Agassiz Consulting Engineers

Sinclair Wash Riparian Habitat Enhancement Feasibility Study

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Project Site Location

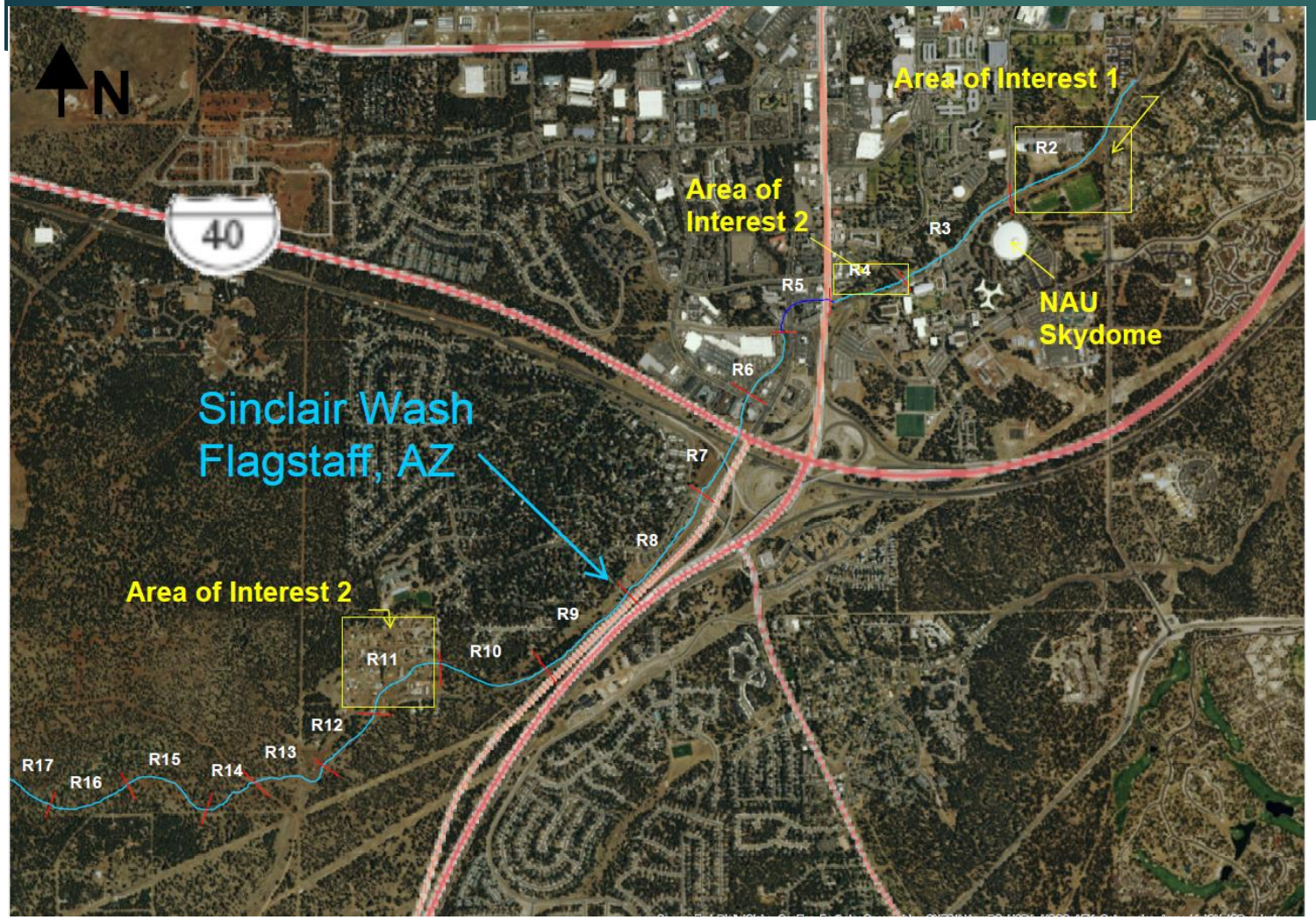


Figure 1: ArcGIS Map of Sinclair Wash

- Location
  - Flagstaff, AZ
  - Woody Mountains to Rio De Flag
- Length
  - 7 miles
  - Focus will be on several reaches of the channel
- Public Use
  - Bike/Foot Trail

Project Scope

- Reach Evaluation using specific reaches
- Design Detention Basins and Vegetated/Rock Swales
- Design Stream Crossings

- **Propose design alternatives and estimate cost to advise what is feasible for the City of Flagstaff.**

Figure 2: West View of Sinclair Wash

[1]

Stream Reach Classification

Table 1: Stream Reach Classification Data

Reach	Location	Bankfull WIDTH (ft)	Channel Bottom Width (ft)	Bankfull DEPTH (ft)	Bankfull X-Section AREA (ft^2)	Width/Depth Ratio (ft/ft)	Maximum DEPTH (ft)	WIDTH of Flood-Prone Area (ft)	Entrenchment Ratio (ft/ft)	Channel Material Size (mm)	Water Surface Slope	Channel Sinuosity	Stream Classification
2	Lone Tree to S. San Francisco	130.00	94.00	8.45	946.40	1.54	9.33	18.67	0.14	3.00	0.005	1.04	G4C
3	S. San Francisco to S. Knoles Dr.	38.17	13.89	4.42	50.63	8.64	4.50	9.00	0.24	3.00	0.006	1.04	G4C
4	S. Knoles Dr. to Cuvlerts under I-17	73.79	18.00	5.25	240.95	14.06	5.33	10.67	0.14	3.00	0.008	1.02	F4
5	Culverts I-17 to Walmart	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	Walmart to Woodlands Village Blvd	73.21	19.42	15.92	737.14	4.59	15.92	31.38	0.44	3.00	0.006	1.05	G4C
7	Woodlands Vill. Blvd to W UV Heights Dr N	25.50	10.00	3.42	60.63	7.46	3.58	7.16	0.28	3.00	0.004	1.02	G4C
8	W. UV Heights Dr. N to W UV Heights Dr S	44.75	12.50	5.43	155.21	8.24	5.71	11.42	0.26	3.00	0.004	1.01	G4C
9	W UV Heights Dr S to Detention Basin	27.58	10.50	1.25	21.46	22.06	1.50	3.00	0.11	3.00	0.002	1.03	F4
10	Detention basin to Mt. Dell	56.17	23.00	5.04	199.50	11.14	5.42	10.29	0.18	3.00	0.007	1.20	G4C
11	Mt. Dell (Sinclair St)	37.66	11.00	4.61	112.18	8.17	5.00	10.00	0.27	3.00	0.007	1.10	G4C
14	Reach 14	24.42	9.10	2.10	35.20	11.63	2.17	4.34	0.18	3.00	0.002	1.10	G4C
15	Reach 15	29.60	29.60	1.78	34.20	16.63	2.00	4.00	0.14	3.00	0.008	1.15	F4
16	Reach 16	38.70	10.60	3.10	76.42	12.48	3.20	6.40	0.17	3.00	0.009	1.05	A3
17	Reach 17	23.90	8.60	2.30	37.38	10.39	2.50	5.00	0.21	3.00	0.025	1.09	A2

Area of Interest #1: Reach 2 (Lone Tree)

Reach 2 Field Assessment

- Erosion at Flagstaff Urban Trail System crossing
- Sedimentation build up
- Scour pools downstream of culverts
- Invasive Species
- Unwanted ponding
- Steep side slopes

Figure 3: Reach 2 Topo

Area of Interest #1: Reach 2 (Lone Tree)

HEC-RAS Analysis

- 2-year, 25-year, 100-year flow existing

Feasibility

- Dimensions of Typical Low Flow Channel
  - 2-ft maximum depth
  - Passes 2-year flow

Table 2: Low Flow Channel Feasibility

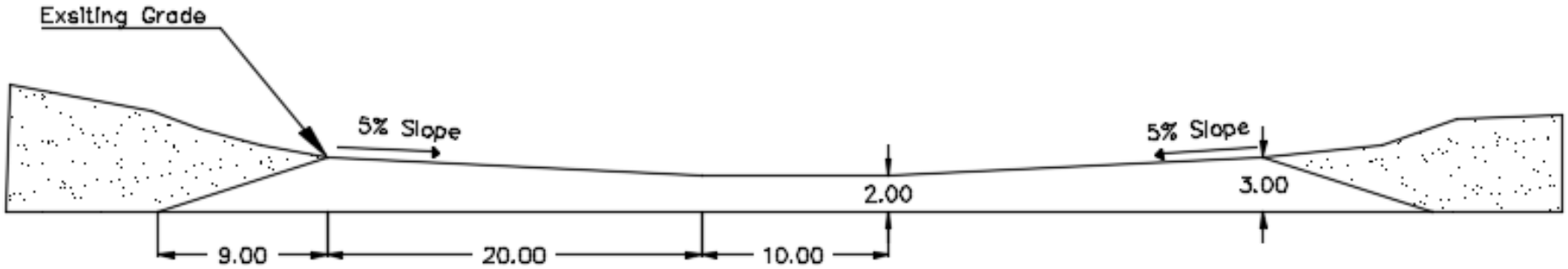
Station	2-Year Flow (cfs)	Velocity (ft/s)	Normal Depth (ft)	Area of flow (ft^3)	Width Required for Low Flow Channel (with a depth of 2ft) (ft)	Width of Channel (ft)
667.10	826.14	3.60	4.28	229.70	108.85	78.00
650.02	826.14	3.56	4.33	232.26	110.13	80.57
634.46	826.14	3.57	4.26	231.55	109.78	81.00
612.66	826.14	3.22	4.15	256.72	122.36	80.00
585.46	826.14	3.08	4.24	268.86	128.43	82.00
533.45	826.14	3.10	4.17	266.86	127.43	68.00
463.92	826.14	4.35	4.08	190.04	89.02	64.00
CULVERT						
341.54	826.14	5.38	3.75	153.54	70.77	59.00
274.02	826.14	3.60	4.00	229.27	108.64	50.00
215.38	826.14	2.93	4.45	281.53	134.77	54.00
158.29	826.14	3.33	3.96	248.10	118.05	61.00
126.94	826.14	2.76	4.02	299.78	143.89	43.00
97.70	826.14	2.78	3.96	297.43	142.72	40.00
54.52	826.14	4.52	3.52	182.70	85.35	46.57

Area of Interest #1: Reach 2 (Lone Tree)

Figure 4: Existing Culverts

Bioremediation Pond Design

- Purpose
  - Mitigate stream crossing erosion
  - Support riparian habitat vitality
  - Provide stream aesthetics and ecological education
- Dimensions
  - Length: 190ft
  - Width: 40ft
  - Depth: 2ft
  - Volume: ~50,000ft^3

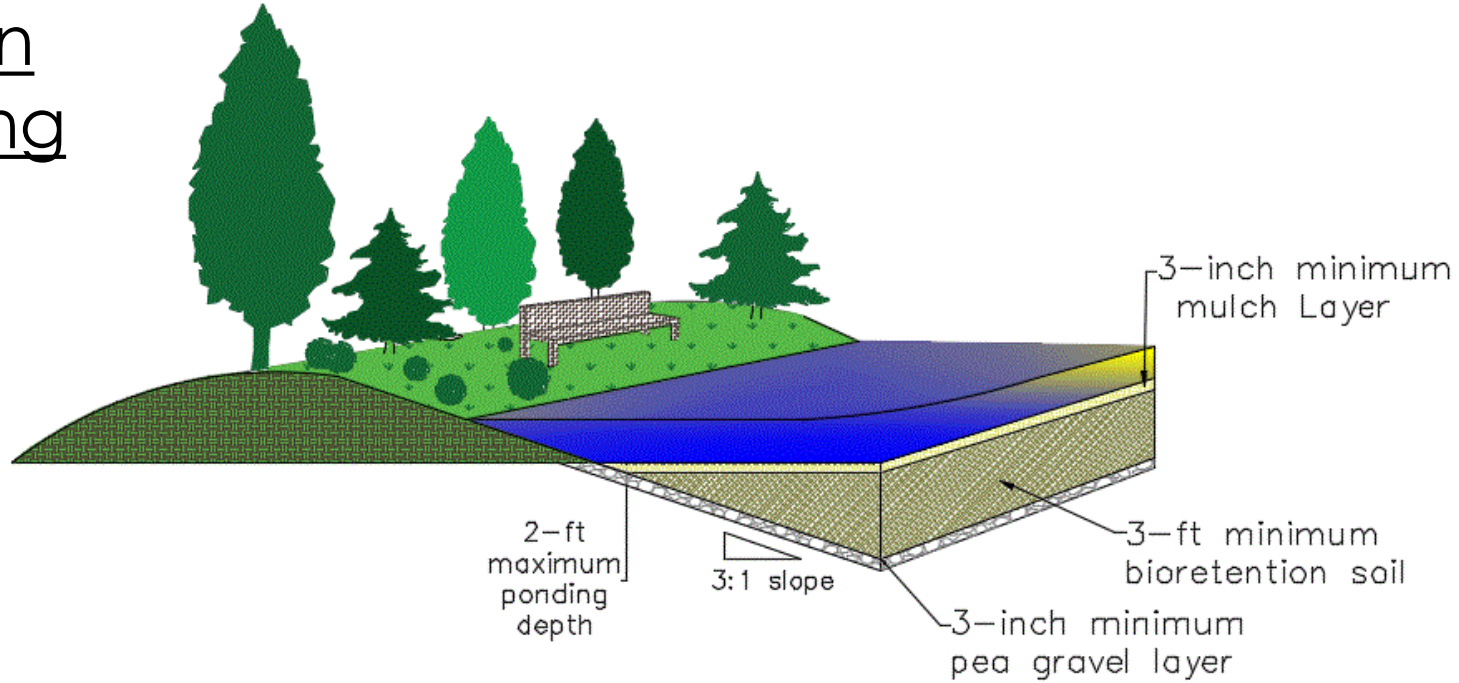


Section Cut 2: Front View of Dam
Looking Downstream

Figure 5: Proposed Dam for Pond Design

Area of Interest #1: Reach 2 (Lone Tree)

Bioremediation Pond Rendering



[6]

Note: Drawing not to scale

Figure 6: Pond Rendering Cross Section

Area of Interest #1: Reach 2 (Lone Tree)

Sediment Trap

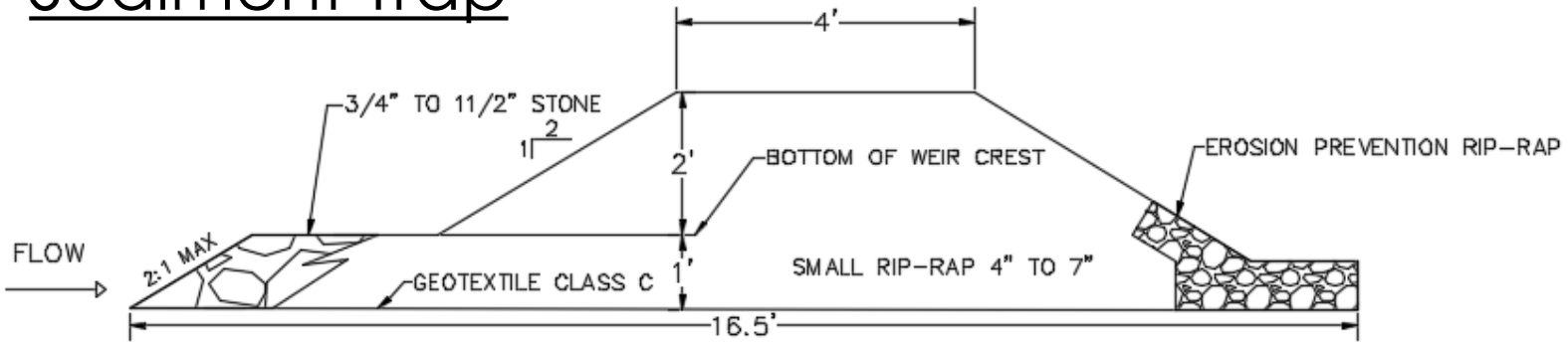
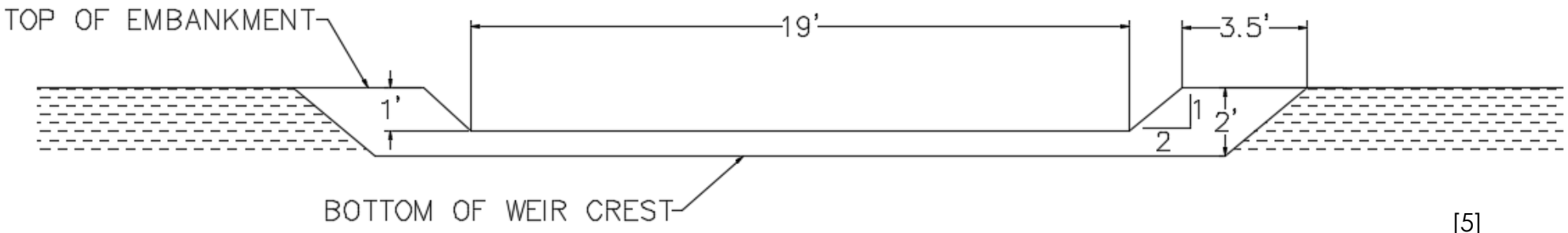


Figure 7: Profile View



[5]

Figure 8: Weir Cross Section Detail

Area of Interest #2 (E. McConnell Dr. and S. Milton Rd.)

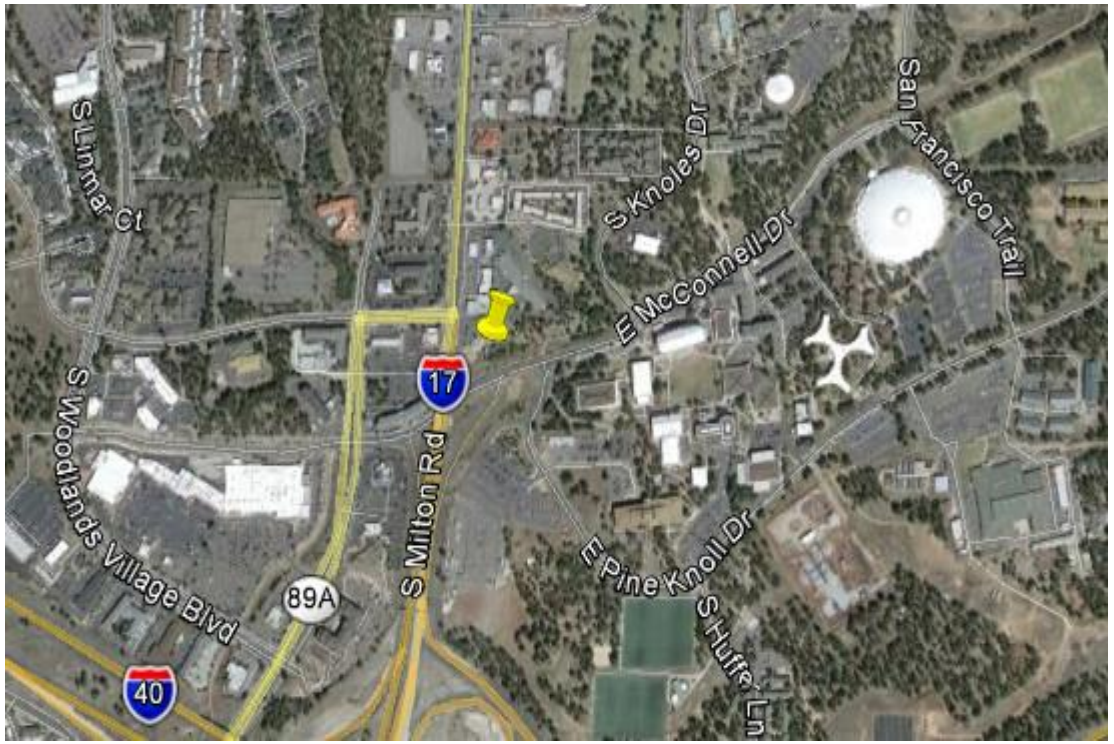
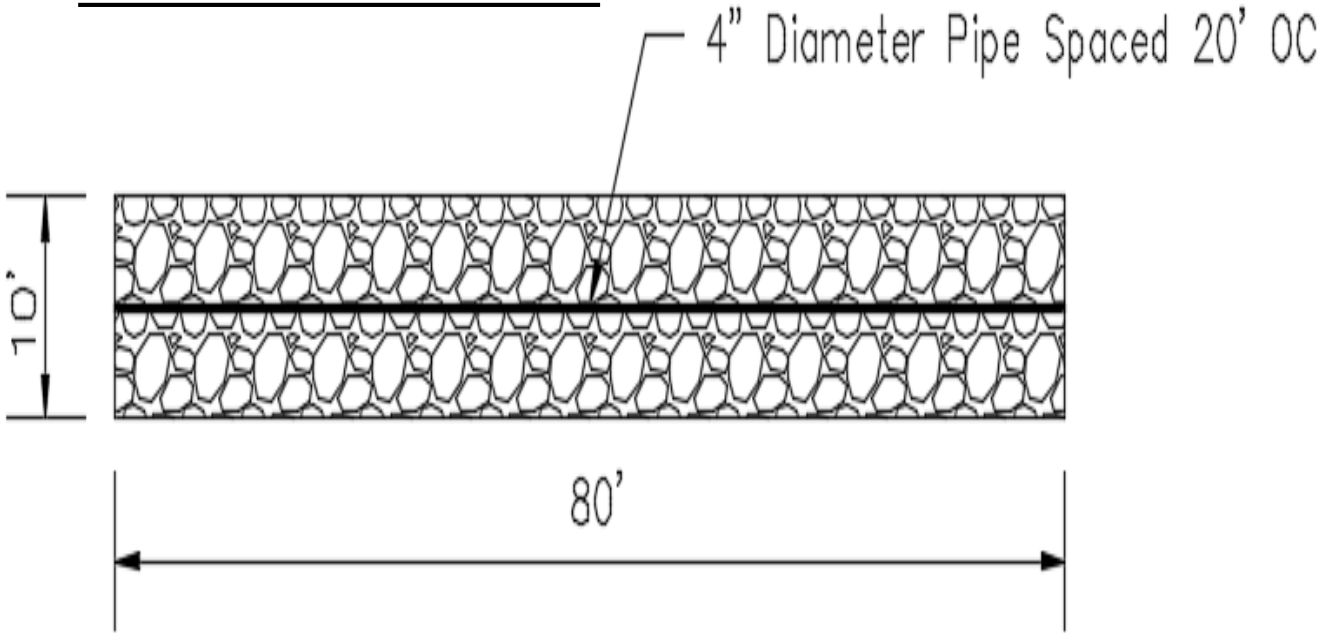


Figure 9: Location of Proposed Detention Basin

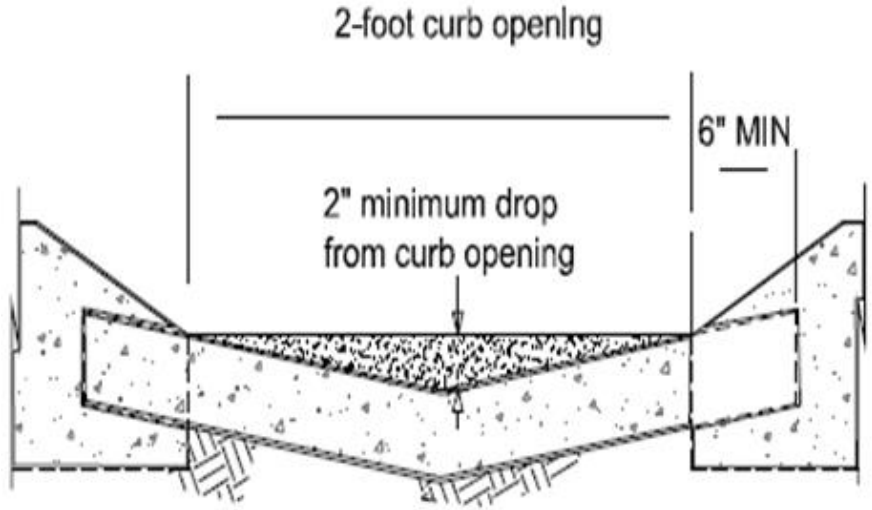
Area of Interest #2 (E. McConnell Dr. and S. Milton Rd.)

Detention Basin



[2]

Figure 10: Detention Basin Plan View



[2]

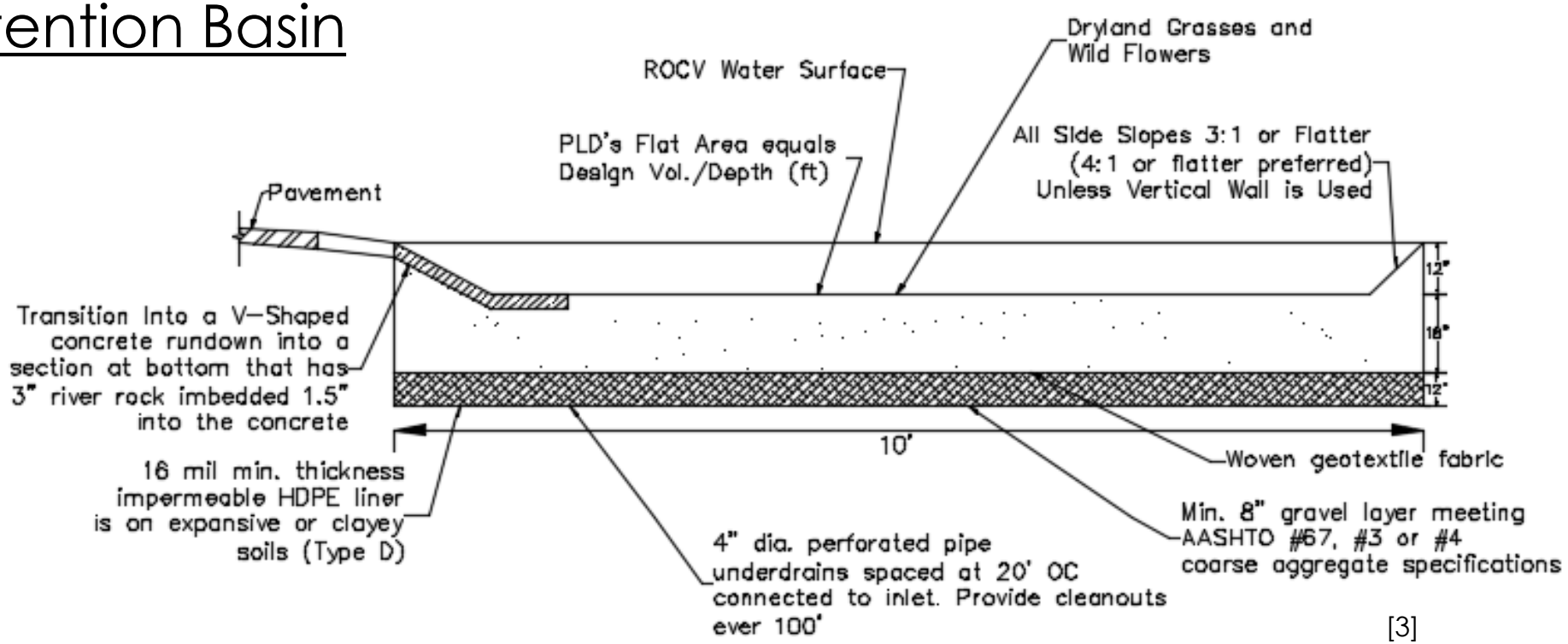
Figure 11: Inlet Profile View

$$Design\ Volume = \frac{1"}{12}\ x\ Area$$

$$Design\ Volume = \frac{1"}{12}\ x\ 7{,}552\ ft^2 = 629.4\ ft^3$$

Area of Interest #2 (E. McConnell Dr. and S. Milton Rd.)

Detention Basin



[3]

Figure 12: Profile View of Detention Basin

Area of Interest #3: Reach 11 (Mountain Dell Neighborhood)

Reach 11 Field Assessment

- Erosion around culverts
- Sediment-filled culverts
- Undersized infrastructure
- Flooding during high intensity storms

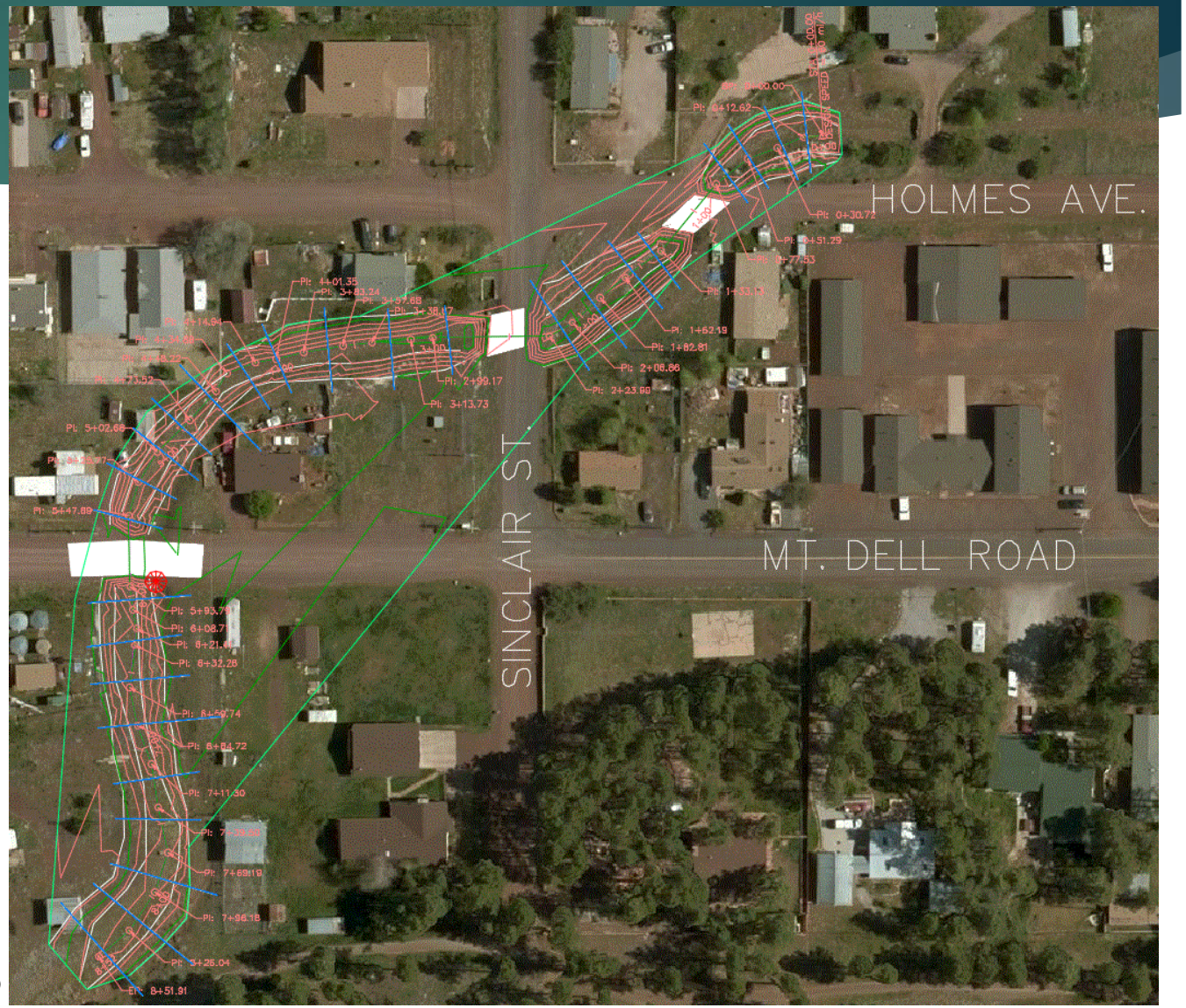


Figure 13: Reach 11 Topo

Area of Interest #3: Reach 11 (Mountain Dell Neighborhood)

HEC-RAS Analysis

- 2-year, 25-year, 100-year flow existing

Table 3: Low Flow Channel Feasibility

Station	2-Year Flow (cfs)	Velocity (ft/s)	Normal Depth (ft)	Area of flow (ft^3)	Width Required for Low Flow Channel (with a depth of 2ft) (ft)	Width of Channel (ft)
29	170.22	2.63	2.26	66.81	30.41	24.00
21	170.22	2.01	3.77	84.86	39.43	23.00
CULVERT						
19	170.22	3.32	3.23	51.31	22.66	12.00
10	170.22	2.33	3.40	72.94	33.47	21.00
CULVERT						
8	170.22	2.88	3.27	33.75	13.88	17.00
5	170.22	3.19	3.54	53.42	23.71	14.00
CULVERT						
3	170.22	6.37	1.60	26.73	10.37	18.00
1	170.22	3.98	2.28	42.80	18.40	17.00

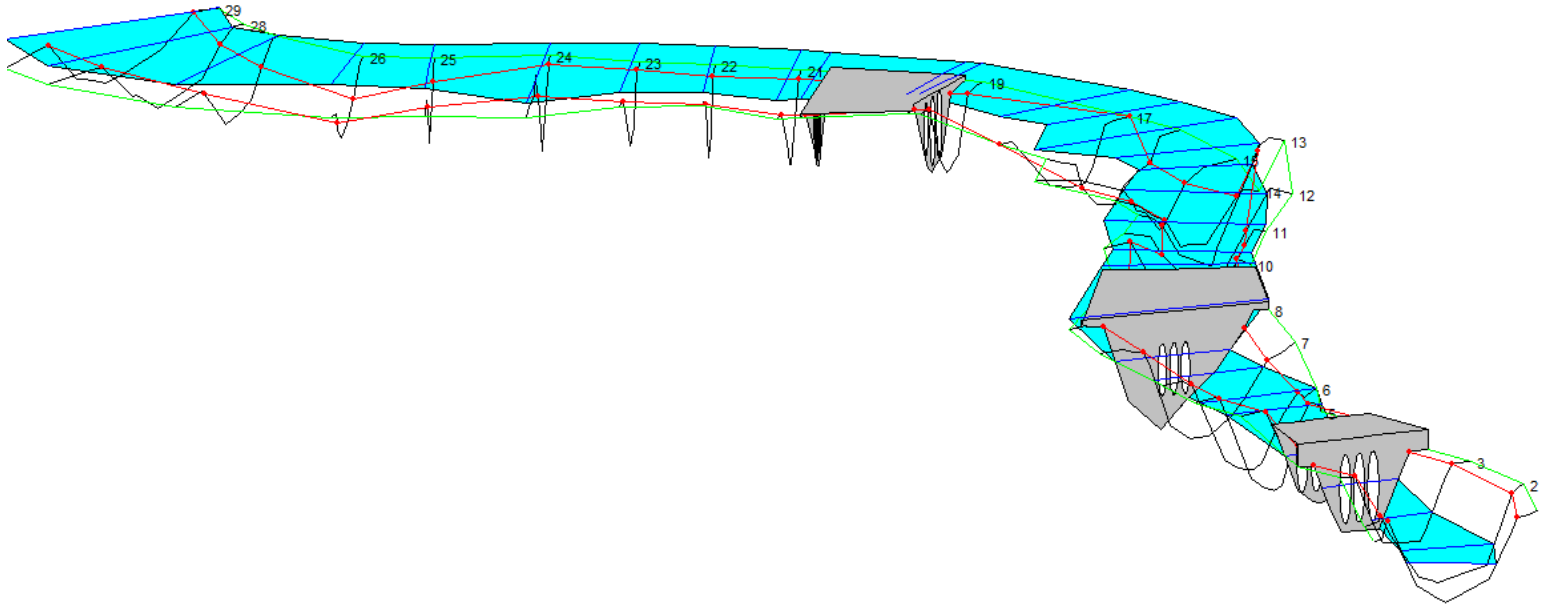
Area of Interest #3: Reach 11 (Mountain Dell Neighborhood)

2-Year Flow

Table 4: HEC-RAS Analysis

Existing 2-year Flow Mountain Dell					
Station	**Flow (cfs)**	**W.S. Elevation (ft)**	**Crossing Elevation (ft)**	**Vel. Chnl (ft/s)**	**Min Velocity to Erode (ft/s)**
29	170.22	1001.3		1.28	5
21	170.22	1001.23		0.98	5
Culvert			**1000.26**		5
19	170.22	1001.17		1.45	5
10	170.22	1001.14		1.04	5
Culvert			**1001.00**		5
8	170.22	998.28		1.78	5
5	170.22	998.21		2.03	5
Culvert			**999.13**		5
3	170.22	994.51		6.37	5
1	170.22	994.23		3.98	5

Figure 14: 2-year Flow Profile



Area of Interest #3: Reach 11 (Mountain Dell Neighborhood)

Box Culvert Design

Figure 15: Existing Culverts

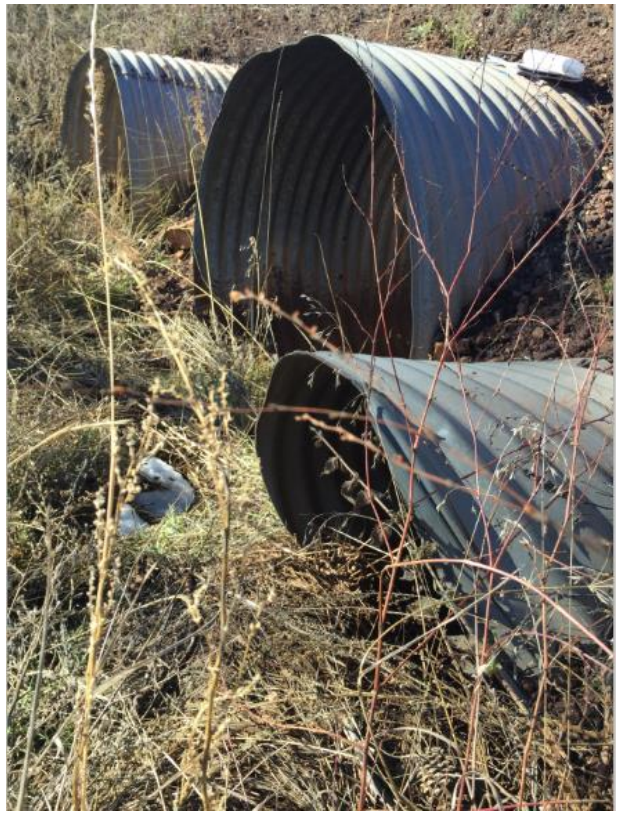
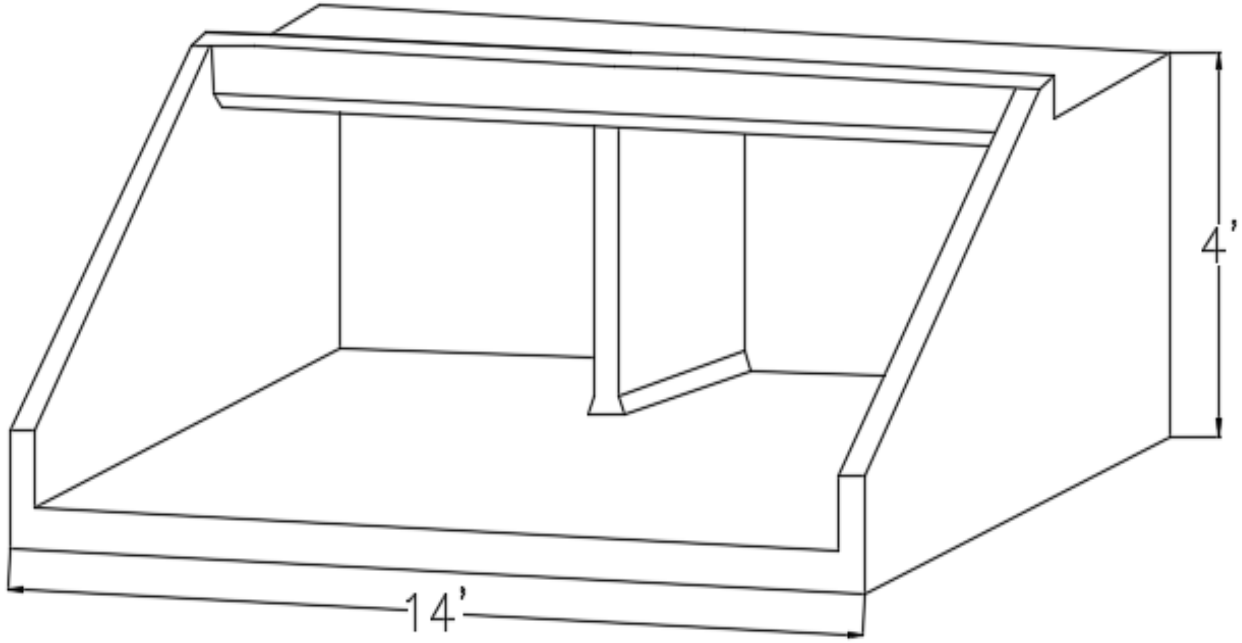


Figure 16: Proposed Box Culverts



Area of Interest #3: Reach 11 (Mountain Dell Neighborhood)

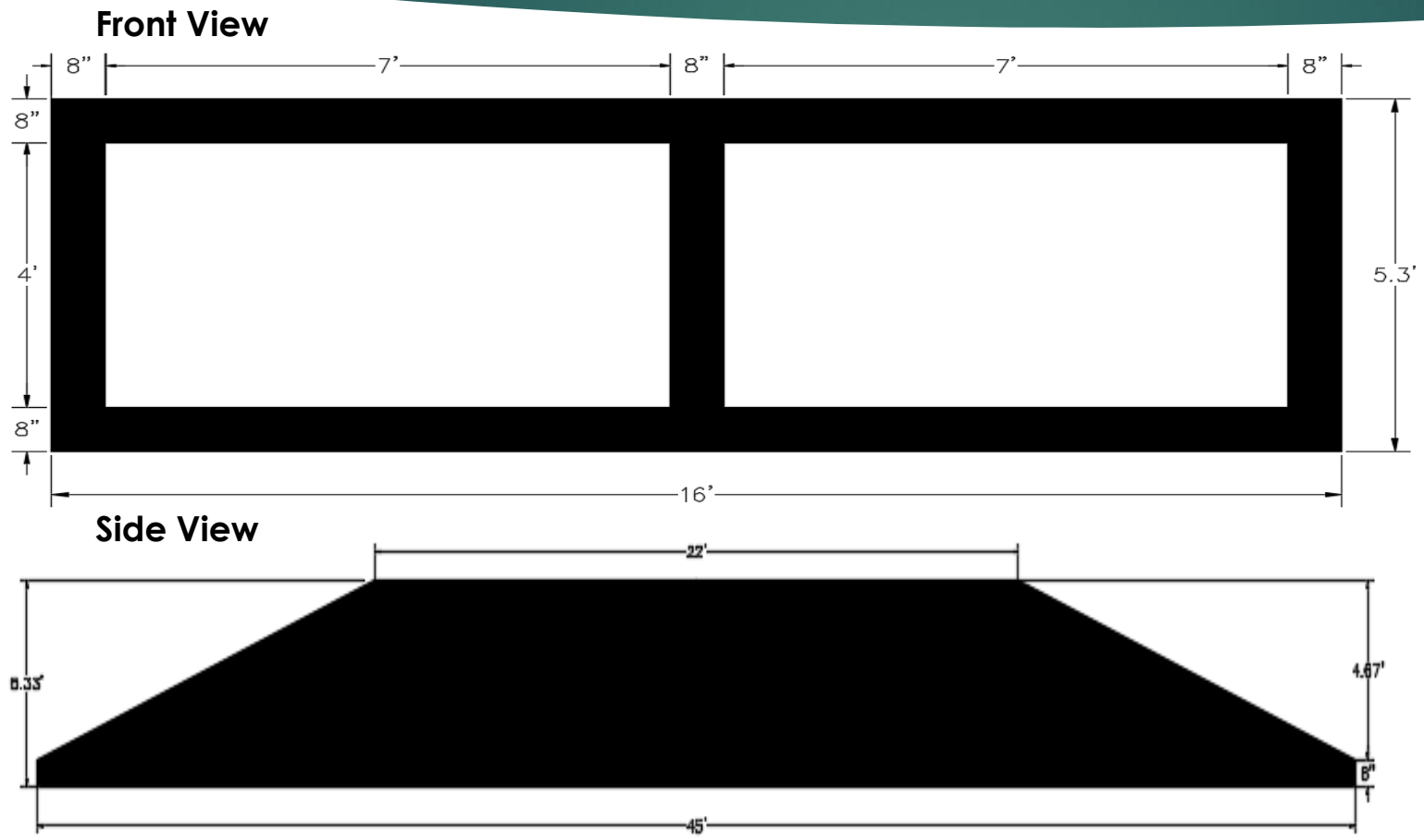


Figure 17: Front and Side Profiles of Proposed Box Culvert

Box Culvert Design

- Reinforced concrete double box culvert (7’ X4’ each)
- 8” concrete walls
- 1:2 side slope

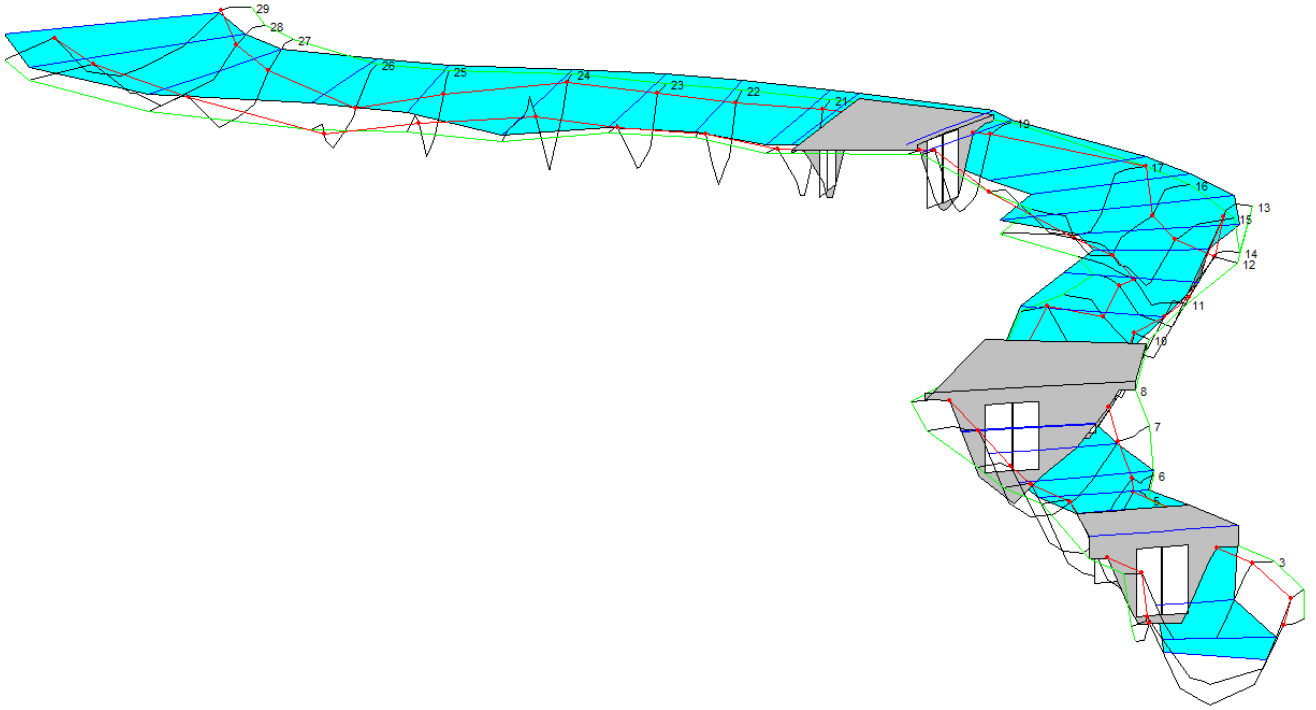
Area of Interest #3: Reach 11 (Mountain Dell Neighborhood)

2-Year Flow

Table 5: HEC-RAS Analysis

Proposed 2-year Flow Mountain Dell					
Station	**Flow (cfs)**	**W.S. Elevation (ft)**	**Crossing Elevation (ft)**	**Vel. Chnl**	**Max Velocity to Erode**
29	170.22	1000.13		2.63	5
21	170.22	999.53		2.01	5
culvert			**1000.26**		5
19	170.22	999.07		3.32	5
10	170.22	998.56		2.33	5
culvert			**1001.00**		5
8	170.22	997.29		2.88	5
5	170.22	997.05		3.19	5
culvert			**999.13**		5
3	170.22	994.51		6.37	5
1	170.22	994.23		3.98	5

Figure 18: 2-year Flow Profile



All Proposed Designs

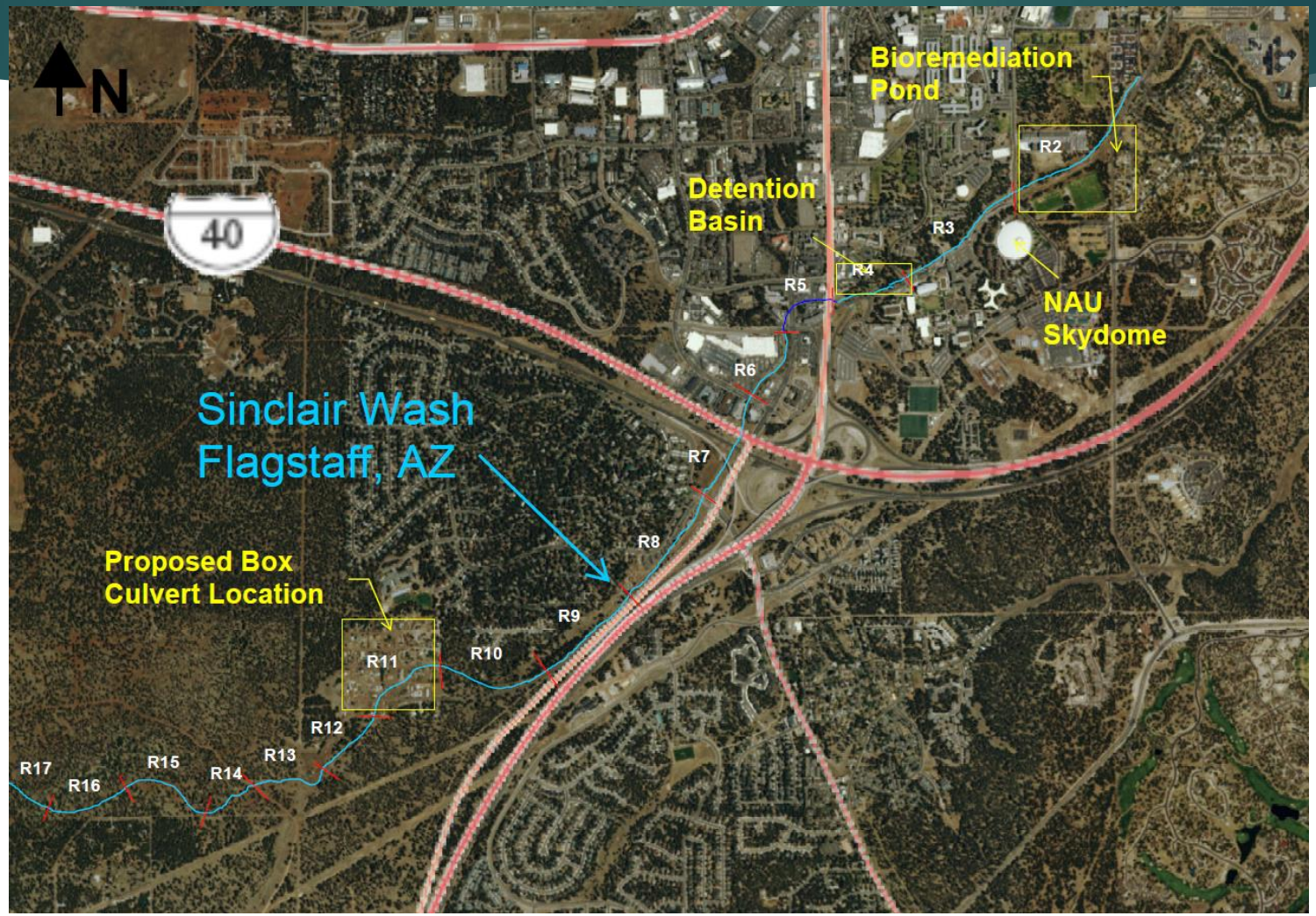


Figure 19: ArcGIS Map of Proposed Design Locations along Sinclair Wash

Riparian Habitat Enhancement

Invasive Species

- Yellow Starthistle (18)
- Dalmation Toadflax (11)
- Prickly Lettuce (30)
- Kochia (15)
- Cheatgrass (28)
- Diffuse Knapweed (15)

Figure 20: Diffuse Knapweed found in Reach 6

Figure 21: Toadflax found in Reach 8

Removal Measures

Table 6: Invasive Vegetation Removal Techniques Decision Matrix

	Physical Removal (10)	Biological Removal (10)	Chemical Removal (10)
Feasible	9	7	7
Cost	6	5	4
Environmental Impact	9	2	2
Total	**24**	**14**	**13**

Figure 22: Physical removal

Figure 23: Biological removal

Figure 24: Chemical removal

Physical Removal Measures

- Avoid disturbing wildlife
- Work during dry season
- Minimize soil disturbance
- Pull – if roots easily come out
- Cut – if roots DON'T easily come out
- **Utilize backhoe for operation and maintenance**

Figure 25: Sinclair Wash Trail

[3]

Native Vegetation

- Willow
- Arizona Rose
- Wild Hops
- Cattail
- Narrowleaf Cottonwood
- Sedge
- Deergrass

Fremont cottonwood (*Populus Fremontii*): Large tree. This is a local native, brought up in elevation for landscaping purposes. It has higher wildlife value than exotic invasives from

more distant areas. Somewhat triangle- to heart- shaped toothed leaves. Bark varies from light to dark grey, and varies from smooth to highly furrowed.

Narrowleaf cottonwood (*Populus angustifolia*): Large tree. Spreads through root sprouts, and may form dense stands of narrow trunks. Long leaves may vary greatly in width. Young leaves may have very different shape than older leaves. Bark similar to Fremont cottonwood, may resemble aspen bark when young. Often co-occurs with aspen (*Populus tremuloides*) in N. AZ riparian areas.

Cost of Implementation of Project

Table 7: Cost to Implement Designs

Design	Area	Cost ($)
Detention Basin	E. McConnell Dr.	$10,130.80
Box Culverts	Mountain Dell	$24,000.00
Pond	Lone Tree Rd.	$8,741.80
Dam	Lone Tree Rd.	$23,011.60
Sedimentation Trap	Lone Tree Rd.	$929.90
Vegetation Enhancement	Sinclair wash	$1,200.00
Total Cost		$68,014.10

Schedule Comparison

Table 8: Predicted vs. Actual Project Schedule

Sinclair Wash Schedule	Predicted Complete Date	Actual Complete Date
1.0 Field Assessment	11/5/2015	11/5/2015
2.0 Design Enhancement Alternatives	4/22/2016	4/24/2016
3.0 Survey Identified Problematic Areas	1/29/2016	2/23/2016
4.0 Geomorphic Assessment	3/10/2016	3/20/2016
5.0 Riparian Habitat Assessment	3/4/2016	3/4/2016
6.0 Hydrologic Assessment-Incorporate LiDAR/GIS	3/10/2016	3/10/2016
7.0 Hydraulic Analysis	3/2/2016	4/22/2016
8.0 Low Impact Development	4/3/2016	4/4/2016
9.0 Cost of Implementation	4/29/2016	4/23/2016
10.0 Impact Analysis	4/3/2016	4/23/2016
11.0 Project Management	5/6/2016	5/6/2016
12.0 Client Communication	5/6/2016	5/6/2016
13.0 Technical Adviser Communication	5/6/2016	5/6/2016
14.0 Budget Management	4/22/2016	4/22/2016
15.0 Project Submittals	5/12/2016	5/12/2016
16.0 50% Design Report	3/10/2016	3/8/2016
17.0 Final Presentation	4/29/2016	4/29/2016
18.0 Website Development	5/12/2016	5/12/2016
19.0 100% Design Report	5/12/2016	5/12/2016

Hour Breakdown

Table 9: Predicted project hours

Task	Project Manager Hours	Project Engineer Hours	Engineer-in-Training Hours	Lab Technician Hours	Intern Hours
Field Assessment	5	23	18	5	31
Design Enhancement Alternatives	34	74	73	105	44
Project Management	125	102	105	56	76
Impact Analysis	12	18	18	5	12
TOTAL	**176**	**217**	**214**	**171**	**163**

Total: 941 hours

Table 10: Actual project hours

Task	Project Manager Hours	Project Engineer Hours	Engineer-in-Training Hours	Lab Technician Hours	Intern Hours
Field Assessment	13	17	23	17	40
Design Enhancement Alternatives	22	62	123	95	98
Project Management	66	73	71	34	51
Impact Analysis	6	6	5	0	4
TOTAL	**107**	**158**	**222**	**146**	**193**

Total: 826 hours

Predicted vs. Actual Cost of Services

Table 11: Predicted project costs

Expense				
Personnel	**Classification**	**Hours**	**Rate ($/hour)**	**Cost**
	Project Manager	176	$158	$27,808
	Project Engineer	217	$78	$16,926
	Engineer-in-Training	214	$62	$13,268
	Lab Technician	171	$75	$12,825
	Intern	163	$24	$3,912
Surveying		16	$150	$2,400
TOTAL				**$77,139**

Table 12: Actual project costs

Expense				
Personnel	**Classification**	**Hours**	**Rate ($/hour)**	**Cost**
	Project Manager	107	$158	$16,906
	Project Engineer	158	$78	$12,324
	Engineer-in-Training	222	$62	$13,764
	Lab Technician	146	$75	$10,950
	Intern	193	$24	$4,632
Surveying		25	$150	$3,750
TOTAL				**$62,326**

Analysis of Impacts

- Economic
  - Benefits to NAU campus
- Environmental
  - Water quality improvement at pond and detention basin locations
  - Riparian habitat enhancement
- Community
  - Construction of proposed infrastructure
  - Enhancement of recreational activities

Figure 26: Sinclair Wash during intense storm

[4]

References

[1] Pictures from capstone Team 2014-2015
[2] "Low Impact Development". City of Flagstaff. 2009. Web. 6 Apr. 2016.
[3] "Willow Bend," in *Friends of the Rio de Flag*, Friends of the Rio de Flag, 2015. [Online]. Available: http://friendsoftheriodeflag.org/projects/willow-bend/.
[4] F. S. J. Reporter, "Flagstaff sees scattered flooding from downpours," Arizona Daily Sun, 2006.
[5] "Sediment Traps & Basin". *Department of Energy & Environment*. 2013. Web. 2 Apr. 2016.
[6] "Typical Bioretention - Level Two with Underdrain,". [Online]. Available: http://www.vwrrc.vt.edu/swc/april_22_2010_update/DCR_BMP_Spec_No_9_BIORETENTION_FinalDraft_v1-8_04132010_files/image014.gif.
[7] Ronald Spiner, "City of Flagstaff Stormwater Management Design Manual," in "City," City of Flagstaff, Flagstaff, Arizona, Jun. 2000.

Questions

- **Acknowledgements:**
  - David McKee – City of Flagstaff Stormwater Manager
  - Mark Lamer, P.E. – Capstone Group Technical Advisor
  - Paul McCloskey – former NAU graduate student

Figure 27: Reach 2 during flooding