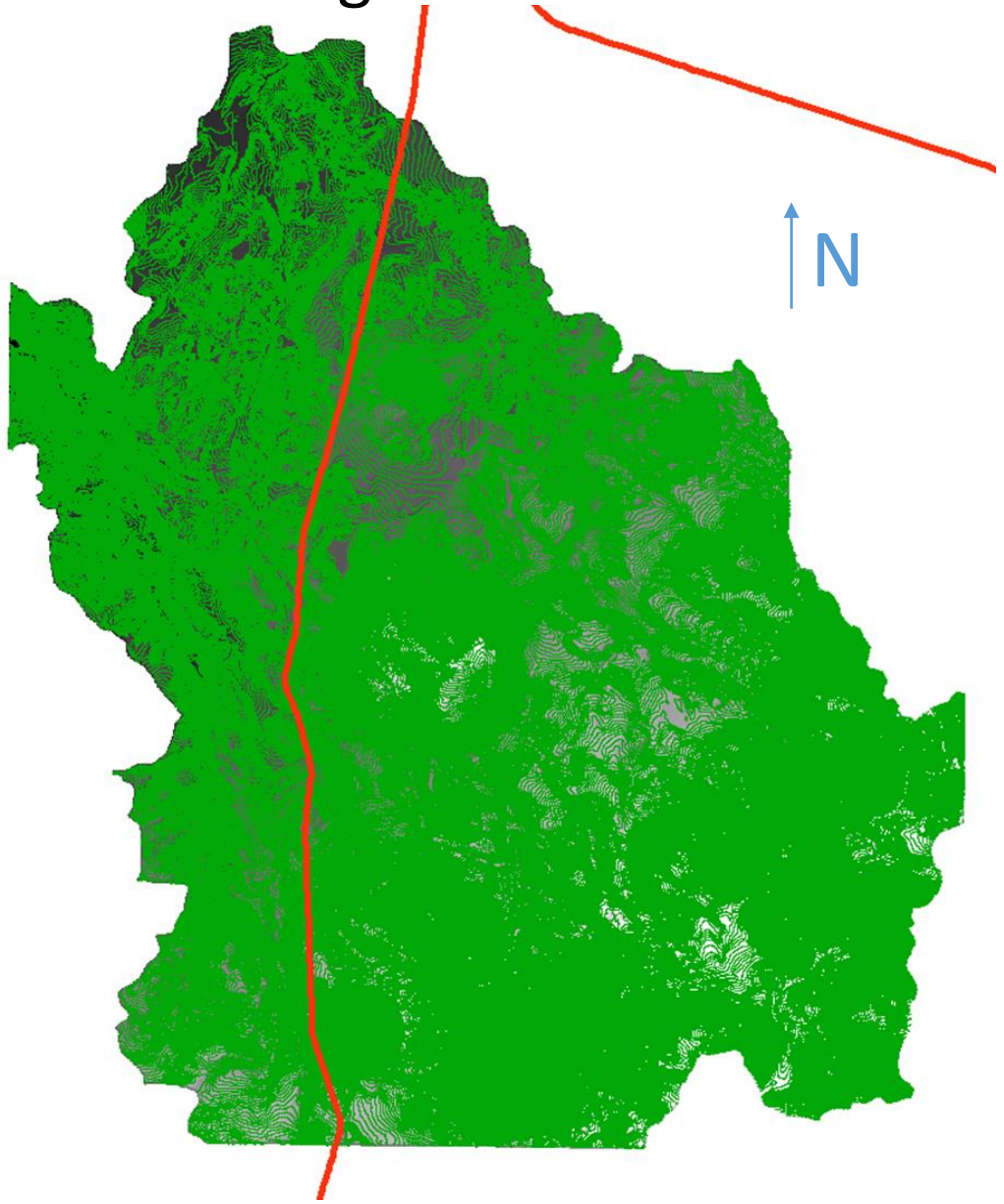


Figure 14: ArcGIS Generated Contour Map[1]

Contour Surface with Alignment

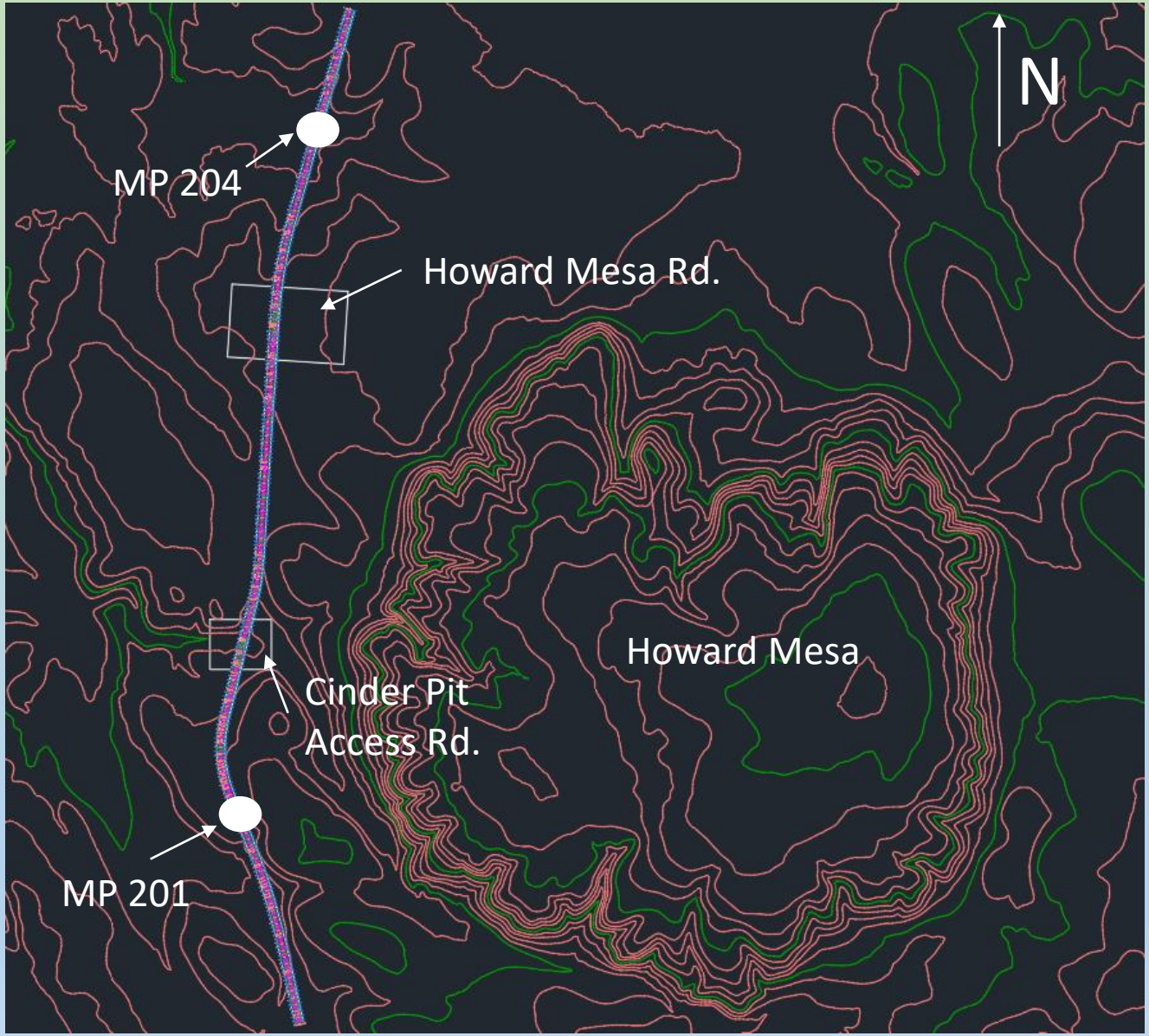


Figure 15: Civil 3D Contour Surface with Alignment [7]

- The alignment is 4.7 miles in length
- A total of 200 foot wide Right of Way
- 3 Intersections located in the project site

Typical Roadway Sections

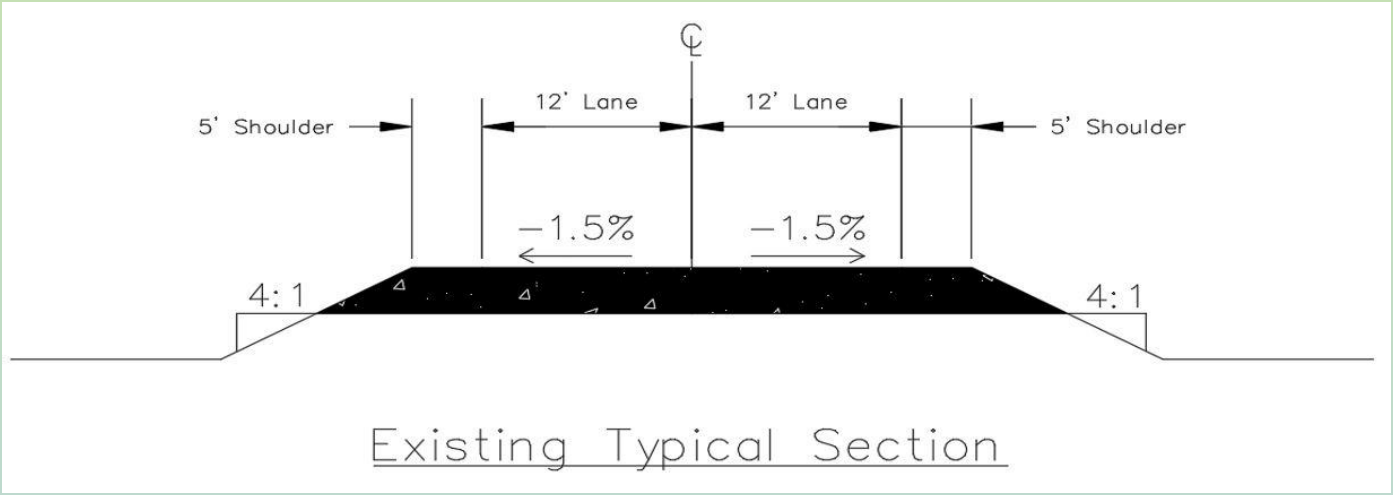


Figure 16: Existing Typical Cross Section [7]

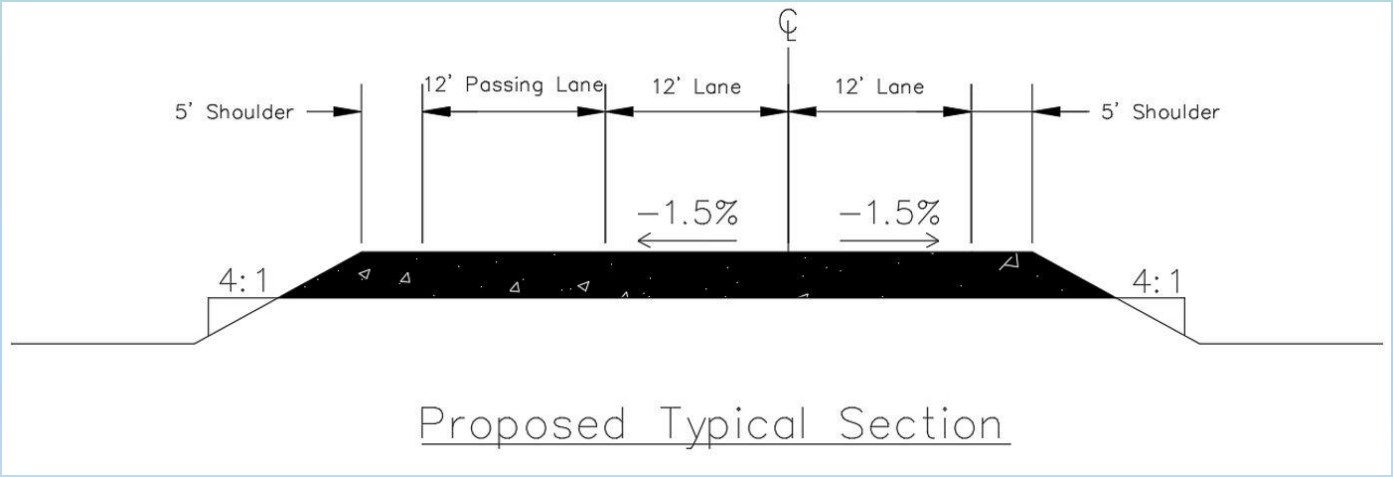


Figure 17: Proposed Typical Cross Section [7]

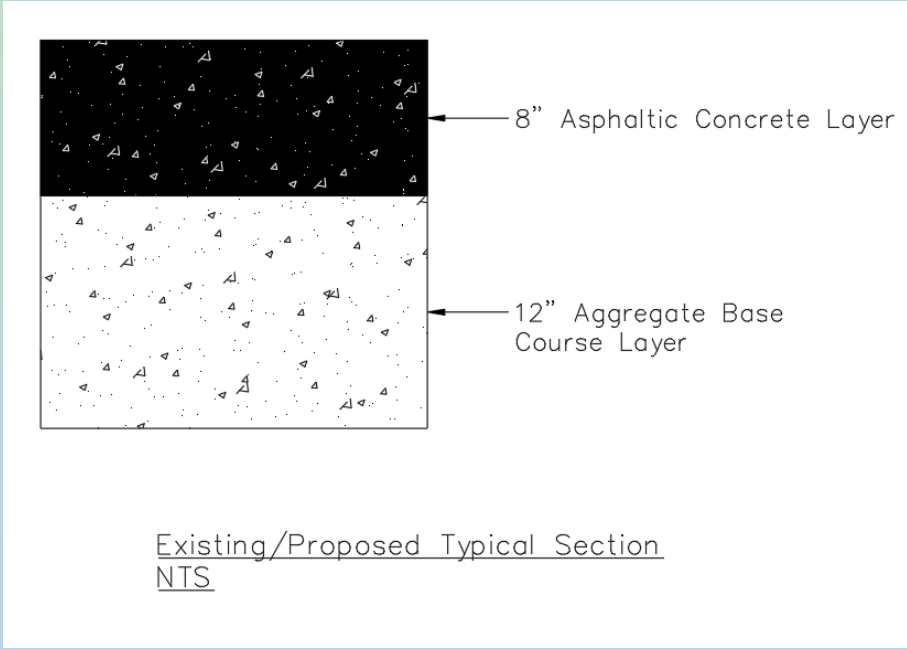


Figure 18: Pavement Cross Section [7]

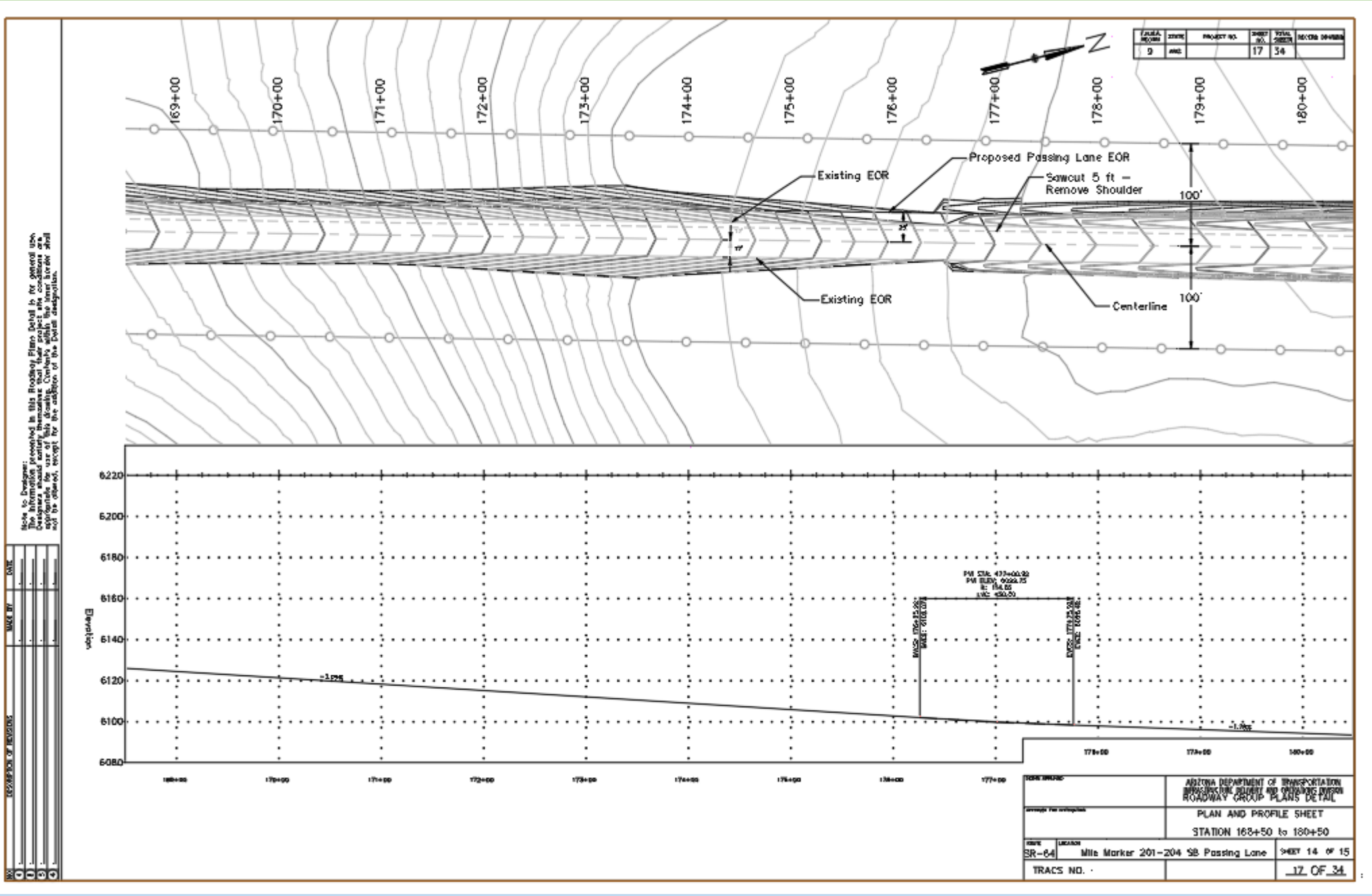
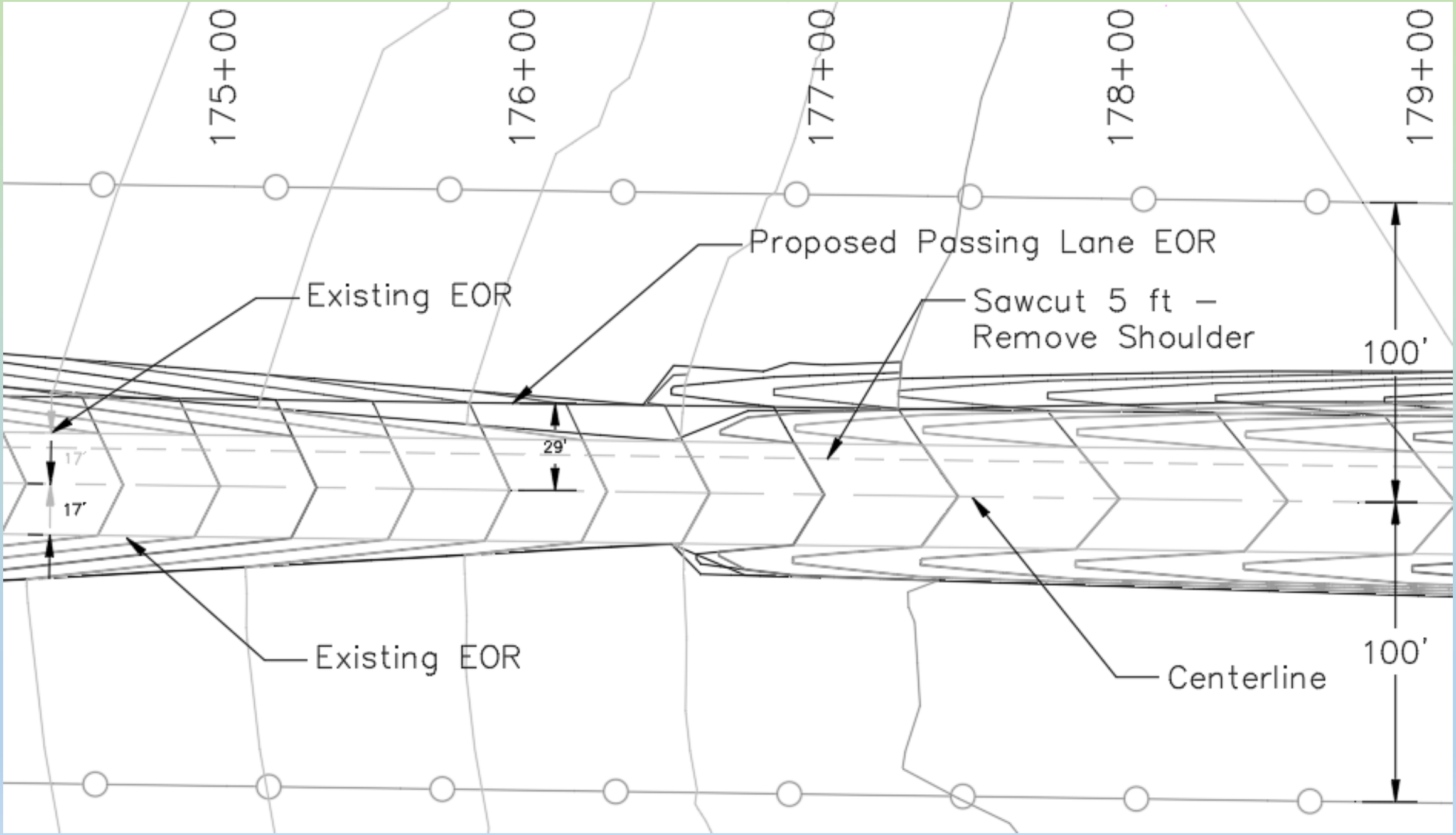


Figure 19: Plan and Profile Sheet Sta. 168+50-180+50 [7]

Plan and Profile



Plan and Profile

Figure 19: Plan and Profile Sheet Sta. 168+50-180+50 [7]

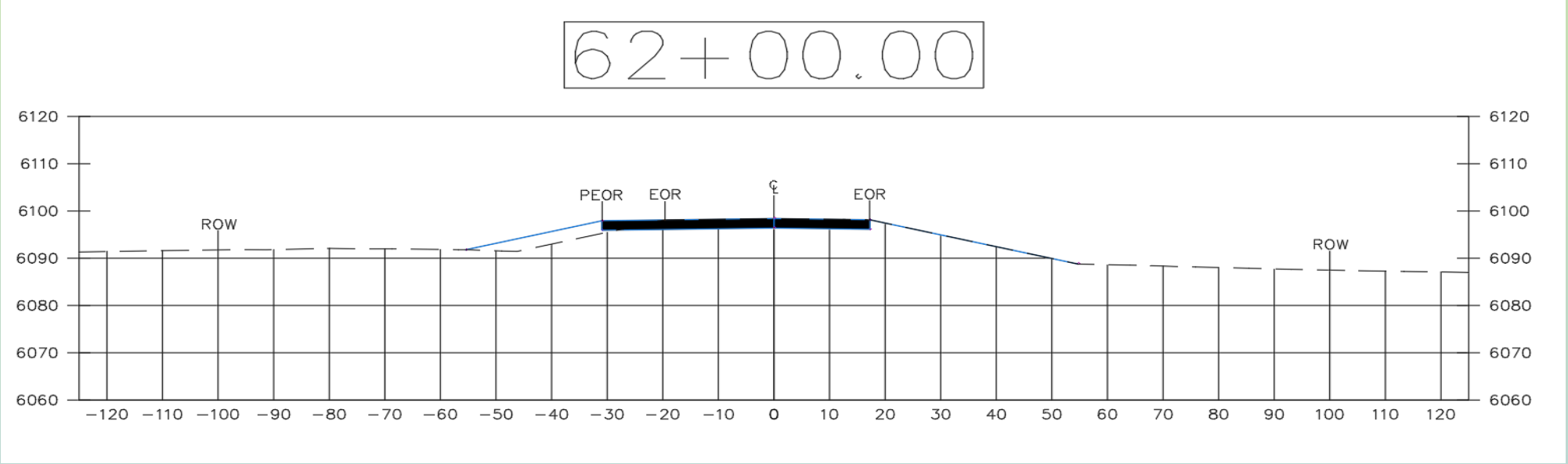


Figure 20: Station 62+00 Cross Section [7]

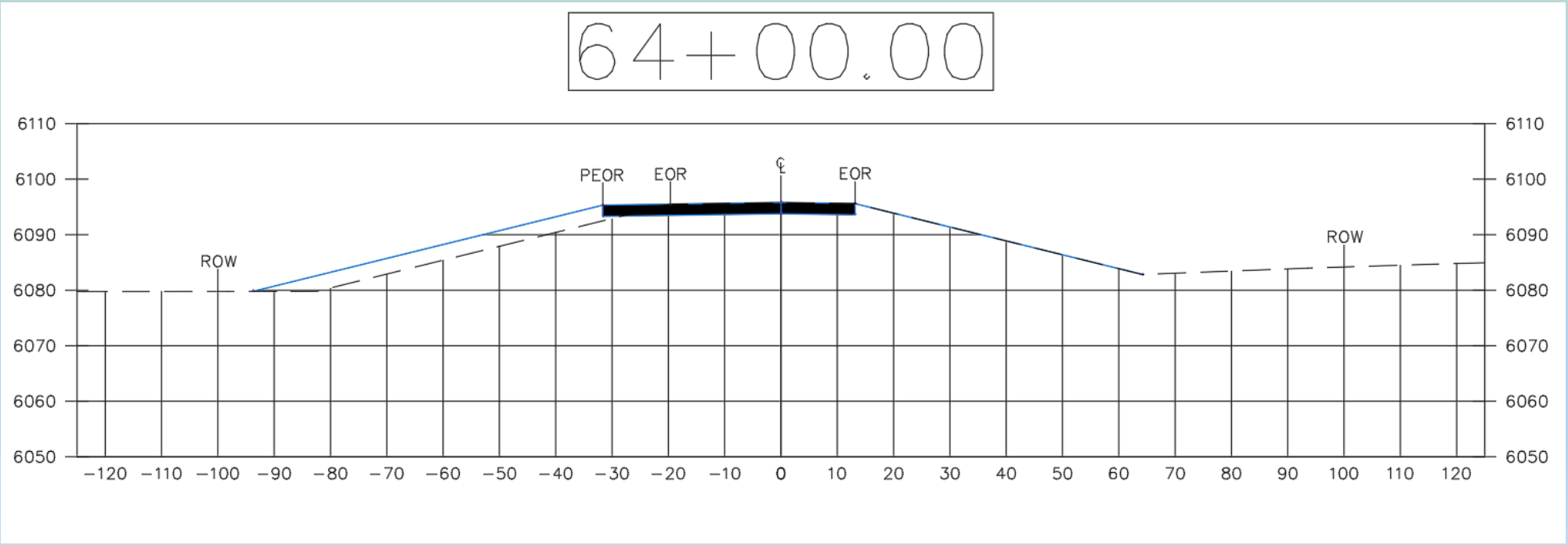


Figure 21: Station 64+00 Cross Section View [7]

Cross Section Sheet

Traffic Control Plan

Table 3: Sequences of Construction

MAINTENANCE OF CONSTRUCTION SEQUENCE			
ACTIVITY NUMBER	CONSTRUCTION ACTIVITY	TRAFFIC CONTROL	COMMENTS
1	Mobilization, signage and barrier setup	Traffic Control as shown in Detailed SA-3 Traffic Plan	Sings are to be placed on embedded posts for the duration of the project
2	Clearing and Grubbing	Traffic Control as shown in Detailed SA-3 Traffic Plan	This activity will have to be started early, to ensure that at least on lane is open to traffic. Contractor shall maintain traffic control during night
3	Culvert Extension/Replacement, Rough Grade (Cut and Fill)	Traffic Control as shown in Detailed SA-3 Traffic Plan	The Contractor shall maintain at least one lane of traffic at all times
4	Placement of ABC Subgrade	Traffic Control as shown in Detailed SA-3 Traffic Plan	The Contractor shall maintain at least one lane of traffic at all times
5	Final Grade (ABC)	Traffic Control as shown in Detailed SA-3 Traffic Plan	The Contractor shall maintain at least one lane of traffic at all times
6	AC Placement (Asphaltic Concrete)	Traffic Control as shown in Detailed SA-3 Traffic Plan	The Contractor shall maintain at least one lane of traffic at all times
7	Signage and Stripping	Traffic Control as shown in Detailed SA-3 Traffic Plan	The Contractor shall maintain at least one lane of traffic at all times
8	Demobilization, Removal of signage and barriers	Traffic Control as shown in Detailed SA-3 Traffic Plan	The contractor is responsible for the proper removal of signs

Traffic Control Plan

Table 4: Traffic Quantities

ITEM #	APPROXIMATE TRAFFIC CONTROL QUANTITIES									UNIT	TOTAL
	ITEM	ACTIVITY NUMBER									
		1	2	3	4	5	6	7	8		
	ESTIMATED DAYS IN USE	3	30	50	15	16	65	16	3		
7016020	Temporary Concrete Barrier (In Use)	34080	340800	681600	85200	170400	937200	119280	34080	LF-Day	2402640
7016031	Barricade (Type III, High Level Flag Trees)	4	40	80	10	20	110	14	4	EA-Day	282
7016032	Portable Sign Stand (Rigid)	20	200	400	50	100	550	70	20	EA-Day	1410
7016035	Warning Lights (Type A)	150	1500	3000	375	750	4125	525	150	EA-Day	10575
7016039	Embedded Sign Post	4	40	80	10	20	110	14	4	EA-Day	282
7016067	Changeable Message Board	6	60	100	30	32	130	32	6	EA-Day	396
7016071	Pilot Vehicle With Driver	72	720	1200	360	384	1560	384	72	Hour	4752
7016075	Flagging Services (Civilian)	72	720	1200	360	384	1560	384	72	Hour	4752

Traffic Control Plan

- Detailed SA-3 Traffic Plan

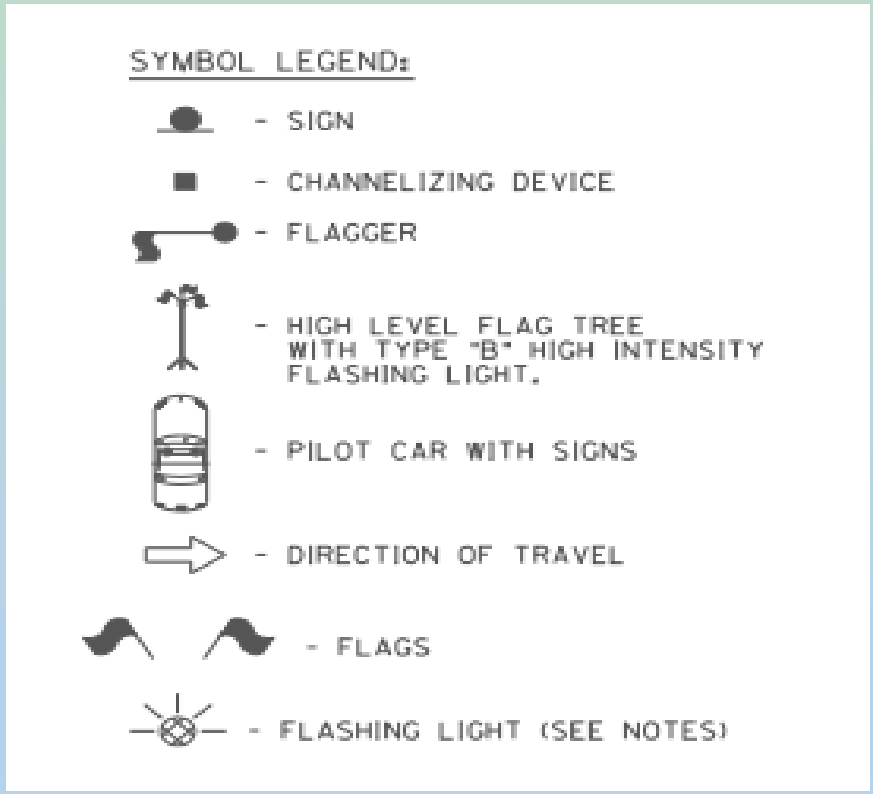


Figure 22: Traffic Control Plan Legend [8]

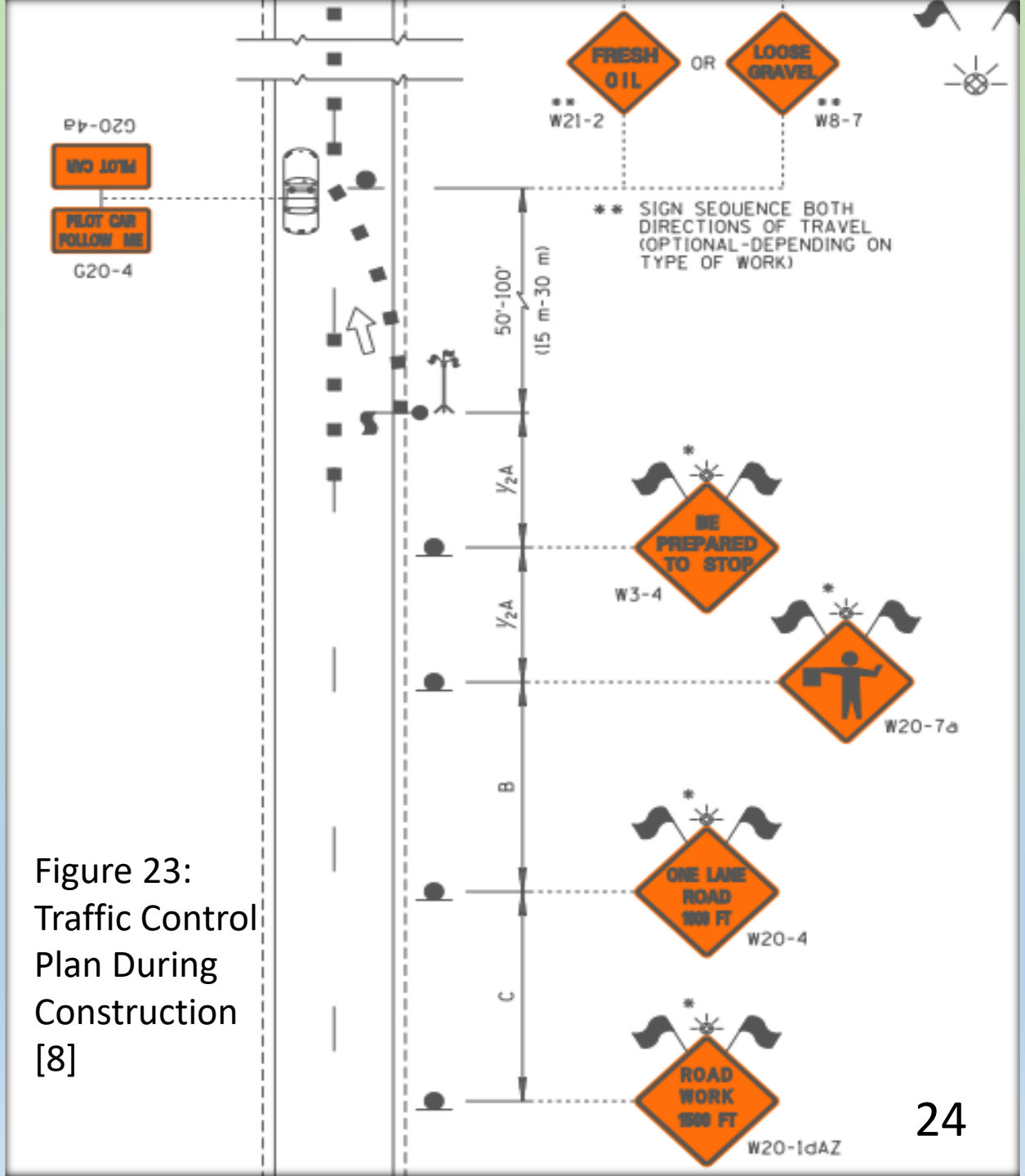


Figure 23: Traffic Control Plan During Construction [8]

Cost of Project Implementation

Table 5: Cost of Passing Lane Construction

	Item Description	Unit	Planned Qty.	Unit Price (2008)	Unit Price (2019)	Amount
2010011	Clearing and Grubbing	ACRE	18	$ 1,600	$ 3,731	$67,833
2020038	Removal of Asphaltic Concrete Pavement	CU. YD.	5867	$ 4	$ 9	$54,724
3030022	Aggregate Base, Class 2	CU. YD.	16427	$ 45	$ 105	$1,723,815
4040111	Bituminous Tack Coat	TON	20	$ 450	$ 1,049	$20,988
4040116	Apply Bituminous Tack Coat	HOUR	50	$ 140	$ 326	$16,324
4040264	Asphalt Binder (PG 64-22)	TON	307	$ 550	$ 1,283	$393,758
4160004	Asphaltic Concrete (3/4" Mix) (End Product)	TON	10980	$ 43	$ 100	$1,101,030
5010011	CMP, 24"	L. FT.	74	$ 75	$ 175	$13,004
5010017	CMP, 30"	L. FT.	81	$ 85	$ 198	$16,119
5010019	CMP, 36"	L. FT.	22	$ 95	$ 222	$4,896
2030301	Roadway Excavation	CU. YD.	2000	$ 15	$ 35	$69,960
6010002	Structural Concrete (Class S)	CU. YD.	28	$ 650	$ 1,516	$42,670
7016020	Temporary Concrete Barrier (In Use)	LF-DAY	2402640	$ 0.20	$ 0.47	$1,120,591
7016031	Barricade (Type III, High Level Flag Trees)	EACH-DAY	282	$ 1	$ 2	$658

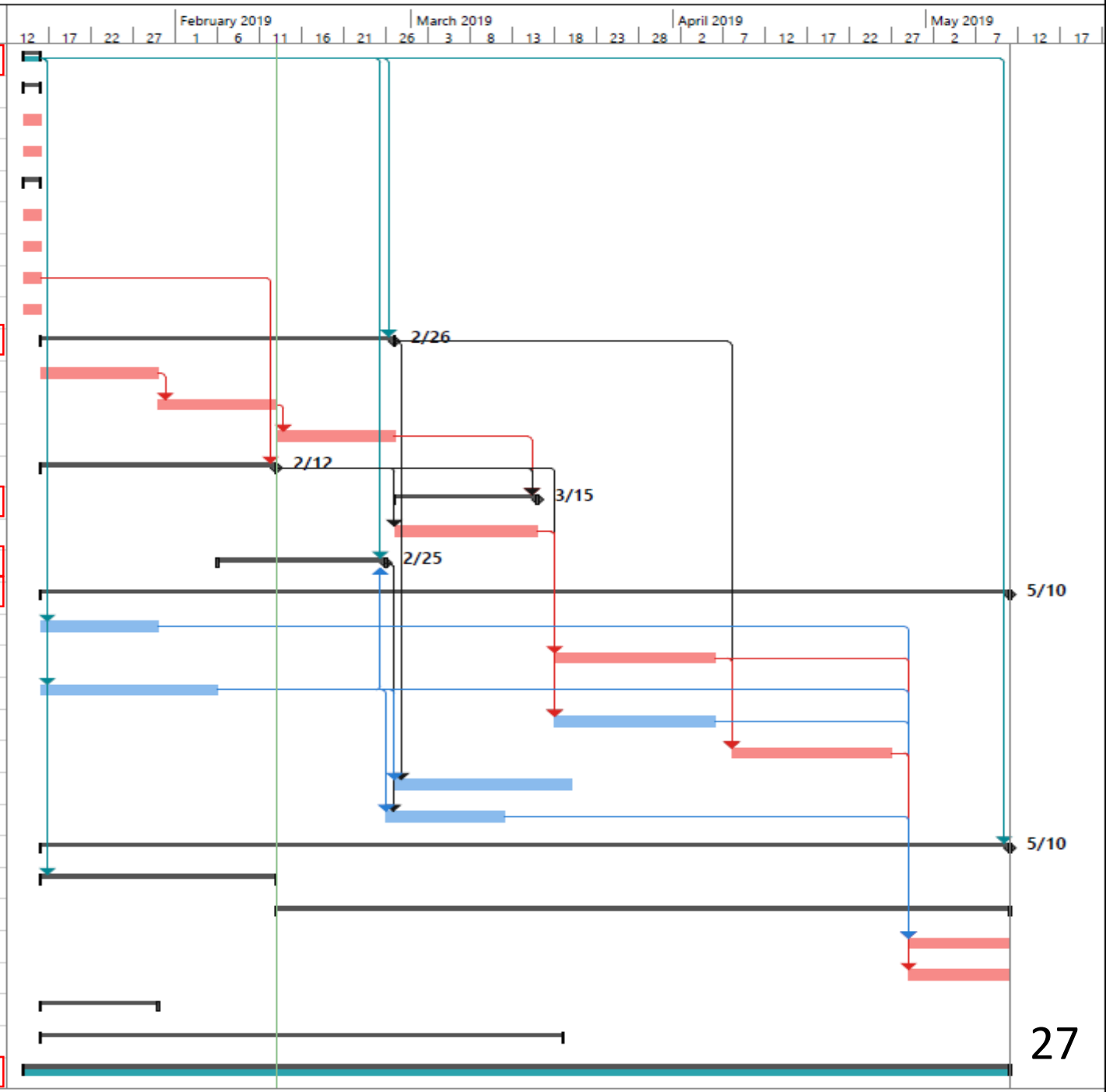
Cost of Project Implementation

Table 5: Cost of Passing Lane Construction (Continued)

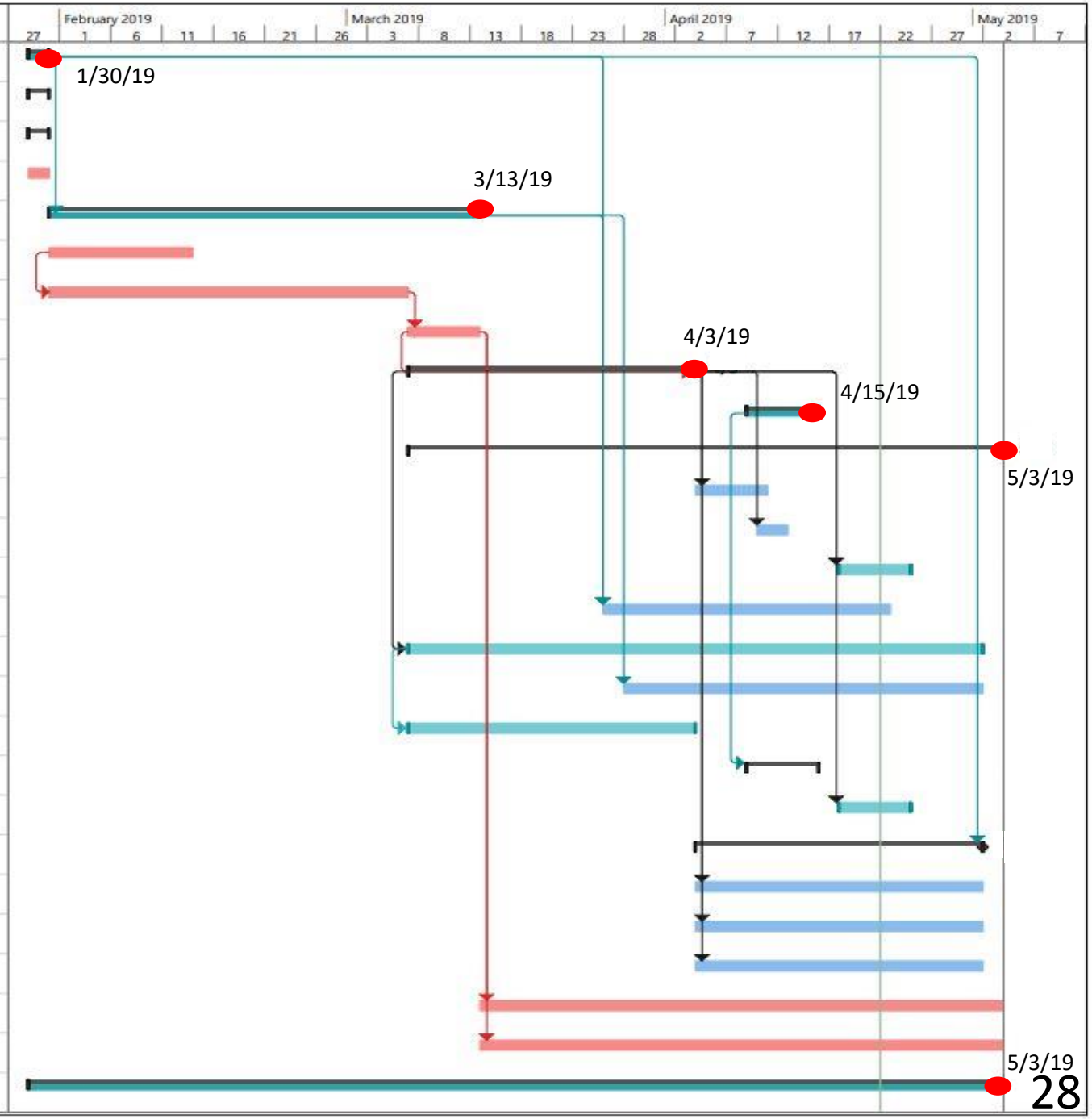
	Item Description	Unit	Planned Qty.	Unit Price (2008)	Unit Price (2019)	Amount
7016032	Portable Sign Stands (Rigid)	EACH-DAY	1410	$ 1	$ 2	$3,288
7016035	Warning Lights (Type A)	EACH-DAY	10575	$ 0.25	$ 1	$6,165
7016039	Embedded Sign Post	EACH-DAY	282	$ 0.15	$ 0.35	$99
7016067	Changeable Message Board	EACH-DAY	396	$ 25	$ 58	$23,087
7016071	Pilot Vehicle with Driver	HOUR	4752	$ 40	$ 93	$443,267
7016075	Flagging Services (Civilian)	HOUR	4752	$ 22	$ 51	$243,797
7060101	Pavement Marker, Recessed, Type D	EACH	792	$ 5	$ 12	$9,235
7080001	Permanent Pavement Marking (Painted)	L. FT.	17040	$ 0.15	$ 0.35	$5,961
9240170	Contractor Quality Control	L. SUM		$ 49,000	$ 114,268	$114,268
9240183	Miscellaneous Work (Seal Cracks)	LB.	350	$ 3	$ 6	$2,041
9250001	Construction Surveying and Layout	L. SUM		$ 34,000	$ 79,288	$79,288
-------	Embankment	CU.YD.	28000	$ 19	$ 45	$1,260,000
9280036	Ground-In Rumble Strip (8 in.)	L. FT.	17040	$ 0.20	$ 0.47	$7,947
					Total Price	**$6,844,812**
	Construction Engineering	% of Total	--------	--------	14	$958,274
	Construction Design Services	% of Total	--------	--------	1	$68,448
	Contingency	% of Total	--------	--------	5	$342,241
					Total Project Cost	**$8,213,774**

SR-64 Critical Path

Task Name	Duration	Start	Finish
1 Site Assessment	2 days	Mon 1/14/19	Tue 1/15/19
1.1 Road Condition Assessment	2 days	Mon 1/14/19	Tue 1/15/19
1.1.1 Asphalt Condition	2 days	Mon 1/14/19	Tue 1/15/19
1.1.2 Shoulder Condition	2 days	Mon 1/14/19	Tue 1/15/19
1.2 Drainage Condition Assessment	2 days	Mon 1/14/19	Tue 1/15/19
1.2.1 Culvert Condition and Location	2 days	Mon 1/14/19	Tue 1/15/19
1.2.2 Wash Integrity	2 days	Mon 1/14/19	Tue 1/15/19
1.3 Soil Sampling	2 days	Mon 1/14/19	Tue 1/15/19
1.4 Right of Way Assessment	2 days	Mon 1/14/19	Tue 1/15/19
2 Hydrology and Hydraulics Analysis	30 days	Wed 1/16/19	Tue 2/26/19
2.1 Map Culverts	10 days	Wed 1/16/19	Tue 1/29/19
2.2 Hydrology	10 days	Wed 1/30/19	Tue 2/12/19
2.3 Hydraulics	10 days	Wed 2/13/19	Tue 2/26/19
3 Geotechnical Analysis	20 days	Wed 1/16/19	Tue 2/12/19
4 Highway Design	13 days	Wed 2/27/19	Fri 3/15/19
4.1 Cross Sections	13 days	Wed 2/27/19	Fri 3/15/19
5 Traffic Control Plan	14 days	Wed 2/6/19	Mon 2/25/19
6 Design Plan Sets	83 days	Wed 1/16/19	Fri 5/10/19
6.1 Face Sheet	10 days	Wed 1/16/19	Tue 1/29/19
6.2 Roadway Sections Plan Sheets	15 days	Mon 3/18/19	Fri 4/5/19
6.3 Existing Conditions Plan Sheets	15 days	Wed 1/16/19	Tue 2/5/19
6.4 Structural Plan Sheets	15 days	Mon 3/18/19	Fri 4/5/19
6.5 Drainage Plan Sheets	15 days	Mon 4/8/19	Fri 4/26/19
6.6 SWPPP Sheet	15 days	Wed 2/27/19	Tue 3/19/19
6.7 Traffic Control Plan Sheets	10 days	Tue 2/26/19	Mon 3/11/19
6.8 Cost Estimate Report Sheet	83 days	Wed 1/16/19	Fri 5/10/19
6.8.1 Scoping	20 days	Wed 1/16/19	Tue 2/12/19
6.8.2 Preliminary Engineering Design	63 days	Wed 2/13/19	Fri 5/10/19
6.8.2.1 Plan Sheets	10 days	Mon 4/29/19	Fri 5/10/19
6.8.2.3 Drainage Report	10 days	Mon 4/29/19	Fri 5/10/19
6.8.3 Construction Implementation	10 days	Wed 1/16/19	Tue 1/29/19
6.8.4 Mobilization and Administration Costs	44 days	Wed 1/16/19	Mon 3/18/19
7 Project Management	85 days	Mon 1/14/19	Fri 5/10/19



ID	Task Name	Duration	Start	Finish
1	1 Site Assessment	2 days	Tue 1/29/19	Wed 1/30/19
2	1.1 Road Condition Assessment	2 days	Tue 1/29/19	Wed 1/30/19
5	1.2 Drainage Condition Assessment	2 days	Tue 1/29/19	Wed 1/30/19
8	1.3 Right of Way Assessment	2 days	Tue 1/29/19	Wed 1/30/19
9	2 Hydrology and Hydraulics Analysis	30 days	Thu 1/31/19	Wed 3/13/19
10	2.1 Map Culverts	10 days	Thu 1/31/19	Wed 2/13/19
11	2.2 Hydrology	25 days	Thu 1/31/19	Wed 3/6/19
12	2.3 Hydraulics	5 days	Thu 3/7/19	Wed 3/13/19
13	3 Highway Design	20 days	Thu 3/7/19	Wed 4/3/19
17	4 Traffic Control Plan	5 days	Tue 4/9/19	Mon 4/15/19
21	5 Design Plan Sets	42 days	Thu 3/7/19	Fri 5/3/19
22	5.1 Face Sheet	5 days	Thu 4/4/19	Wed 4/10/19
23	5.2 Typical Roadway Sections Sheet	3 days	Wed 4/10/19	Fri 4/12/19
24	5.3 Geometric Control Sheet	5 days	Thu 4/18/19	Wed 4/24/19
25	5.4 Existing Conditions and Removal Sheet	20 days	Tue 3/26/19	Mon 4/22/19
26	5.5 Roadway Plan and Profile Sheets	40 days	Thu 3/7/19	Wed 5/1/19
27	5.6 Drainage Plans and Details Sheets	25 days	Thu 3/28/19	Wed 5/1/19
28	5.7 Intersection Plans and Details	20 days	Thu 3/7/19	Wed 4/3/19
29	5.8 Traffic Control Plan Sheets	5 days	Tue 4/9/19	Mon 4/15/19
32	5.9 Roadway Cross Section Sheets	5 days	Thu 4/18/19	Wed 4/24/19
33	5.10 Cost Estimate Report Sheet	20 days	Thu 4/4/19	Wed 5/1/19
34	5.10.3.1 Site Obstruction Removal	20 days	Thu 4/4/19	Wed 5/1/19
35	5.10.3.2 Excavation, Backfill, Embankment	20 days	Thu 4/4/19	Wed 5/1/19
36	5.10.3.3 Construction	20 days	Thu 4/4/19	Wed 5/1/19
37	5.11 Drainage Report- Roadway	37 days	Thu 3/14/19	Fri 5/3/19
38	5.12 Drainage Report- Structures	37 days	Thu 3/14/19	Fri 5/3/19
39	6 Project Management	69 days	Tue 1/29/19	Fri 5/3/19



Previous Staffing Hours

Table 6: Old Staffing Plan

Task Name	STAFF (hours)				Task Total
	Project Manager	Senior Engineer	Engineer Step I	Drafter	
1 Site Assessment	30	30	20	32	112
2 Hydrology and Hydraulics Analysis	0	12	18	24	54
3 Geotechnical Analysis	0	35	45	0	80
4.0 Highway Design	26	21	29	50	126
5 Traffic Control Plan	36	0	0	0	36
6 Design Plan Sets	102	106	88	88	384
6.1 Face Sheet	8	4	4	12	28
6.2 Roadway Sections Plan Sheets	0	10	10	10	30
6.3 Existing Conditions Plan Sheets	0	10	10	10	30
6.4 Roadway Construction Plan Sheets	0	10	10	10	30
6.5 Drainage Plan Sheets	0	10	20	20	50
6.6 SWPPP Sheet	0	10	0	10	20
6.7 Traffic Control Plan Sheets	2	12	6	16	36
6.8 Cost Estimate Report Sheet	92	40	28	0	160
7 Project Management	47	45	55	47	194
STAFF TOTAL	**194**	**204**	**200**	**241**	**839**

Current Staffing Hours

Table 7: Current Staffing Plan

Task Name	STAFF (hours)				Task Total
	Project Manager	Senior Engineer	Engineer Step I	Drafter	
1 Site Assessment	11	13	14	12	50
2 Hydrology and Hydraulics Analysis	12	17	24	23	76
3 Highway Design	15	22	24	52	113
4 Traffic Control Plan	8	13	12	10	43
5 Design Plan Sets	86	107	87	143	423
5.1 Face Sheet	3	4	3	8	18
5.2 Roadway Sections Plan Sheets	7	7	6	20	40
5.3 Existing Conditions Plan Sheets	5	6	6	18	35
5.4 Structural Plan Sheets	7	7	10	9	33
5.5 Drainage Plan Sheets	8	8	5	16	37
5.6 Traffic Control Plan Sheets	5	6	5	16	32
5.7 Cost Estimate Report Sheet	51	69	52	56	228
6 Project Management	20	20	20	20	80
STAFF TOTAL	**152**	**192**	**181**	**260**	**785**

Engineering Cost

Table 8: Initial Cost Estimate for Staff Members/Total Hours

Billable Services			
Staff	Hours	Cost per Hour	Cost Per Staff
Project Manager	194	$ 140	$ 27,160
Senior Engineer	204	$ 112	$ 22,848
Engineer Step I	200	$ 34	$ 6,800
Drafter	241	$ 36	$ 8,676
Totals	**839**	-----	**$ 65,484**

Table 9: Final Cost for Staff Members/Total Hours

Billable Services			
Staff	Hours	Cost per Hour	Cost Per Staff
Project Manager	152	$ 140	$ 21,280
Senior Engineer	192	$ 112	$ 21,504
Engineer Step I	181	$ 34	$ 6,154
Drafter	260	$ 36	$ 9,360
Totals	**785**	-----	**$ 58,298**

Table 10: Billing Rates of Staff Involved with the Project

Billing Rates				
Staff	Cost per Hour	Benefits (%)	Profit (%)	Cost Per Hour
Project Manager	$ 129	30	10	$ 181
Senior Engineer	$ 80	30	10	$ 112
Engineer Step I	$ 24	30	10	$ 34
Drafter	$ 26	30	10	$ 36

Conclusion

- The passing lane is 3 miles in length
  - Between Marker 201 and Marker 204
- Culvert A must be replaced before construction.
- 9 Culverts need to be extended.
- The total cost for constructing the lane is $8,213,000
- Total project duration is 198 days, 141 working days

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- [8] Arizona Department Of TRANSPORTATION, "TRAFFIC CONTROL DESIGN GUIDELINES 2010," ADOT, 2011.
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