TEICHERT AGGREGATES

OFF-CHANNEL MINING AND RECLAMATION APPLICATION

CACHE CREEK HYDRAULICS STUDY
for
SHIFLER MINING REACH

Prepared for

Teichert Aggregates
P.O. Box 15002
Sacramento, CA 95851-1002
(916) 484-3319

Prepared by

Cunningham Engineering Corporation
2940 Spafford Street, Suite 200
Davis, CA 95618
(530) 758-2026

Steven J. Greenfield, PE, 50880
Project Manager

STEVEN J. GREENFIELD
No. C50880
CIVIL

1/27/16

January 26, 2016

TEICHERT AGGREGATES

OFF-CHANNEL MINING AND RECLAMATION APPLICATION

CACHE CREEK HYDRAULICS STUDY – SHIFLER REACH

INTRODUCTION

This report has been prepared in support of Teichert Aggregates' proposed mining permit application for the Shifler property. The study provides estimates of 100-year water surface elevations (WSE's) and the lateral extents of the computed 100-year water surface in Cache Creek.

SITE DESCRIPTION

The subject mining reach lies between County Roads 94B and 96 in Yolo County along the south creek bank. More specifically, the creek reach abutting the Shifler site begins near County Road 94B (Creek Station 1123+95), and extends downstream (east) almost 3,400 feet (Creek Station 1090+00). For the purposes of the hydraulic analysis, the study reach begins just upstream of the CR 94B bridge (at Creek Station 1144+30) and extends east to a point approximately 1,500 feet downstream of the existing Schwarzgruber mining site (Station 1000+00).

SCOPE OF HYDRAULICS STUDY

The purpose of this study is to estimate approximate 100-year water surface profiles in Cache Creek abutting the Shifler property for two channel bank geometries as follows:

1. Current bank geometry (same geometry as that used in the 2011 analysis for the adjacent Schwarzgruber reach).
2. Bank geometry translated such that the North and South banks coincide with the 1996 Test 3 Line.

This analysis only addresses existing conditions and possible future streambank improvements in the creek. It does not include analysis of mining or other work within the Cache Creek channel, or any analyses of flow effects on the bridges, or analysis of pit capture.

BACKGROUND

Computer Model

This study was completed using the Hydrologic Engineering Center River Analysis System (HEC-RAS) computer program. The program models one-dimensional, steady state, gradually-varied flow in order to compute water surface profiles.

Peak Discharge

Numerous hydrologic studies of Cache Creek have been performed over the years. In 1994, the US Army Corps of Engineers (Corps) completed a reconnaissance level report titled *Westside Tributaries to Yolo Bypass, CA* that established peak flow rates for the Capay Gauge located approximately 14 miles upstream of County Road 94B. The 100-year peak discharge was 63,500 cubic feet per second (cfs).

On previous hydraulic studies within Cache Creek, CEC conducted sensitivity analyses to determine the magnitude of change in the 100-year WSE's using the range of flow rates presented by the Corps in their report titled *Lower Cache Creek, Yolo County, CA – City of Woodland and Vicinity Flood Reduction Study, F3 Milestone Conference Report, Administrative Draft, March 12, 2001*. A comparison of the two values presented for the Capay Gauge site (63,500 cfs for 1994 study versus 61,500 cfs for 2001 study) showed that the modeled WSE is <u>not</u> highly sensitive to differences in peak discharge rates on the order of 2,000 cfs, relative to construction tolerances at a typical mining site.

These flows are generally consistent with the most recent 2010 Flood Insurance Study (FIS) for the City of Woodland which shows 100-year flows of approximately 63,700 cfs in the subject study reach. This study uses a flow rate of 63,700 cfs.

It is noted that these are recommended values for analysis or design purposes. Actual flow rates are subject to various factors, including the timing of releases from the Clear Lake and Indian Valley reservoirs.

Additional Cache Creek studies in the subject area that incorporated analysis of the WSE's include a study for Yolo County by Northwest Hydraulics in conjunction with EIP Associates for the "Technical Studies and Recommendations for the Lower Cache Creek Resource Management Plan" (October 1995); and a study for Yolo County/Martin Kane Associates by Northwest Hydraulics titled "Design Hydraulic Study/Location Hydraulic Study, Capay Bridge Located on County Road 85" (September 1995).

Channel Topography

This 2010 analysis is based on aerial topography flown April 2010 provided by Towill Surveying, Mapping and GIS Services via Yolo County. Horizontal and vertical control for the aerial topography was based on a control network tied by Towill, incorporated to a network of published benchmarks. The vertical datum is NAVD 88. As noted above, this is the same bank geometry that was used for the recent (2011) analysis for the Schwarzgruber reach, which lies immediately downstream.

Areas of storage that have no conveyance are represented on the cross-section plots as "ineffective flow areas" and the tops of banks are graphically represented on the cross section plots as "bank stations". The streamwise locations of the cross-sections are shown on the fold-out drawing (Sheet 1 of 1) in Appendix D, attached.

ANALYSIS APPROACH

To determine the 100-year water surface approximation, a numerical model of the creek topography and flow characteristics was created using HEC-RAS. The creek centerline was approximated based on the existing bank geometry, and begins approximately 9,500 feet downstream of the Shifler site (i.e. at Station 1000+00). Since the hydraulic model addresses a high-flow condition, the HEC-RAS centerline does not necessarily follow the stream thalweg at all locations. Cross-sections were spaced approximately every 500 feet, with additional cross-sections added to model the CR 94B bridge and the Teichert Conveyor bridge crossing at approximate Station 1071+10.

A starting WSE of 94 (NAVD 88) was applied as a downstream boundary condition at Station 1000+00 (see Appendix D). This was based on the 100-year WSE as previously determined in the 2010 Flood Insurance Study for the City of Woodland, and as indicated on FEMA FIRM Map 06113C0430G.

This analysis utilized a roughness coefficient (Manning's "n") of 0.038 for channel flow. This is consistent with the 2010 City of Woodland FIS, in which the reported channel "n" value for Cache Creek is in the range 0.030 to 0.045 (average = 0.038). This study's channel "n" value of 0.038 is also consistent with previous Cache Creek studies done by Cunningham Engineering Corporation (CEC) in neighboring reaches in 1996, 2001, 2007 and 2009.

A roughness value of 0.070 was applied to overbank flow.

STUDY RESULTS

The numerical results are presented in Appendices A through D, attached. These results are not meant to be exact predictions of future WSE's. The results of the model indicate that, within the subject mining reach, the 100-year discharge will be contained within the high banks on the south side of the creek channel. However, between station 1000+00 and 1030+00 of the existing channel boundary conditions, the 100-year WSE extends above the northern bank. The model of the Test 3 geometry indicates that the 100-year WSE will be generally lower than under existing conditions and will be contained within the high banks of the creek channel.

OTHER RECENT STUDIES

In early 2014, California DWR released a recently completed CVFED hydraulic model for the Lower Sacramento River and tributaries, including Cache Creek. DWR's Cache Creek modeling incudes unsteady 1-dimensional (HEC-RAS) simulations for the 10-year and 500-year events, extending as far upstream as the Capay Diversion Dam. In addition, DWR prepared a 2-dimensional (TUFLOW) 200-year model for Cache Creek, with the upstream modeling limit located about ½ mile downstream of the CR94B bridge. The RAS and TUFLOW models' stream geometrics are both referenced to vertical datum NAVD 88.

The documentation for the 200-year and 500-year models includes water surface profile plots. We reviewed those profiles as they traverse the Shifler reach, and found that DWR's computed 200-year and 500-year water surface profiles are lower than the creek's south bank along the north edge of the Shifler property. By way of illustration:

- At Teichert Conveyor, WSE_{500}= 95.7; Top of south bank ≈ 99.6
- At ½ mile downstream of CR94B Bridge, WSE_{500}= 96.8; Top of south bank ≈ 99.8
- Immediately downstream of CR94B Bridge, WSE_{500}= 97.2; Top of south bank ≈ 105.9

CONCLUSIONS AND RECOMMENDATIONS

1. The HEC-RAS model predicts that, for the existing (2010) channel geometry and the Test 3 geometry, the estimated 100-year discharge will stay within the creek's south bank along the Teichert reach between CR 96 and CR 94B (Creek Station 1015+00 to 1123+95). The model indicates some overtopping of the north bank near the downstream end of the analysis reach (just downstream of the Shwarzgruber property).

2. In addition, DWR's recent modeling indicates that the estimated 200-year and 500-year discharges will also stay within the creek's south bank along the Shifler reach.

3. To maintain historic 100-year flood capacity, any significant sand and gravel bars should be removed in areas where aggradation is observed to be occurring within the channel boundaries. This can be determined by comparison of current topographic surveys with historic surveys performed within the last 10 years. It is noted however that such work is not within the scope of this mining application.

Attachments:

Appendix A – HEC-RAS Results Table
Appendix B – Creek Cross-Sections
Appendix C – Creek Water Surface Profile
Appendix D – Fold-out drawing: Approximate 100-year Water Surface Elevations

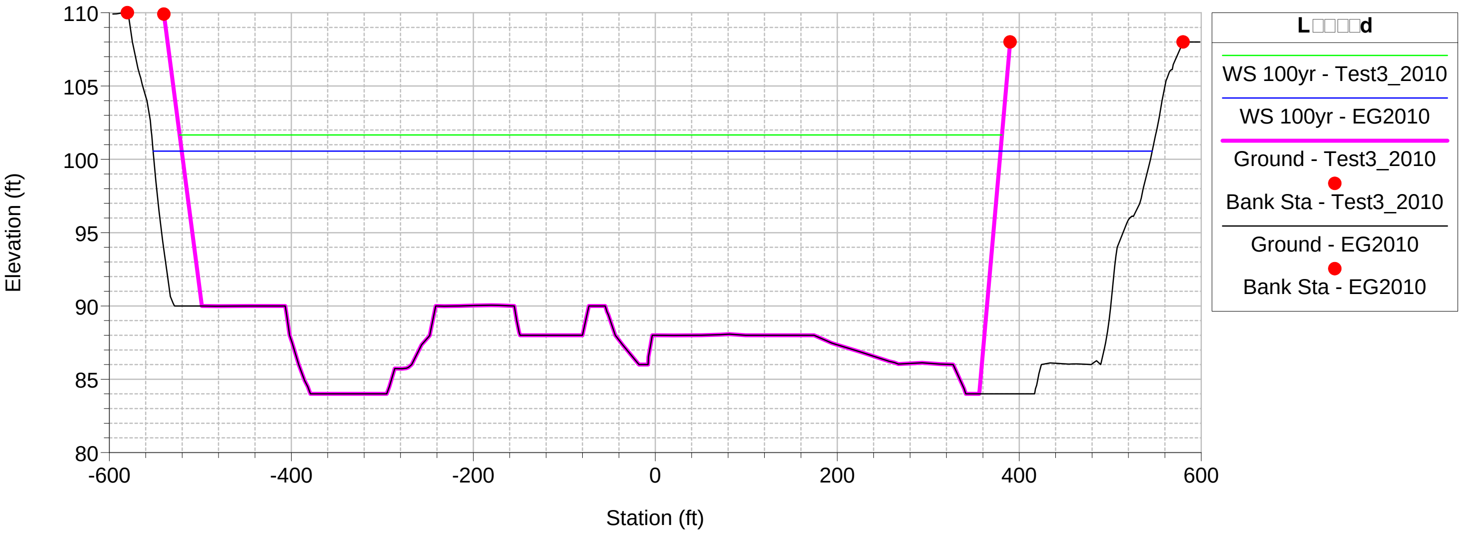
HEC-RAS   River: Cache Creek   Reach: Teichert   Profile: 100yr

Reach	River Sta	Profile	Plan	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Teichert	114429.5	100yr	EG2010	63700.00	84.00	100.56		100.88	0.000458	4.55	14012.44	1097.93	0.22
Teichert	114429.5	100yr	Test3_2010	63700.00	84.00	101.67		102.07	0.000528	5.12	12445.08	903.84	0.24
Teichert	114000	100yr	EG2010	63700.00	84.00	100.39		100.68	0.000409	4.33	14695.80	1139.08	0.21
Teichert	114000	100yr	Test3_2010	63700.00	84.00	101.39		101.84	0.000544	5.35	11901.35	827.02	0.25
Teichert	113500	100yr	EG2010	63700.00	82.00	100.10	91.17	100.45	0.000498	4.77	13353.58	1159.40	0.23
Teichert	113500	100yr	Test3_2010	63700.00	82.00	100.96		101.53	0.000631	6.08	10470.05	668.53	0.27
Teichert	113000	100yr	EG2010	63700.00	81.94	99.98		100.23	0.000307	4.03	15803.34	1089.49	0.19
Teichert	113000	100yr	Test3_2010	63700.00	81.94	99.99		101.06	0.001230	8.28	7696.39	510.65	0.38
Teichert	112650	100yr	EG2010	63700.00	80.00	99.79		100.10	0.000376	4.48	14219.06	972.87	0.21
Teichert	112650	100yr	Test3_2010	63700.00	80.00	98.93		100.49	0.001782	10.03	6351.68	415.24	0.45
Teichert	112455	100yr	EG2010	63700.00	80.00	97.31	92.32	99.73	0.002917	12.49	5098.29	344.27	0.57
Teichert	112455	100yr	Test3_2010	63700.00	80.00	97.23	92.59	99.92	0.003190	13.18	4834.54	321.25	0.60
Teichert	112425			Bridge									
Teichert	112395	100yr	EG2010	63700.00	80.00	96.15		99.11	0.003733	13.81	4611.95	323.78	0.64
Teichert	112395	100yr	Test3_2010	63700.00	80.00	96.74		99.19	0.002941	12.55	5077.14	342.38	0.57
Teichert	112000	100yr	EG2010	63700.00	80.00	97.06		97.80	0.000908	6.88	9254.93	644.77	0.32
Teichert	112000	100yr	Test3_2010	63700.00	80.00	95.82		97.91	0.002972	11.60	5489.19	425.33	0.57
Teichert	111500	100yr	EG2010	63700.00	78.00	97.18		97.39	0.000315	3.64	17516.34	1446.82	0.18
Teichert	111500	100yr	Test3_2010	63700.00	78.00	96.02		96.68	0.001001	6.52	9776.47	803.54	0.33
Teichert	111000	100yr	EG2010	63700.00	78.00	97.11		97.25	0.000185	3.06	20820.83	1505.90	0.14
Teichert	111000	100yr	Test3_2010	63700.00	78.00	96.05		96.30	0.000317	3.99	15978.79	1157.83	0.19
Teichert	110500	100yr	EG2010	63700.00	78.00	97.06		97.16	0.000123	2.54	25062.41	1742.87	0.12
Teichert	110500	100yr	Test3_2010	63700.00	78.00	95.94		96.14	0.000257	3.60	17707.73	1279.34	0.17
Teichert	110000	100yr	EG2010	63700.00	77.97	97.01		97.10	0.000115	2.52	25236.49	1686.17	0.11
Teichert	110000	100yr	Test3_2010	63700.00	77.97	95.83		96.02	0.000222	3.42	18605.88	1291.30	0.16
Teichert	109500	100yr	EG2010	63700.00	76.00	96.91		97.04	0.000145	2.85	22378.91	1487.15	0.13
Teichert	109500	100yr	Test3_2010	63700.00	76.00	95.68		95.89	0.000266	3.72	17109.08	1204.49	0.17
Teichert	109000	100yr	EG2010	63700.00	75.94	96.80		96.95	0.000182	3.12	20440.70	1406.60	0.14
Teichert	109000	100yr	Test3_2010	63700.00	75.94	95.59		95.76	0.000221	3.29	19382.19	1432.97	0.16
Teichert	108500	100yr	EG2010	63700.00	74.00	96.75		96.87	0.000123	2.77	22982.80	1405.81	0.12
Teichert	108500	100yr	Test3_2010	63700.00	74.00	95.55		95.66	0.000129	2.69	23707.89	1583.70	0.12
Teichert	108000	100yr	EG2010	63700.00	72.00	96.67		96.80	0.000133	2.97	21437.92	1253.21	0.13
Teichert	108000	100yr	Test3_2010	63700.00	72.00	95.49		95.60	0.000111	2.69	23690.22	1414.10	0.12
Teichert	107400	100yr	EG2010	63700.00	72.00	96.49		96.70	0.000197	3.68	17295.66	966.13	0.15
Teichert	107400	100yr	Test3_2010	63700.00	72.00	95.44		95.53	0.000089	2.44	26081.30	1523.75	0.10
Teichert	107135	100yr	EG2010	63700.00	71.94	96.23	83.34	96.61	0.000381	4.95	12860.90	755.60	0.21
Teichert	107135	100yr	Test3_2010	63700.00	71.94	95.36	81.64	95.50	0.000140	3.02	21126.67	1258.04	0.13
Teichert	107110			Bridge									
Teichert	107085	100yr	EG2010	63700.00	70.00	96.23		96.58	0.000337	4.75	13414.35	767.23	0.20
Teichert	107085	100yr	Test3_2010	63700.00	70.00	95.36		95.49	0.000115	2.88	22131.50	1215.84	0.12
Teichert	106500	100yr	EG2010	63700.00	70.00	96.19		96.39	0.000195	3.55	17966.55	1066.92	0.15
Teichert	106500	100yr	Test3_2010	63700.00	70.00	95.11		95.37	0.000288	4.09	15579.18	1004.97	0.18
Teichert	106000	100yr	EG2010	63700.00	70.00	96.10		96.28	0.000213	3.33	19129.27	1340.87	0.16
Teichert	106000	100yr	Test3_2010	63700.00	70.00	94.98		95.23	0.000285	3.99	15962.47	1059.07	0.18
Teichert	105500	100yr	EG2010	63700.00	70.00	96.01		96.17	0.000193	3.17	20114.06	1408.01	0.15
Teichert	105500	100yr	Test3_2010	63700.00	70.00	94.82		95.08	0.000304	4.04	15749.72	1076.20	0.19
Teichert	105000	100yr	EG2010	63700.00	70.00	95.86		96.06	0.000237	3.56	17912.93	1224.25	0.16
Teichert	105000	100yr	Test3_2010	63700.00	70.00	94.51		94.88	0.000494	4.88	13053.84	962.90	0.23
Teichert	104500	100yr	EG2010	63700.00	68.00	95.79		95.96	0.000156	3.30	19274.28	1071.78	0.14
Teichert	104500	100yr	Test3_2010	63700.00	68.00	94.29		94.65	0.000411	4.84	13173.33	851.93	0.22

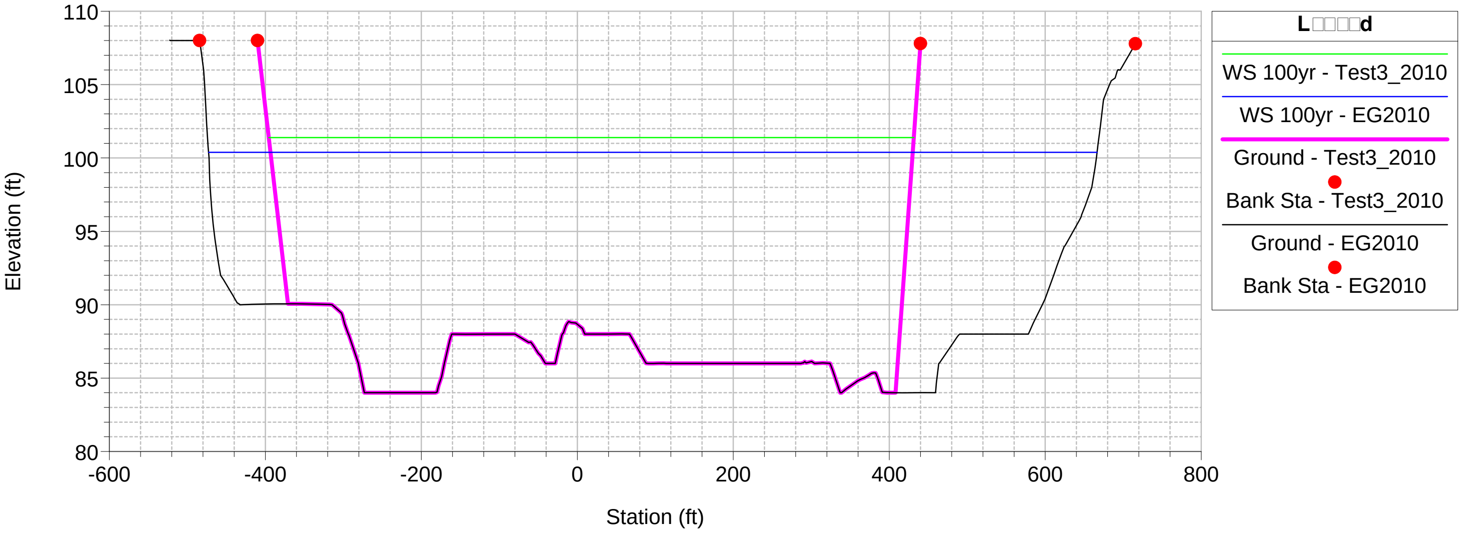
HEC-RAS River: Cache Creek Reach: Teichert Profile: 100yr (Continued)

Reach	River Sta	Profile	Plan	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Teichert	104000	100yr	EG2010	63700.00	68.00	95.77		95.88	0.000088	2.61	24363.31	1259.29	0.10
Teichert	104000	100yr	Test3_2010	63700.00	68.00	94.11		94.45	0.000357	4.72	13482.32	813.41	0.20
Teichert	103500	100yr	EG2010	63700.00	68.00	95.79		95.84	0.000034	1.76	36127.38	1659.76	0.07
Teichert	103500	100yr	Test3_2010	63700.00	68.00	94.10		94.29	0.000157	3.46	18413.63	969.14	0.14
Teichert	103000	100yr	EG2010	63700.00	66.00	95.59		95.79	0.000180	3.57	17833.46	977.09	0.15
Teichert	103000	100yr	Test3_2010	63700.00	66.00	94.14		94.21	0.000057	2.12	30022.34	1541.74	0.08
Teichert	102500	100yr	EG2010	63700.00	66.00	95.55		95.69	0.000143	3.35	24739.39	1378.23	0.13
Teichert	102500	100yr	Test3_2010	63700.00	66.00	94.10		94.18	0.000074	2.27	28117.87	1566.03	0.09
Teichert	102000	100yr	EG2010	63700.00	64.00	94.86		95.52	0.000501	6.58	10140.94	489.27	0.25
Teichert	102000	100yr	Test3_2010	63700.00	64.00	94.08		94.14	0.000052	2.05	31065.20	1569.04	0.08
Teichert	101650	100yr	EG2010	63700.00	64.00	94.43		95.29	0.000749	7.66	9212.92	502.54	0.30
Teichert	101650	100yr	Test3_2010	63700.00	64.00	94.05		94.12	0.000053	2.11	30126.47	1468.86	0.08
Teichert	101400	100yr	EG2010	63700.00	64.00	94.48		95.08	0.000392	6.21	10322.25	448.48	0.23
Teichert	101400	100yr	Test3_2010	63700.00	64.00	94.05		94.11	0.000042	1.99	31936.32	1415.00	0.07
Teichert	101000	100yr	EG2010	63700.00	62.13	94.45		94.88	0.000338	5.36	12763.26	602.00	0.20
Teichert	101000	100yr	Test3_2010	63700.00	62.13	94.04		94.09	0.000026	1.81	35265.78	1265.00	0.06
Teichert	100500	100yr	EG2010	63700.00	62.00	94.18		94.70	0.000362	5.89	11745.42	534.23	0.21
Teichert	100500	100yr	Test3_2010	63700.00	62.00	94.03		94.08	0.000024	1.81	35245.05	1190.00	0.06
Teichert	100000	100yr	EG2010	63700.00	62.00	94.00	81.10	94.49	0.000445	6.02	12753.33	661.94	0.23
Teichert	100000	100yr	Test3_2010	63700.00	62.00	94.00	67.64	94.06	0.000032	2.04	31187.79	1079.00	0.07

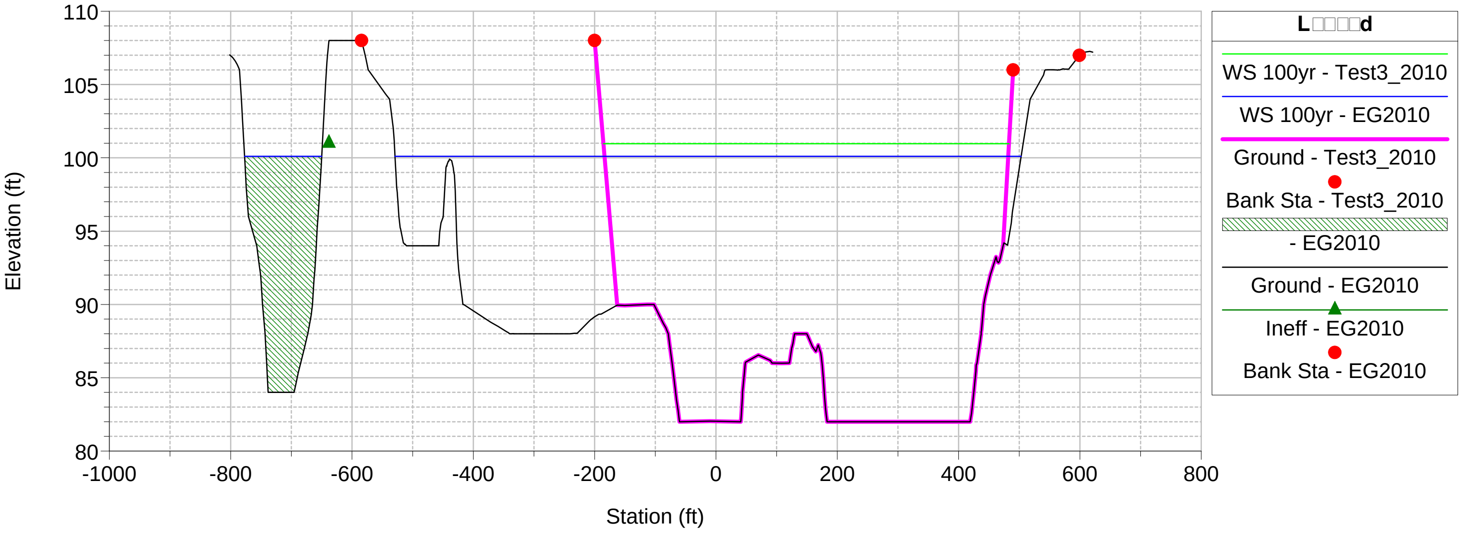
Teichert Woodland Plan: 1) EG2010 2) Test3_2010
RS = 114429.5 STA 1144+29.5



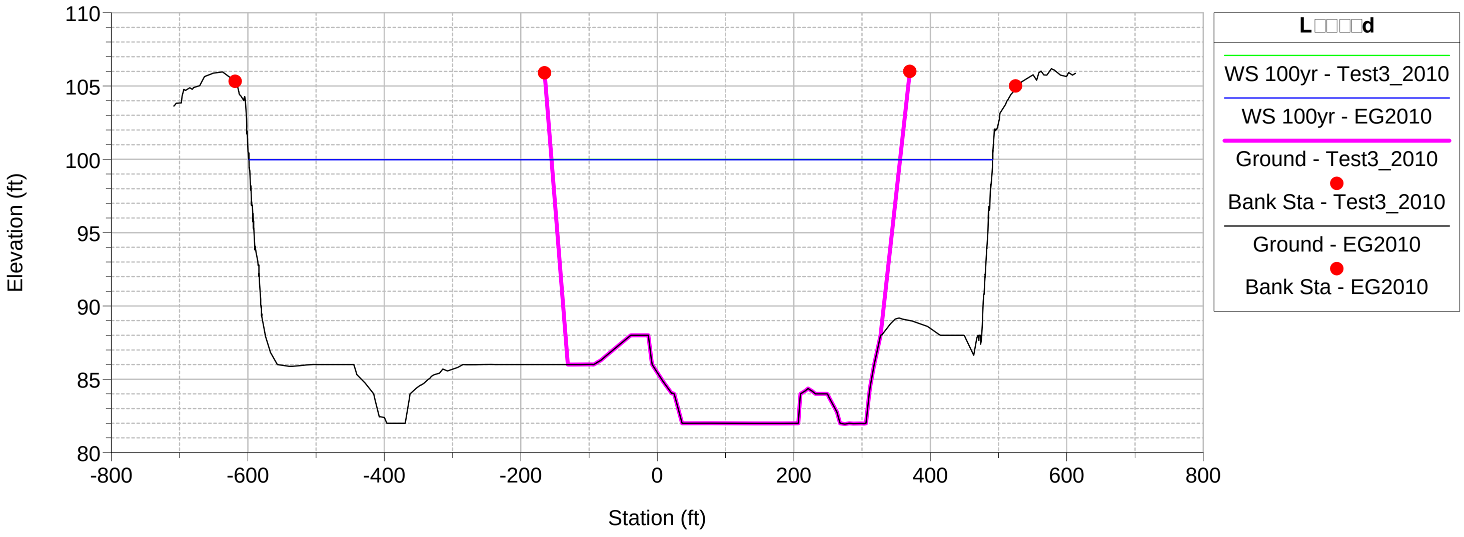
Teichert Woodland Plan: 1) EG2010 2) Test3_2010
RS = 114000 STA 1140+00



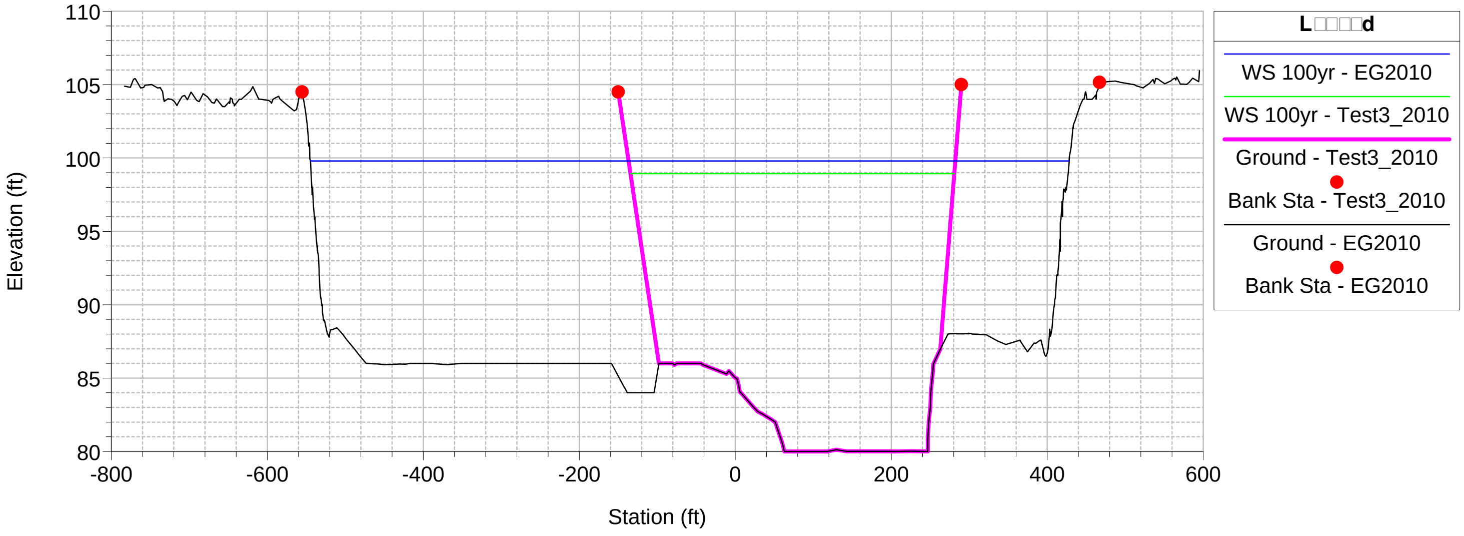
Teichert Woodland Plan: 1) EG2010 2) Test3_2010
RS = 113500 STA 1135+00



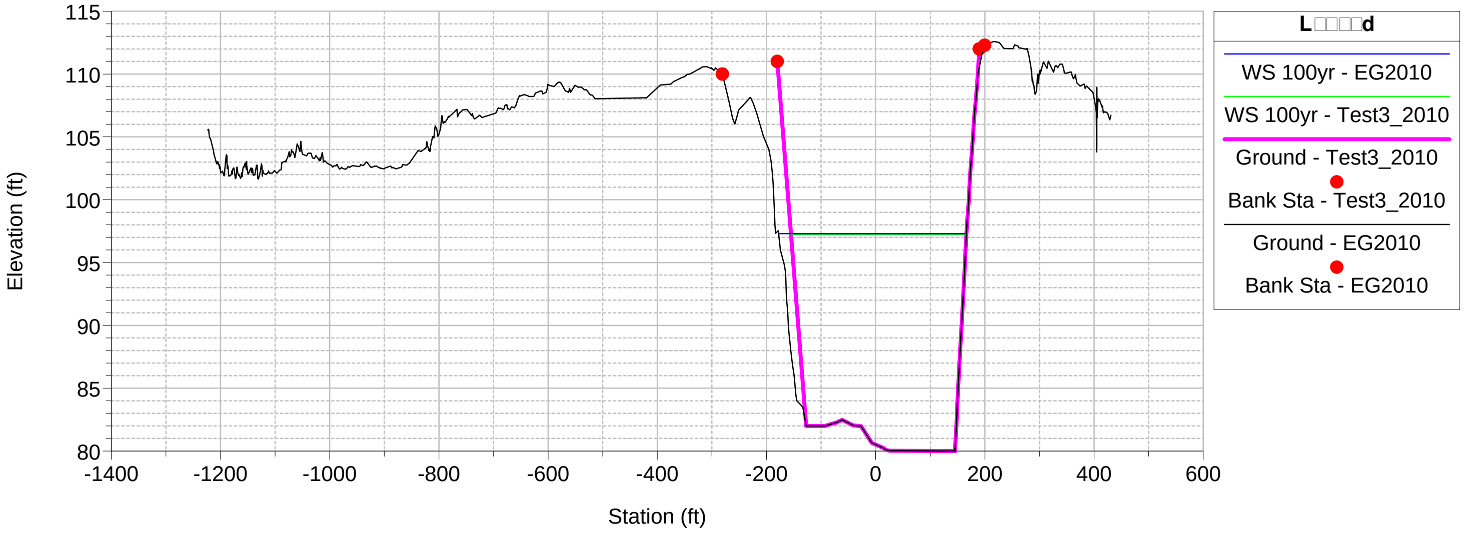
Teichert Woodland Plan: 1) EG2010 2) Test3_2010
RS = 113000 STA 1130+00



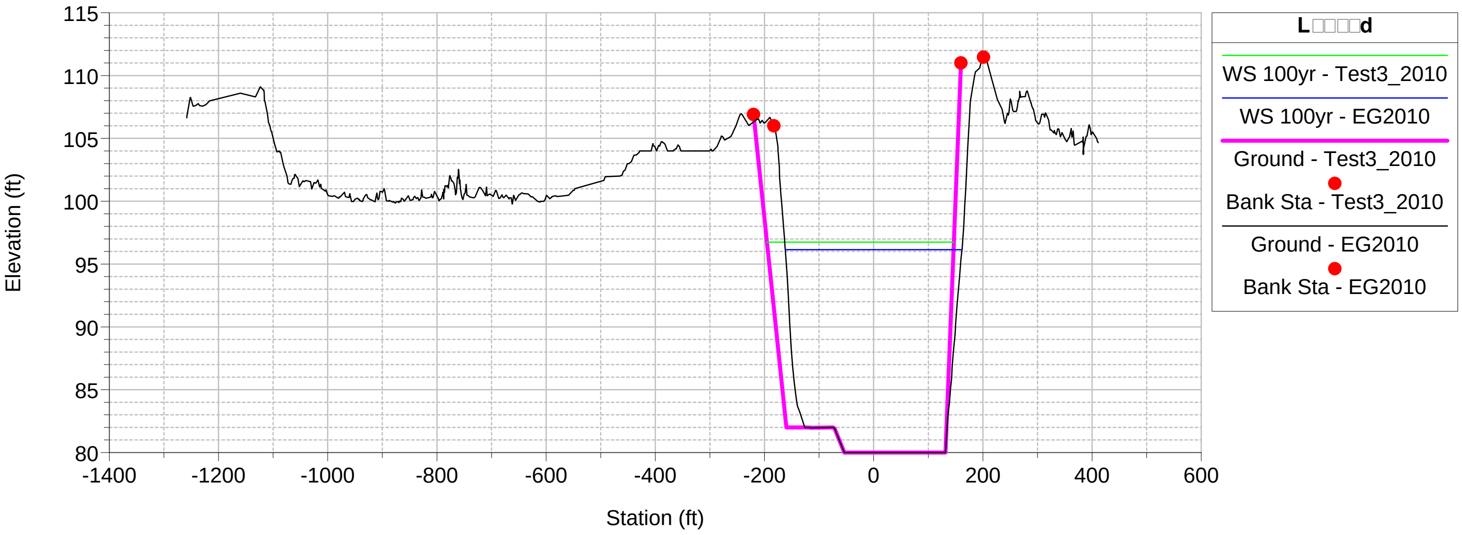
Teichert Woodland Plan: 1) EG2010 2) Test3_2010
RS = 112650 STA 1126+50



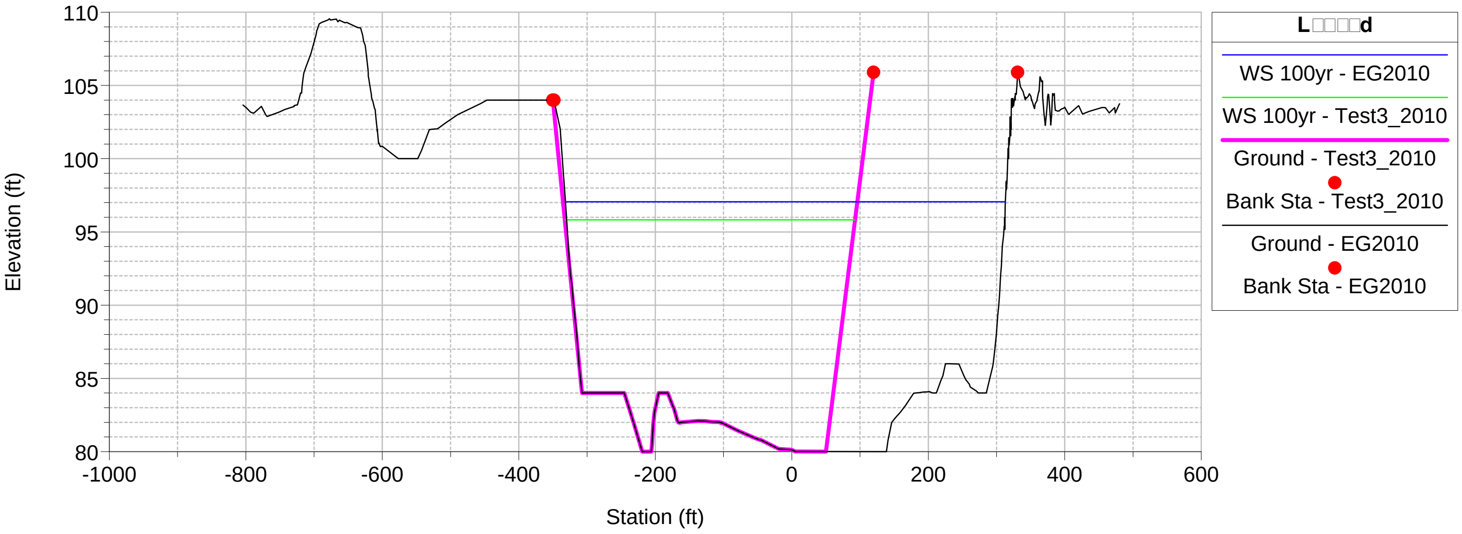
Teichert Woodland Plan: 1) EG2010 2) Test3_2010
RS = 112455 STA 1124+55



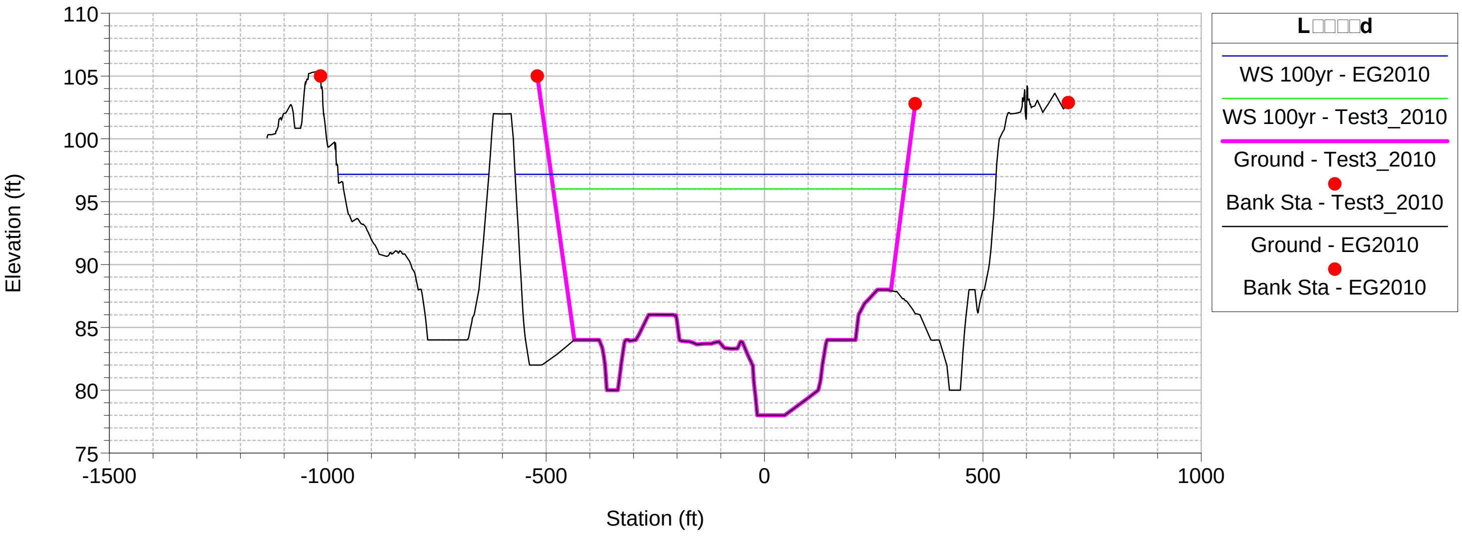
Teichert Woodland Plan: 1) EG2010 2) Test3_2010
RS = 112395 STA 1123+95



Teichert Woodland Plan: 1) EG2010 2) Test3_2010
RS = 112000 STA 1120+00

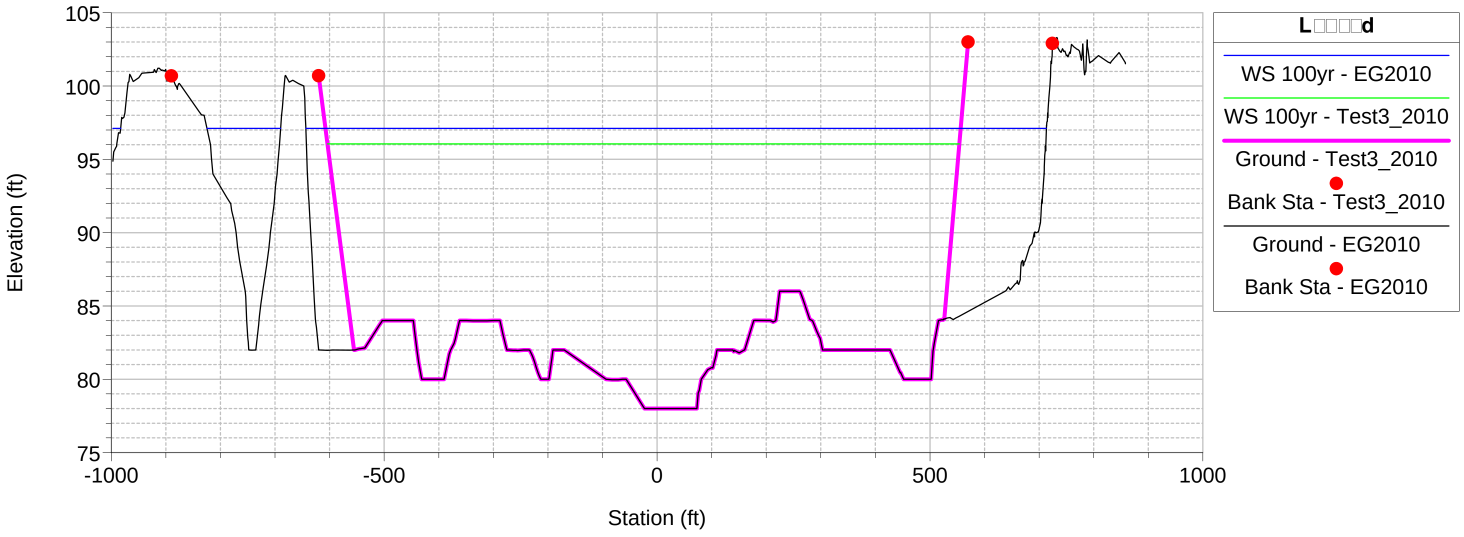


Teichert Woodland Plan: 1) EG2010 2) Test3_2010
RS = 111500 STA 1115+00



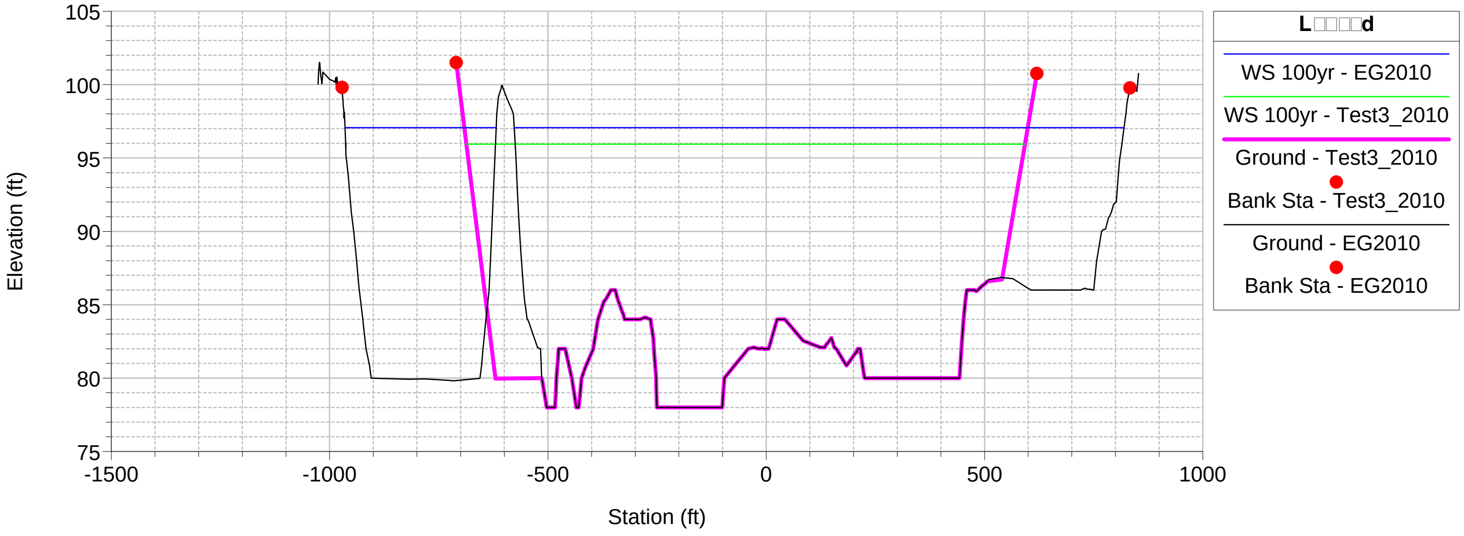
Teichert Woodland Plan: 1) EG2010 2) Test3_2010

RS = 111000 STA 1110+00



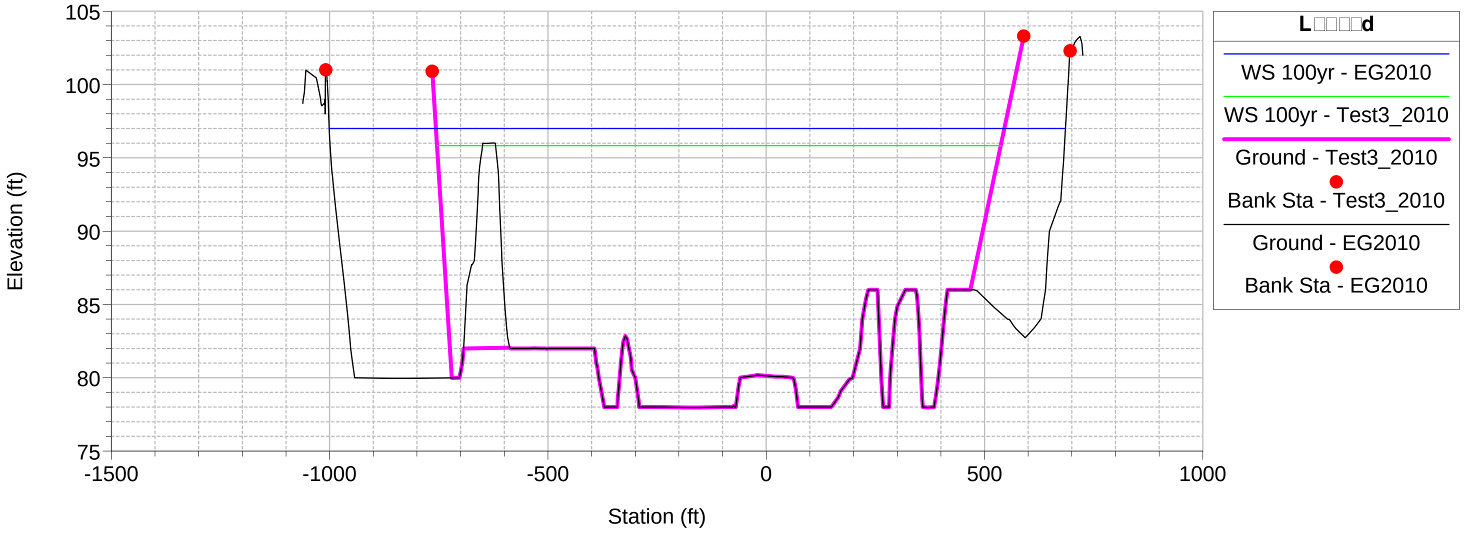
Teichert Woodland Plan: 1) EG2010 2) Test3_2010

RS = 110500 STA 1105+00



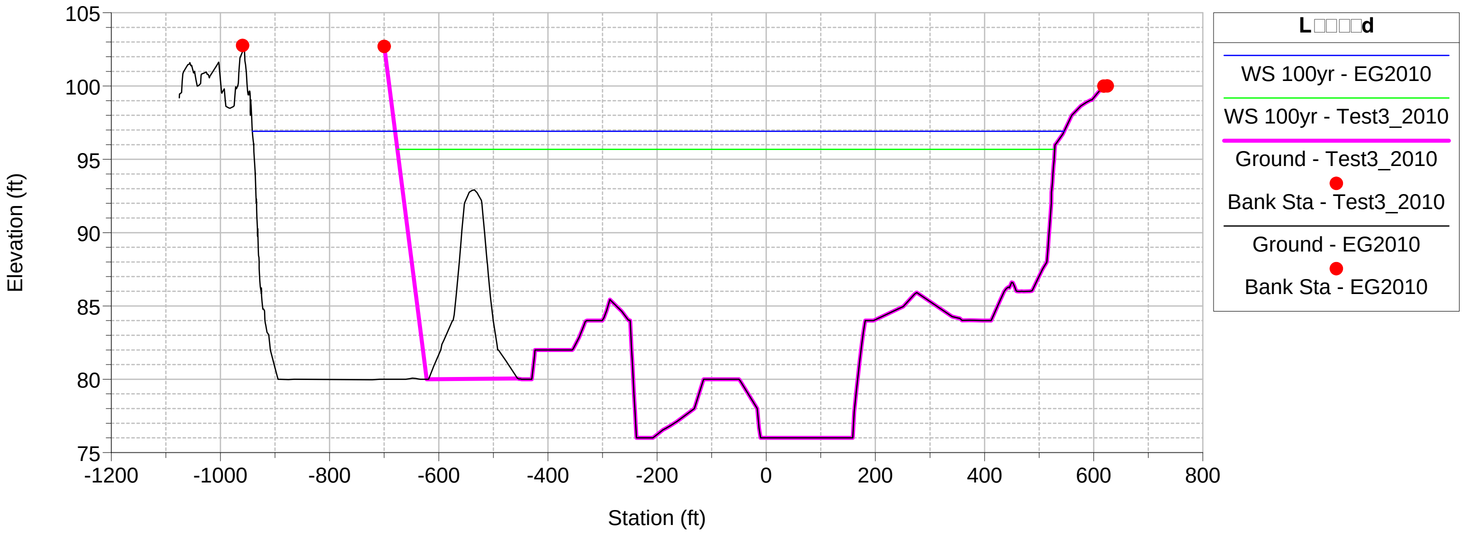
Teichert Woodland Plan: 1) EG2010 2) Test3_2010

RS = 110000 STA 1100+00



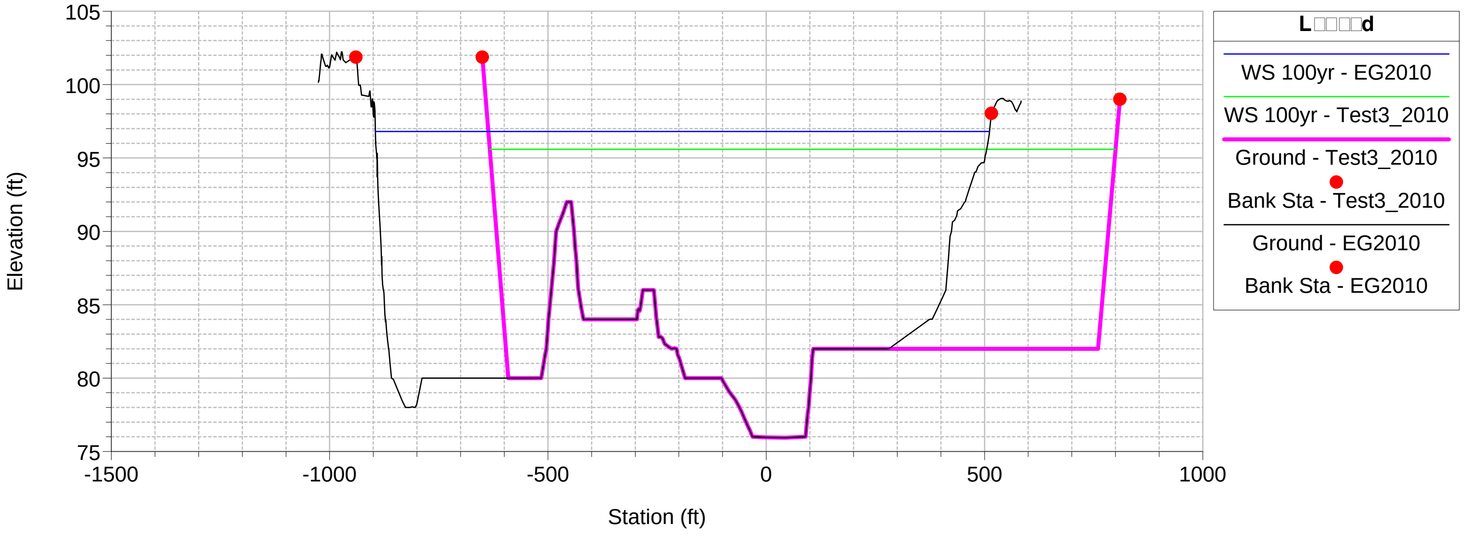
Teichert Woodland Plan: 1) EG2010 2) Test3_2010

RS = 109500 STA 1095+00



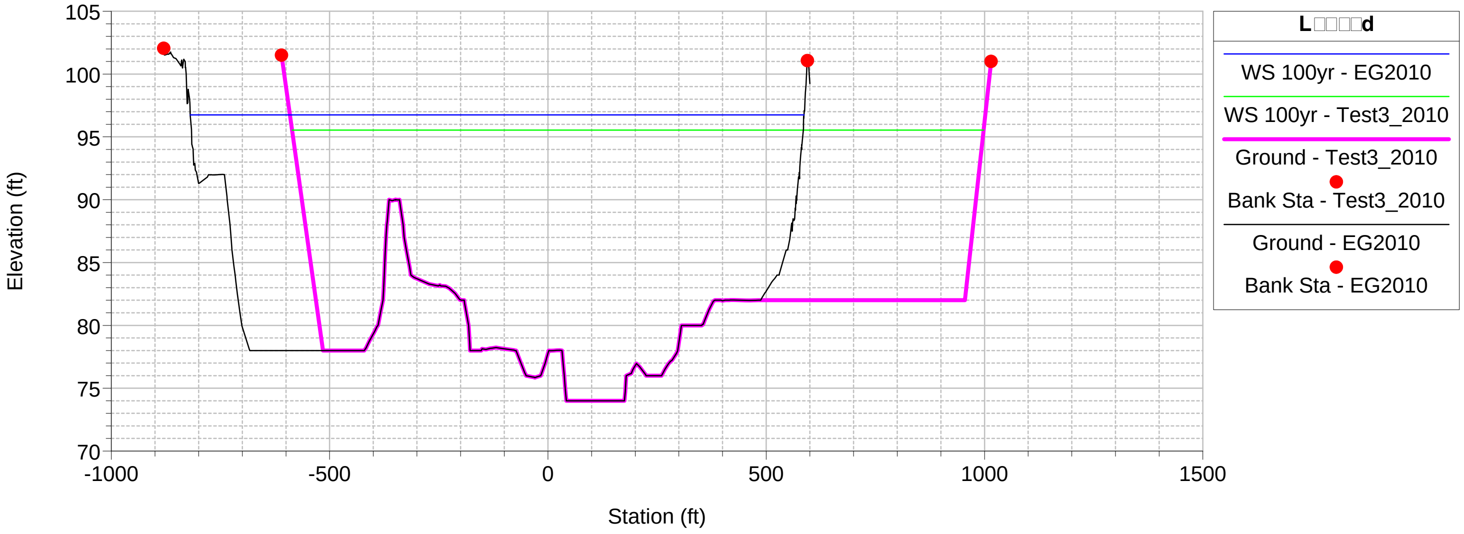
Teichert Woodland Plan: 1) EG2010 2) Test3_2010

RS = 109000 STA 1090+00

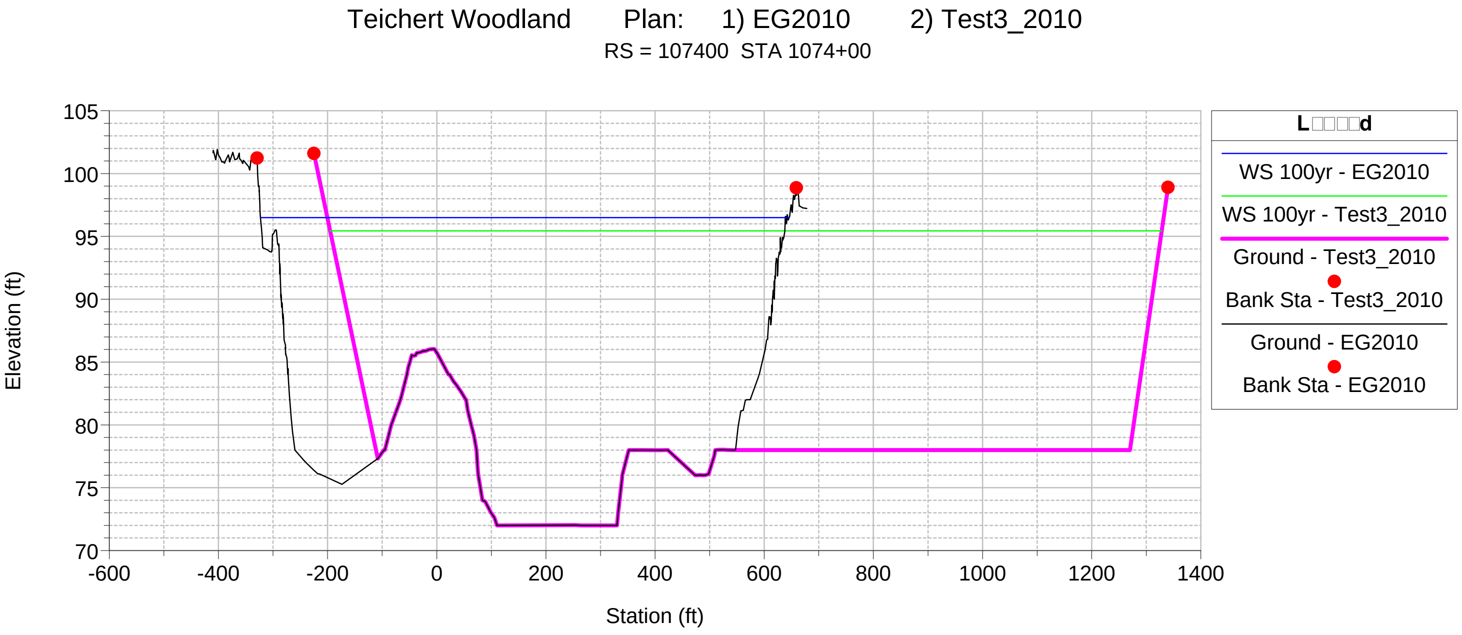


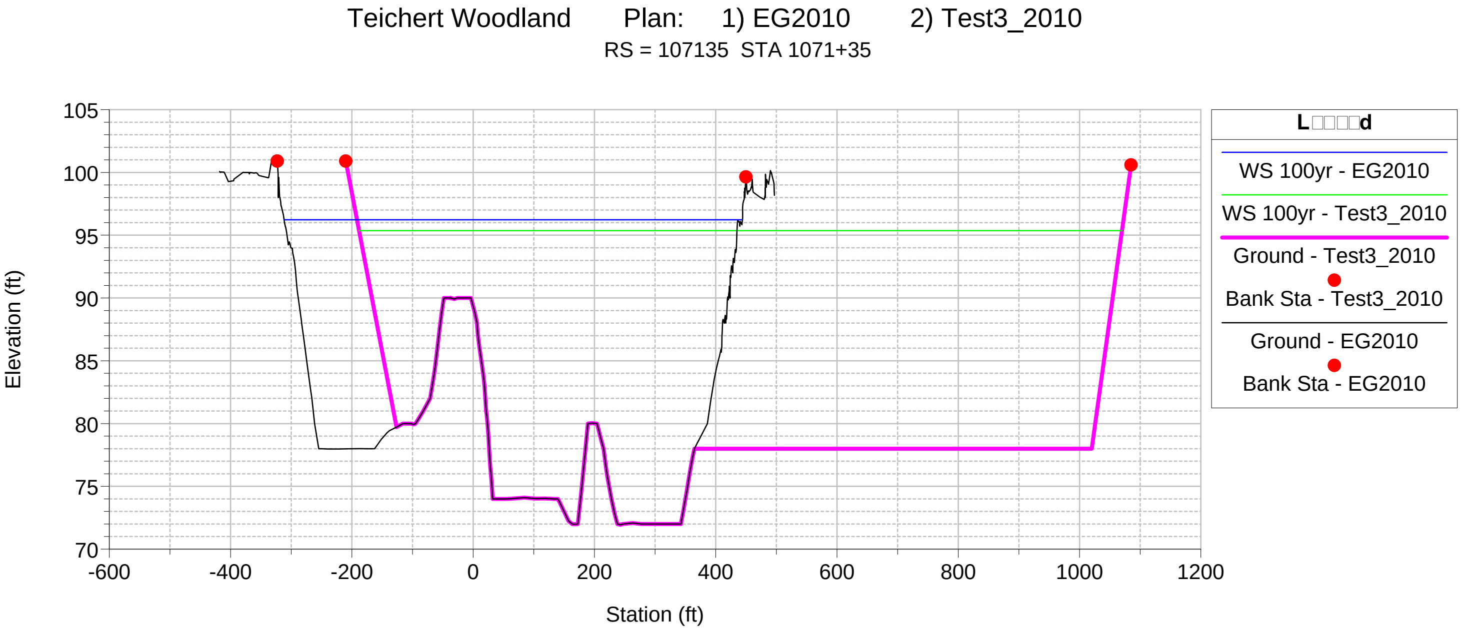
Teichert Woodland Plan: 1) EG2010 2) Test3_2010

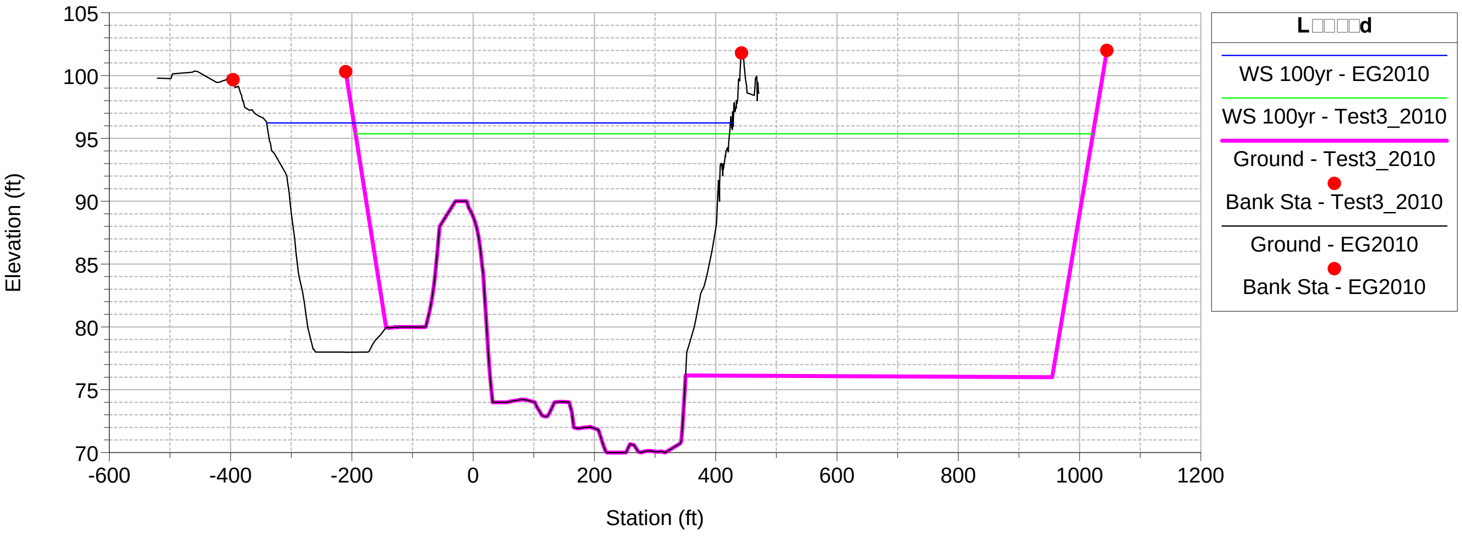
RS = 108500 STA 1085+00

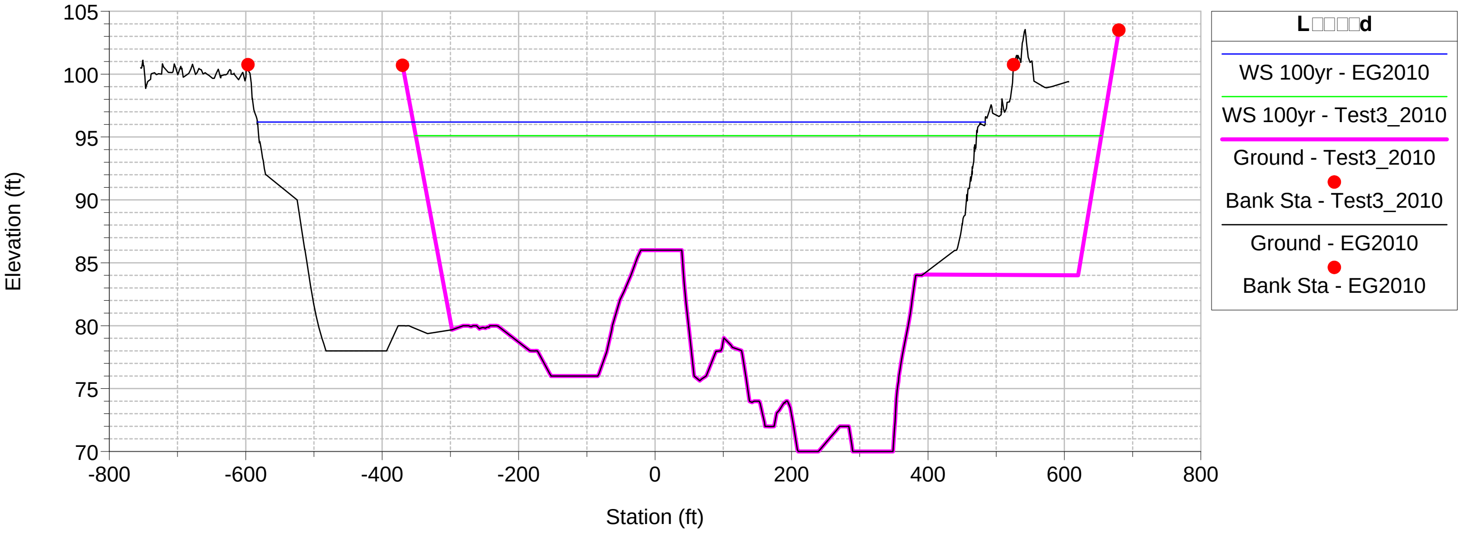


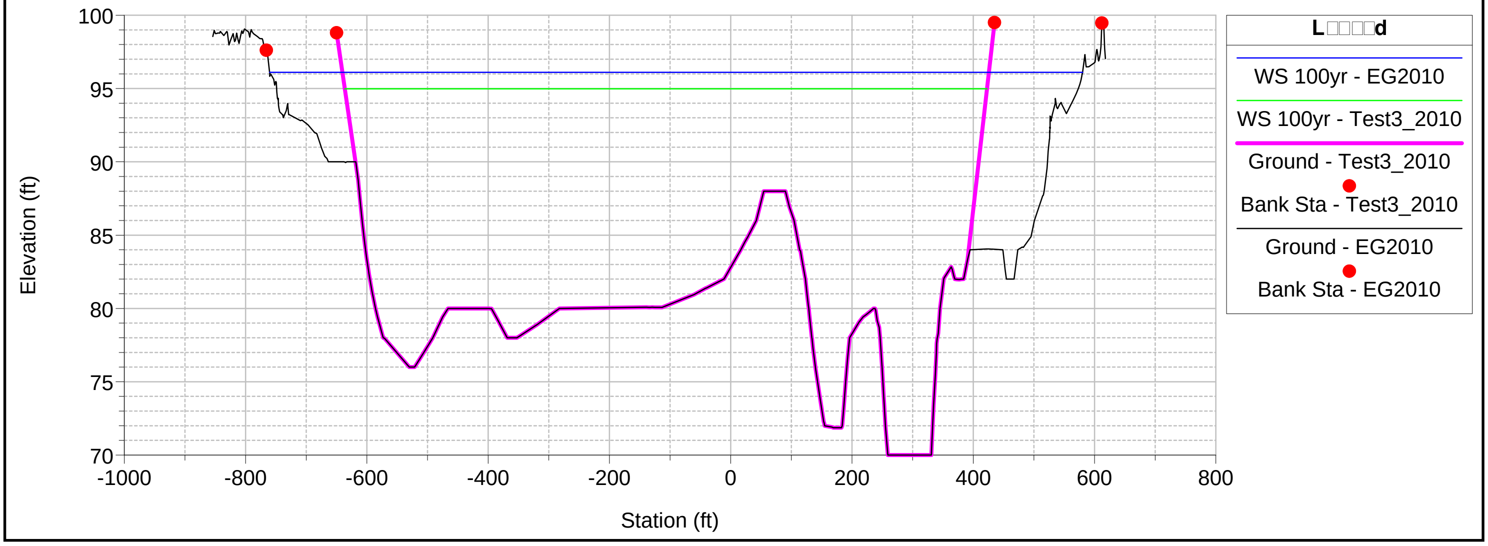

Teichert Woodland Plan: 1) EG2010 2) Test3_2010
RS = 108000 STA 1080+00


Teichert Woodland Plan: 1) EG2010 2) Test3_2010
RS = 107400 STA 1074+00

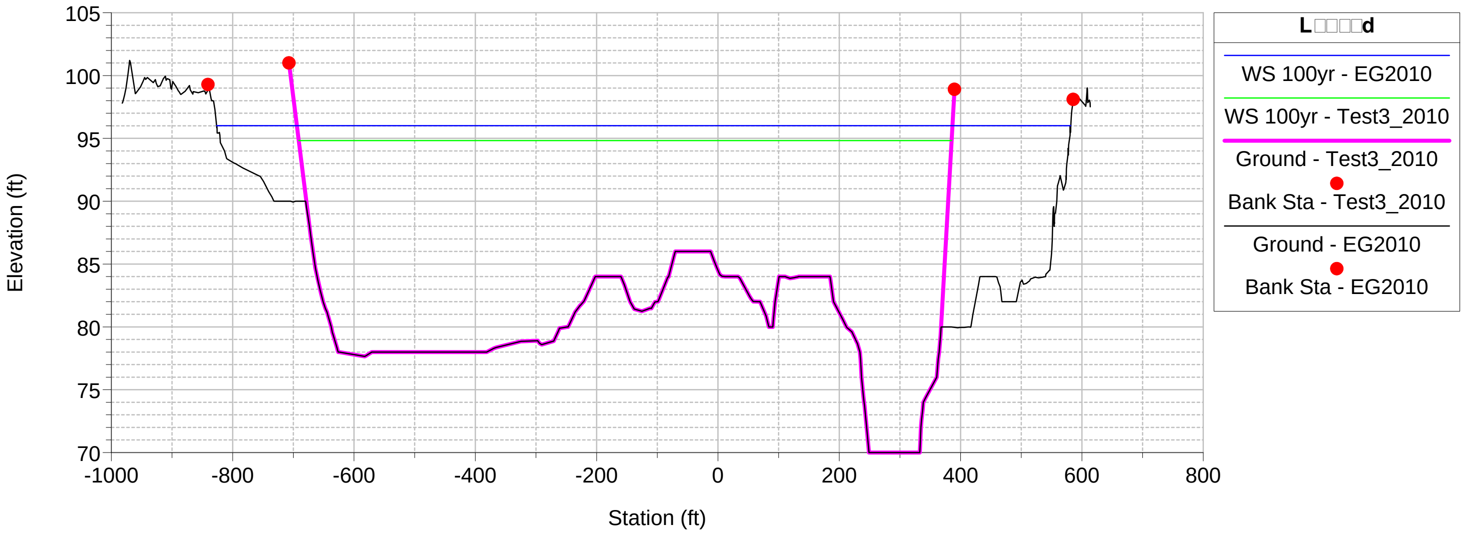

Teichert Woodland Plan: 1) EG2010 2) Test3_2010
RS = 107135 STA 1071+35


Teichert Woodland Plan: 1) EG2010 2) Test3_2010
RS = 107085 STA 1070+85

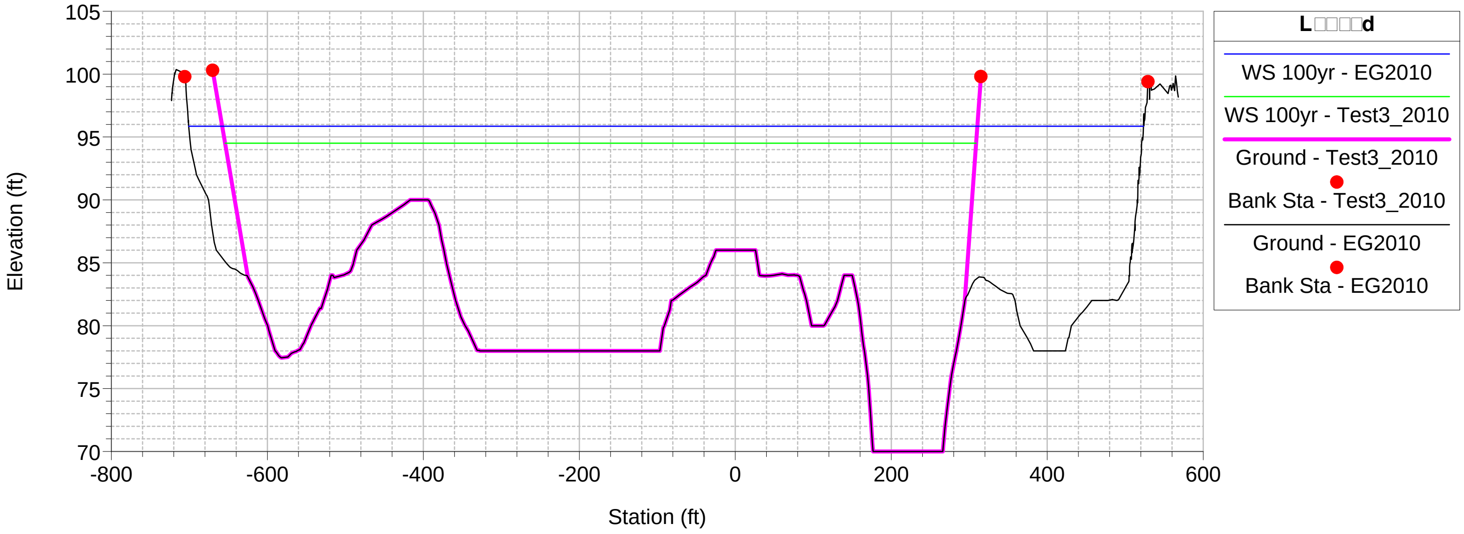

Teichert Woodland Plan: 1) EG2010 2) Test3_2010
RS = 106500 STA 1065+00


Teichert Woodland Plan: 1) EG2010 2) Test3_2010
RS = 106000 STA 1060+00

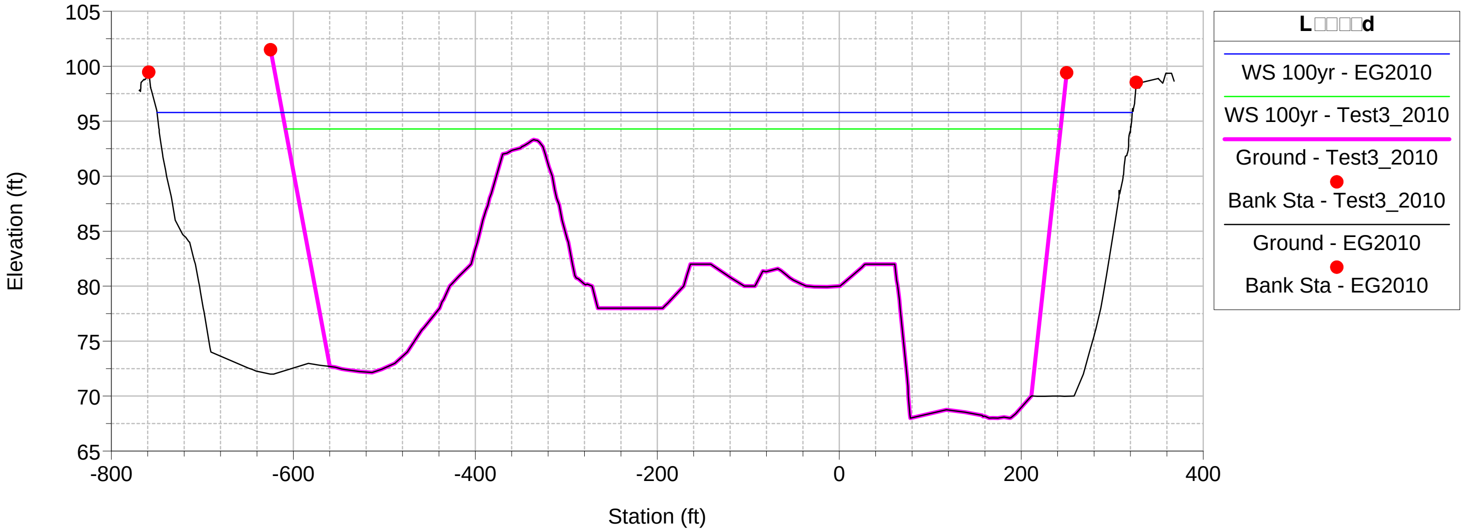
Teichert Woodland Plan: 1) EG2010 2) Test3_2010
RS = 105500 STA 1055+00

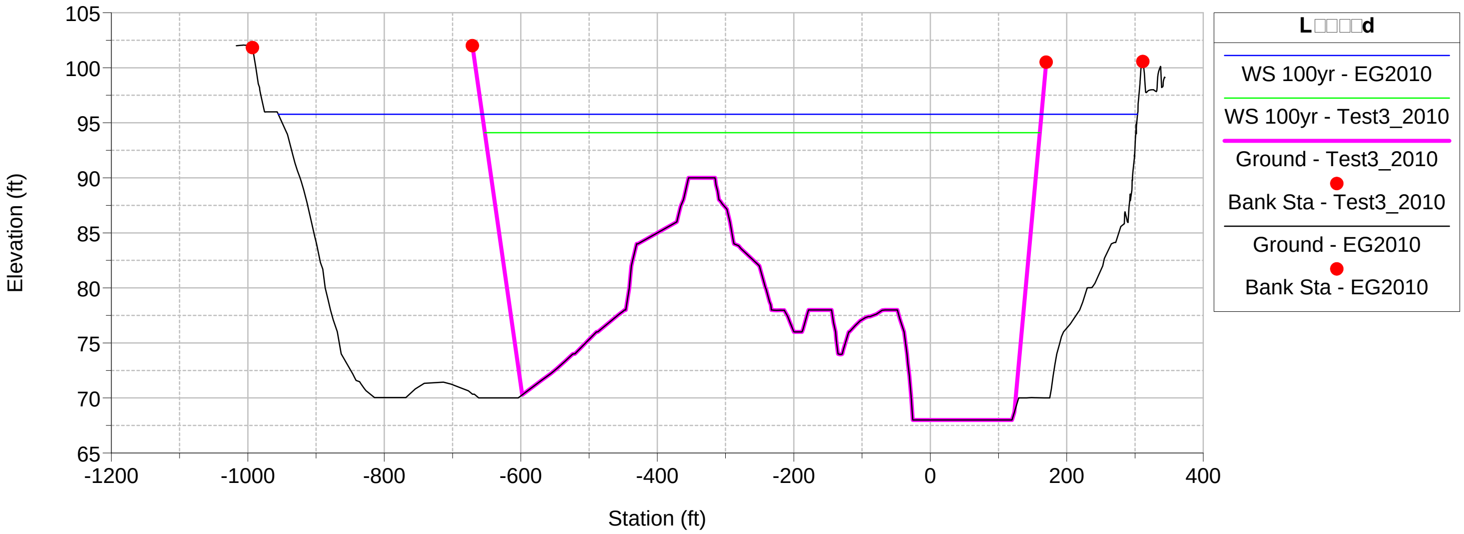


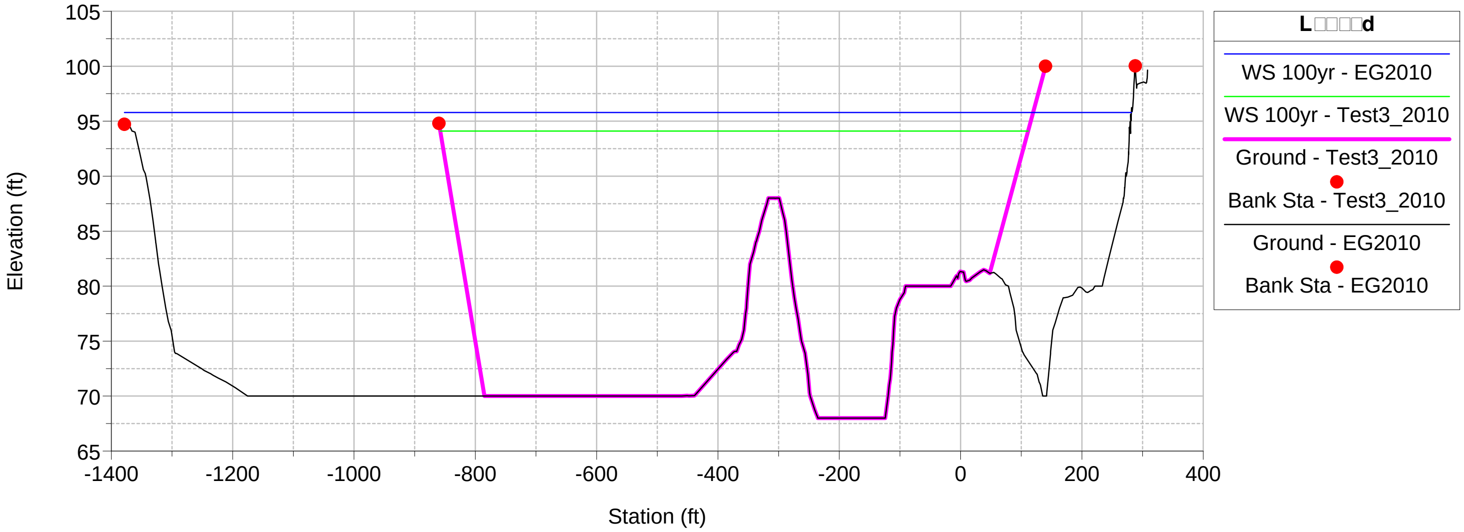
Teichert Woodland Plan: 1) EG2010 2) Test3_2010
RS = 105000 STA 1050+00

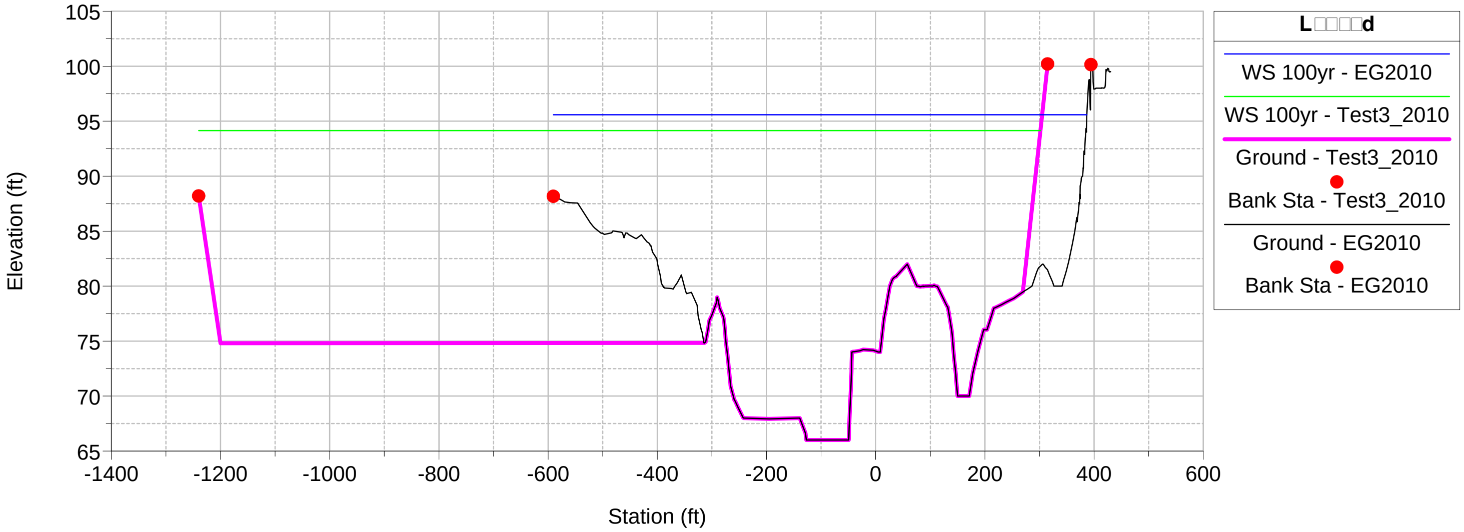


Teichert Woodland Plan: 1) EG2010 2) Test3_2010
RS = 104500 STA 1045+00



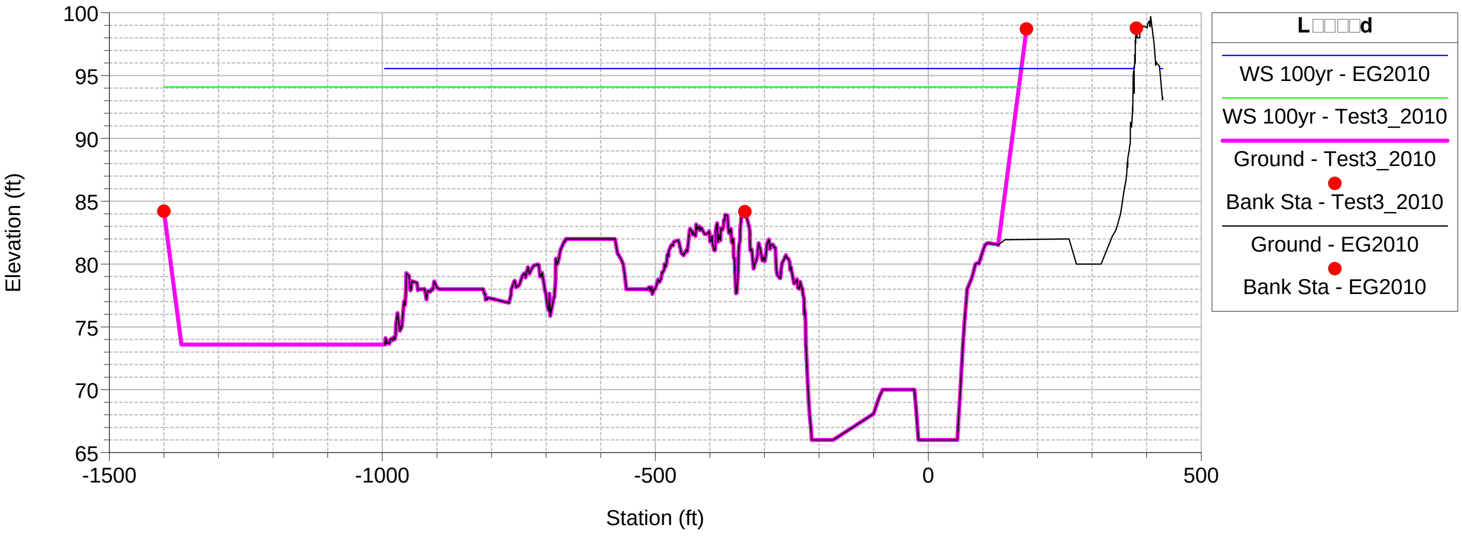

Teichert Woodland Plan: 1) EG2010 2) Test3_2010
RS = 104000 STA 1040+00


Teichert Woodland Plan: 1) EG2010 2) Test3_2010
RS = 103500 STA 1035+00


Teichert Woodland Plan: 1) EG2010 2) Test3_2010
RS = 103000 STA 1030+00

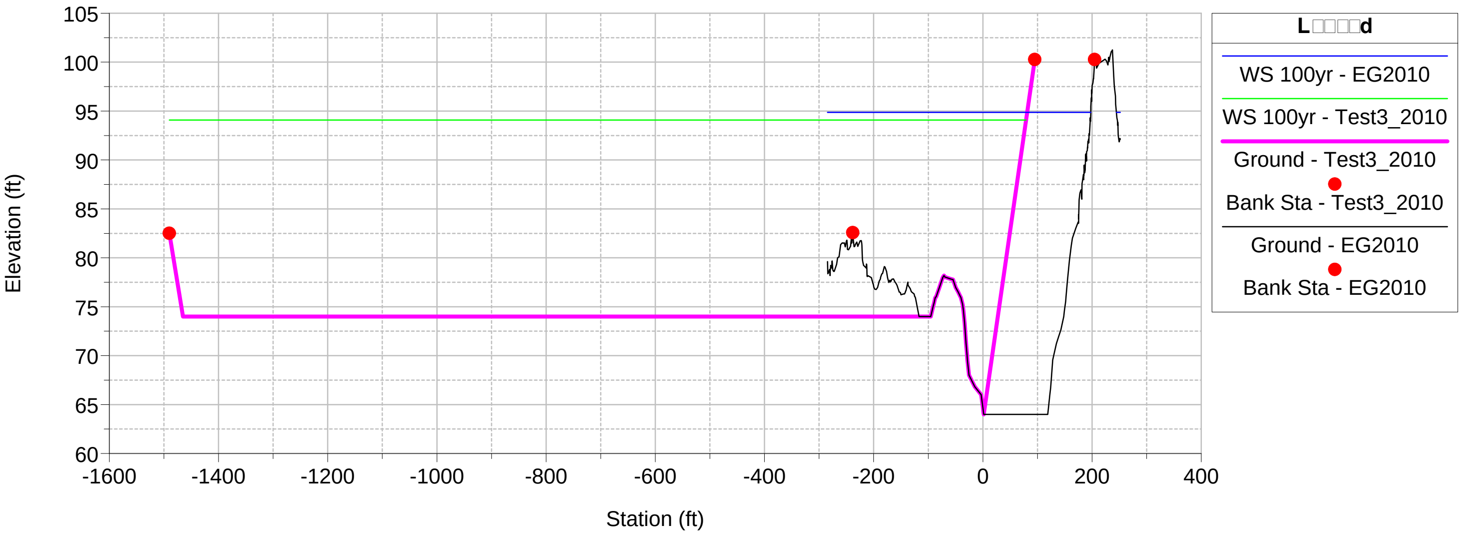
Teichert Woodland Plan: 1) EG2010 2) Test3_2010

RS = 102500 STA 1025+00



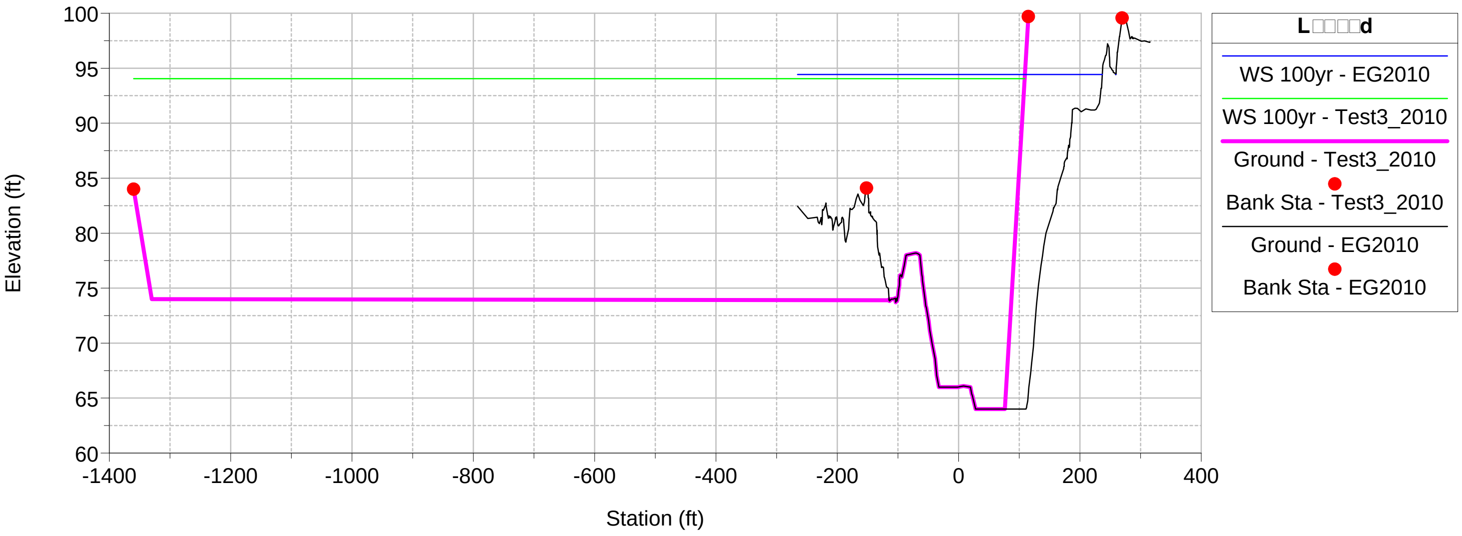
Teichert Woodland Plan: 1) EG2010 2) Test3_2010

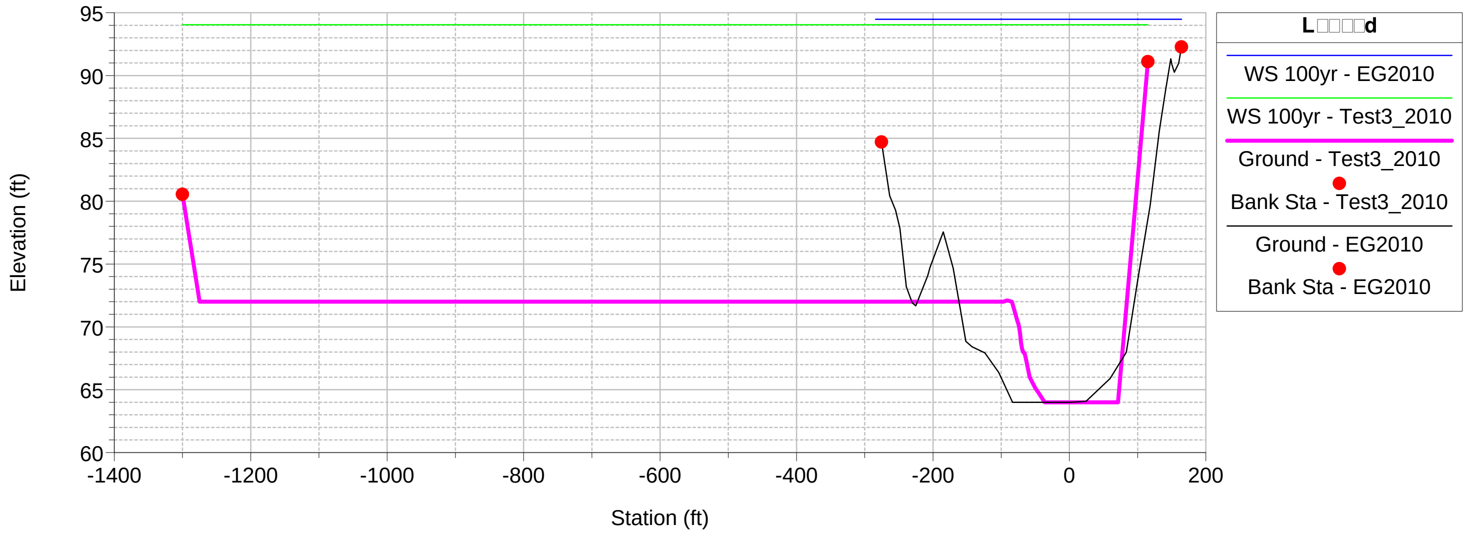
RS = 102000 STA 1020+00



Teichert Woodland Plan: 1) EG2010 2) Test3_2010

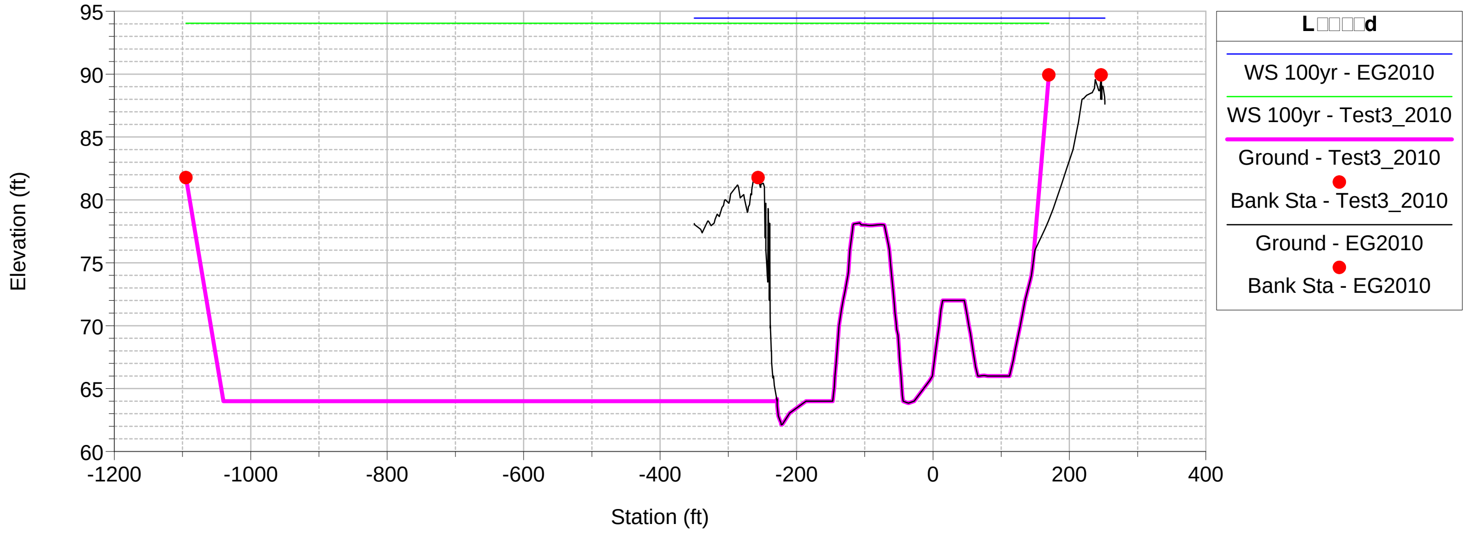
RS = 101650 STA 1016+50





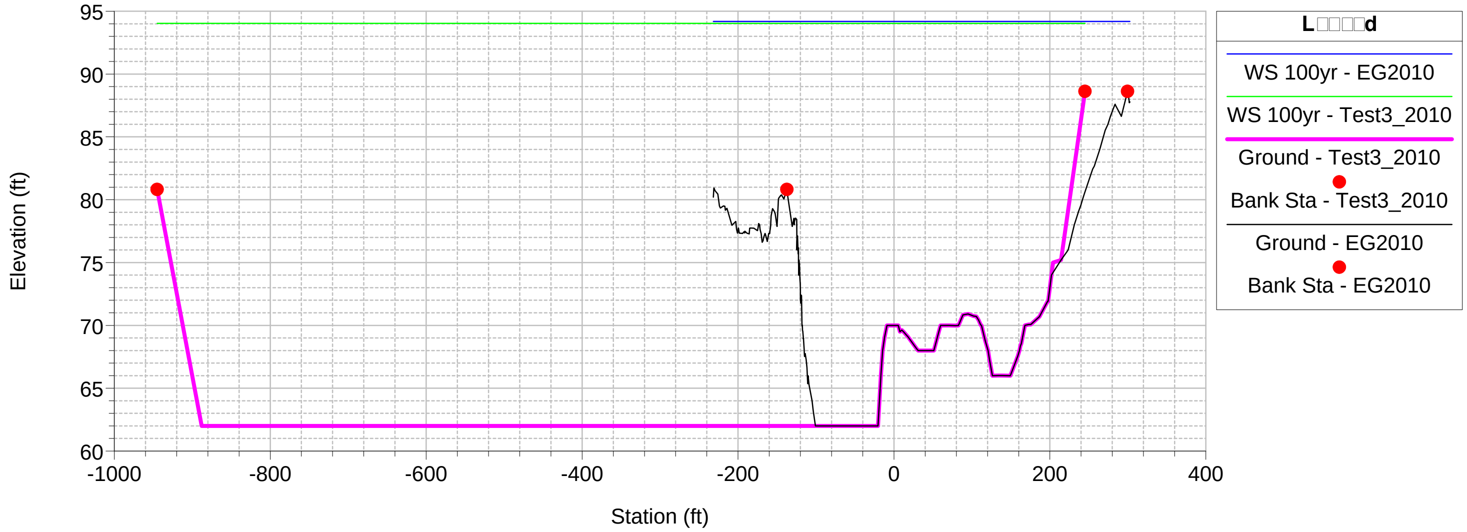
Teichert Woodland Plan: 1) EG2010 2) Test3_2010

RS = 101400 STA 1014+00



Teichert Woodland Plan: 1) EG2010 2) Test3_2010

RS = 101000 STA 1010+00



Teichert Woodland Plan: 1) EG2010 2) Test3_2010

RS = 100500 STA 1005+00


Teichert Woodland Plan: 1) EG2010 2) Test3_2010
RS = 100000 STA 1000+00
Elevation (ft)
95
90
85
80
75
70
65
60
-1000
-800
-600
-400
-200
0
200
400
600
Station (ft)
Legend
WS 100yr - Test3_2010
WS 100yr - EG2010
Ground - Test3_2010
Bank Sta - Test3_2010
Ground - EG2010
Bank Sta - EG2010


Teichert Woodland Plan: 1) EG2010 1/20/2011 2) Test3_2010 1/20/2011
Cache Creek Teichert
Elevation (ft)
120
110
100
90
80
70
60
Main Channel Distance (ft)
0
2000
4000
6000
8000
10000
12000
14000
16000
10050...
10100...
101400
101650
102000
102500
103000
103500
104000
104500
105000
105500
106000
106500
107085
107400
108000
108500
109000
109500
110000
110500
111000
111500
112000
112395
112650
113000
113500
114000
114429.5
L□□□□d
WS 100yr - EG2010
WS 100yr - Test3_2010
Ground
LOB
ROB
Ground

LEGEND:

(-1.4') STA: 1200+00 | 95.6(94.2)

CREEK STATION

100 YEAR FLOOD ELEVATIONS IN FEET
95.6: 2010 EXISTING GEOMETRY
(94.2): TEST 3 GEOMETRY

100-YR FLOOD ELEVATION
DIFFERENCE IN FEET
(-1.4'): TEST 3 - 2010 EXISTING

—— — —— CREEK MODEL CENTERLINE

——-·-—— PROPERTY LINE

— — — — TEST 3 LINE

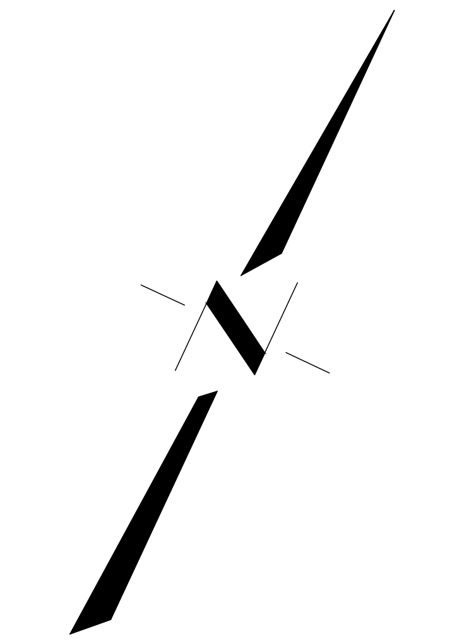
- - - - - - 100-YR FLOOD EXTENTS
(2010 EXISTING GEOMETRY)

BENCHMARK:

EXISTING TOPOGRAPHY BASED ON AERIAL TOPOGRAPHY FLOWN APRIL 2010 PROVIDED BY TOWILL, INC VIA YOLO COUNTY HORIZONTAL AND VERTICAL CONTROL FOR THE AERIAL TOPOGRAPHY IS BASED ON A CONTROL NETWORK TIED BY TOWILL, INCORPORATED TO A NETWORK OF PUBLISHED BENCHMARKS. THE VERTICAL DATUM IS NAVD88.

NOTES:

1. 100-YEAR WATER SURFACE ELEVATIONS CALCULATED USING 100-YEAR FLOW (Q_{100})=61,500 CUBIC FEET PER SECOND BASED ON U.S. ARMY CORPS OF ENGINEERS "LOWER CACHE CREEK, YOLO COUNTY, CA-CITY OF WOODLAND AND VICINITY FLOOD REDUCTION STUDY," MARCH 12, 2001.
2. 100-YEAR FLOOD ELEVATIONS ANALYSIS BASED ON APRIL 2010 AERIAL TOPOGRAPHY AND AUGUST 2010 HEC-RAS HYDRAULIC MODEL.



0 250 500 1000 1500
SCALE IN FEET

DESIGNED BY	NC
DRAWN BY	NC
CHECKED BY	ML
SCALE	1" = 500'

NO.	DATE	REVISIONS	BY	APPD.

CECWEST.COM
Project Planning ■ Civil Engineering ■ Landscape Architecture

■ Sacramento Office
2120 20th Street, Suite Three
Sacramento, CA 95818
(916) 455-2026

■ Corporate Office
2940 Spafford Street, Suite 200
Davis, CA 95618
(530) 758-2026

TEICHERT AGGREGATES
CACHE CREEK HYDRAULICS STUDY
APPROXIMATE 100-YEAR FLOOD ELEVATIONS

SHEET
1
OF
1

DATE: 6/4/14

JOB NO: 1129.01

S:\Projects\1100\1129 Teichert Woodland\AutoCAD\1129-01 Hydraulic Analysis\1129-01 Exhibits\1129-01 Hydraulic Analysis Exhibit.dwg - Layout1 10/12/2015 - 9:24AM Plotted by: Liz

TECHNICAL MEMORANDUM

To: Jason Smith – Teichert Aggregates

From: Steve Greenfield, PE

Date: December 23, 2019
Updated October 30, 2020

Subject: Shifler Off-Channel Mining and Reclamation Application
Cache Creek Channel Stability Analysis

Introduction

Based upon the request of Yolo County, Natural Resources Department, more specifically the request from the Cache Creek Technical Advisory Committee (TAC), Cunningham Engineering Corporation (CEC) has prepared this Technical Memorandum focused on the stability of the embankment of Cache Creek adjacent to the subject mining and reclamation application. The current Yolo County Off-Channel Mining Ordinance (OSCMO) requires a 700-foot setback to the creek bank. The setback may be reduced to 200 feet if the applicant can demonstrate that:

- The lesser setback will not adversely affect channel stability;
- The existing bank configuration or proposed bank stabilization measures will provide protection from lateral erosion and pit capture equivalent to a 700-foot setback, and;
- Channel maintenance and reshaping activities along the proposed mining reach are consistent with the Channel Form Template (CFT)[1]

The project that is proposed within the reduced setback is the Shifler aggregate mine. The mine is planned to be located immediately east of CR 94B and south of Cache Creek. The proposed mine will encompass approximately 277 acres. The existing property is relatively flat with a frontage along Cache Creek of approximately 3,070 linear feet. The Moore Canal, an irrigation canal owned and operated by the Yolo County Flood and Water Control District traverses the central portion of the proposed mining area in a general west to east direction. As Cache Creek flows eastward the southern creek embankment traverses away from the property toward the northeast.

---

[1] Prior to 2018 the CFT was referred to as the Test 3 Line. The CFT replaced the Test 3 Line with the update of the Cache Creek Improvement Program and related documents. Although not coincident the intent of the Test 3 Line and the CFT are similar, both providing similar guidance for smoothing abrupt channel width transitions. References to the Test 3 Line in this technical memo are either for comparison purposes or references from documents predating the 2018 update

The Shifler Mining and Reclamation Plans submitted to Yolo County, propose to relocate the Moore Canal to approximately 250 feet from the top of the channel bank with the edge of the active mining pit approximately 350 feet from the bank. CEC prepared the *Teichert Aggregates Off-Channel Mining and Reclamation Application, Cache Creek Hydraulic Study* dated January 26, 2016 to demonstrate that the 100- and 500-year storm event flows for Cache Creek will stay within the south bank of the creek along the Shifler reach between County Road 96 and Country Road 94B. Additionally, when modeled in 2016, assuming Test 3 implementation throughout the study area, the 100-year water surface elevation was slightly lower by approximately 1 foot on average.

In addition to demonstrating that Cache Creek flows do not exceed the south top of bank in the 100-year event condition, the TAC requested additional information regarding the erodibility potential of the south embankment and a risk assessment for southward creek migration and potential pit capture.

To address the potential erodibility CEC completed the following tasks:

- Reviewed historical topographic maps and aerial photographs.
- Reviewed *Stream Migration and Sediment Movement on Lower Cache Creek from Capay Dam to Interstate 5 at Yolo, CA*, Masters of Science thesis prepared by Tami Leathers, Summer 2010.
- Reviewed flow velocity data based on the 2D HEC-RAS model of Cache Creek prepared by FlowWest from 2018.
- Updated flow velocity data in HEC-RAS based on updated 2019 digital terrain model provided by FlowWest.
- Conducted a site visit on November 1, 2019 with the Applicant's geotechnical engineer and fluvial geomorphologist to observe the condition of the south bank.
- Reviewed the current stream bank alignment in conjunction with the CFT.
- Reviewed a meander width analysis prepared by Teichert along the reach of Cache Creek for years 1937, 1957, and 2018.

Historical Data on Cache Creek

USGS historical topographic maps dating back to 1907 were reviewed for this area of Cache Creek. The maps indicate that the bank to bank geometry hasn't changed significantly in the last century. The maps indicate gravel pits within the reach of Cache Creek near the Shifler property from sometime in the 1950's to mid-1990's. Interior to the banks the geometry of the main channel does tend to meander and shift after high flow seasons. Channel migration and sediment transport is apparent based on a review of aerial imagery available on Google Maps dating back to 1993. High flow events during the 2016 storm season removed in-channel sediment and vegetation immediately downstream of the CR94B bridge. From a review of topographic data from 2010, 2015, and 2019 provided by Yolo County, CEC has determined that approximately 4-5 vertical feet of sediment removal occurred in the central portion of the active channel during the 2016 winter flows in this vegetated area. However, based on aerial photo review, negligible evidence of erosion of the south bank was noted resulting from the 2016 event, even though high volumes of water were documented to have flowed across said bank. Furthermore, the alignment of the southern bank has not changed significantly between the 2010 and 2019 topography suggesting little erosion has occurred there. See Attachment A for historical maps and aerial imagery referenced.

Summary of Leathers 2010 Master of Science Thesis Report

The 2010 Master's thesis, *Stream Migration and Sediment Movement on Lower Cache Creek from Capay Dam to Interstate 5 at Yolo, CA,* by Tami Leathers is a desktop analysis that assessed historical datasets to determine trends in aggradation and degradation of sediment on Lower Cache Creek, and lateral and vertical channel movements related to high flow events and projects performed on the creek. Our review focused on the conditions before and after a bridge failure in 1978 at County Road 89 and subsequent bank erosion in proximity of the former road crossing. The intent of reviewing the CR 89 area erosion was to compare it with conditions at County Road 94B to evaluate the relative risk of similar bank erosion occurring beyond the proposed 200-ft setback area of the planned Shifler mine. Summarized below are some general conclusions in the report followed by our comparison of the reaches in the vicinity of CR 89/94B.

General Conclusions

The following are conclusions of the Leathers 2010 Thesis Report:

- Areas that had higher flows and steeper creek banks historically have experienced more significant erosion.
- Flood duration seems to have a stronger relationship to erosion than shorter, larger events.
- Adjacent riparian vegetated slopes and upland areas fare better than areas cleared for agricultural use.

CR 89 Reach Summary

Aerial photos from 1937, 1953, 1971, 1985, 1998, and 2006 were included in the study. The CR 89 bridge failed in 1978. Both the 1937 and 1953 photos depict a dense riparian area along the north embankment. Sediment deposition indicates substantial aggradation along the north bank between 1937 and 1953, shifting the channel approximately 70 feet to the south. The riparian vegetation in the area was cleared for agricultural use sometime between 1953 and 1971.

The CR 89 bridge failed in 1978. The Leathers 2010 Thesis states:

- "Although this bridge failure was not directly related to stream migration, *it is speculated* that stream migration was *an indirect cause* to its failure" and,
- "Stream migration was not the direct cause of the bridge failure…" (Note the rest of the sentence had to do with the cost of repairs and was not related to the cause of failure).

To date the bridge has not been reconstructed. Since its failure streambank migration to the north has been significant, migrating at least 480 feet since 1985.

Site Visit Observations

A site visit was completed on November 1, 2019 to assess conditions of the southern bank of Cache Creek. The visual inspection revealed little to no evidence of erosion along the southern bank in the area of the proposed project. The bank is 90-95% vegetated with mature trees, willows, shrubs, and grasses present. These features increase the roughness coefficient of the stream in the flood stage and assists with additional bank reinforcement and stabilization. Throughout the entire reach along the Shifler property the southern bank has a mid-slope terrace. The portion above the terrace is armored with what appears to an asphalt-like material that is likely part of fill material placed sometime in the past. This resistant bank material provides additional protection against erosion. Recent fine sediment deposition noted upon the mid-slope terrace bench is evidence that flow velocities decrease once it reaches the bench. This further reduces the erosion potential on the southern bank. See Attachment B for photographs from the site visit illustrating the highly vegetated, terraced, and partially armored southern bank along the Shifler property.

According to the Geology Memo[2] completed by Geocon dated November 27, 2019, the floodplain near-surface soil consists of "predominately fine sand and silt, which is indicative of lower-energy alluvial deposition." The upper bank is predominately a clay-rich "overburden material" with some slope armoring material. The active stream channel is underlain with a coarse granular material of sand and gravel which is associated with active stream channels.

---

[2] TECHNICAL MEMORANDUM – LOCAL GEOLOGY, SHIFLER MINING AND RECLAMATION PROJECT, YOLO COUNTY, CALIFORNIA

2D HEC-RAS Model Results and Analysis

The roughness coefficients within the 2018 HEC-RAS 2D model created by FlowWest along the bank are indicative of the dense vegetation that occurs there. A portion of the southern bank land cover is listed as riparian forest with a Manning's n value of 0.08 and the remainder of the bank is classified as herbaceous vegetation with a Manning's n value of 0.04.

The 2018 model was run with data from both the 2017 and 2019 Digital Terrain Models. The 100-year storm flows for both years indicates the highest velocities and shear stresses occur closest to the CR 94B bridge upstream of the Shifler property. There is a section about 900 feet immediately downstream (east) of the CR 94B bridge where the model indicates the maximum velocities and shear stresses occur along the proposed project where the reduced setback is requested. The maximum shear stress along this reach was reduced from 2017 to 2019 from 0.7 lbs/ft^2 (33.5 N/m^2) to 0.5 lbs/ft^2 (23.9 N/m^2). The velocities in this area generally range from 2 to 3 ft/s for both years. Maximum velocity increased from 2017 to 2019 from 4.3 ft/s to 4.6 ft/s. See Attachment C for a map of these results. The maximum shear stress and velocity values from the 100-year storm models were used as the most conservative approach to determine the risk for erosion. The threshold of whether sediment deposition or erosion will occur is typically a factor of the flow characteristics of the stream, the sediment regimes (i.e. the size and distribution of sediment), and the resistance of channel bank materials to erosion. There are several equations and schools of thought for determining whether a channel boundary is stable, but generally these equations use shear stress, velocity, and bed/bank material in the channel to assess erosion potential. It should be noted that these variables do not predict absolutely whether erosion will occur.

The critical shear stress determines at what shear stress particle motion is initiated and is based on the dimensionless Shields parameter and the bed grain size and density. There are many tables and graphs available that show the critical shear stress based on grain size. One table of critical shear stress from the U.S. Geological Survey Scientific Investigations Report is shown in Attachment D. This table indicates the critical shear stress based on particle classification. The maximum shear stress from the HEC-RAS model using the 2019 Terrain (23.9 N/m^2) is within the critical shear stress range of coarse gravel. However, according to the publication: "This analysis determines whether or not a given grain size is mobile, but does not calculate potential for erosion or deposition, which is determined by the divergence or convergence in the sediment transport rate". Furthermore, the analysis does not account for consolidation of the particles in the stream bed. Therefore, this method is not an adequate representation of potential for erosion in the channel or the bank.

The Hjulström-Sundborg Diagram is another approach to determine sediment movement and uses the flow velocity and particle size to determine whether a particle is eroded, deposited, or in transit. This relationship (see Attachment D) indicates the velocity threshold for erosion of a 10mm gravel is about 100 cm/s (3.2 ft/s), which is greater than most of the maximum velocities found in the HEC-RAS model along the southern bank of the Shifler reach. However, the surface material discussed in the Geology Memo from Geocon describes more of a clay, sand and silt along the floodplain which could be eroded at these velocities. Of these three particle types, silt is the most erosive, followed by sand, then clay. Clay particles are very cohesive and resistant to erosion. That said, the presence of significant vegetation and asphalt armoring eliminates the ability to make a direct correlation for velocity and grain size in terms of erosion susceptibility. The *Lower American River - Erosion Susceptibility Analysis for Infrequent Flood Events* completed by Ayers Associates in 2004 cited the following references as velocity thresholds for the initiation of erosion with varying vegetation covers:

1. *Erosion of Bare, Fine Grained Sandy Soils: Velocity exceeding 2 fps (SCS, 1977) and (Corps, 1970)*
2. *Erosion with Annual Grass Cover: Velocity exceeding 3.5 fps (SCS, 1954)*
3. *Erosion with Grass-Lined Earth, Kentucky Blue Grass: Velocity exceeding 5 fps (Corps, 1970)*
4. *Erosion of Dense Vegetation: Velocity exceeding 5 fps (FHWA, 1988)*

The maximum velocity along the southern bank through the project frontage based on the HEC-RAS 2D model is 4.6 ft/s with the majority of the velocities in the 2 to 3 ft/s range. All the modeled velocities along the southern bank of the Shifler reach are below the threshold of 5 ft/s referenced above in the FHWA study for erosion of dense vegetation.

Meander Width Analysis

An assessment of the meander width on Cache Creek was performed by Teichert's fluvial geomorphologist (Attachment F). The assessment analyzed the meander width on Cache Creek using air photos from 1937, 1957, and 2018. Results of the meander width assessment indicate that Cache Creek had a relatively narrow meander width corridor of 1,539 feet in 1937, which was prior to widespread in-stream gravel mining. By 1957 in-stream gravel mining was in full swing and resulted in a much larger meander width of 2,169 feet. Following prohibition of in-stream gravel mining activities in 1996 the meander width on Cache Creek narrowed to 1,404 feet, which is similar to the 1,539-foot meander width in 1937.

The meander width assessment also noted the presence of the Gordon Slough (aka. West Adams Canal) distributary bar on the north bank of Cache Creek immediately west of the 94B bridge. The distributary bar redirects flow in Cache Creek to the central part of the channel and prevents the formation of a meander bend on the north side of Cache Creek. The presence of the distributary bar and the 94B bridge fix the location of Cache Creek and establish a west-to-east flow pattern along the Shifler property and therein concentrating flow in the central portion of the channel, away from the southern bank.

The analysis concludes that the creek has historically meandered during the study time period; however, its time period of greatest meander coincides with in-channel mining activities and disruption that has been prohibited since 1996. The current post in-channel mining creek stability along the Shifler Reach is similar to that in 1937, prior to the onset of in-channel mining

Comparison of Current Bank Alignment with the Channel Form Template

A map of the current location of the Cache Creek bank and the approximate location of the CFT along the Shifler reach is shown in Attachment E. The approximate location of the CFT very closely follows the current bank alignment. Therefore, mitigation measures to modify the bank to match the CFT along the project frontage are unnecessary. As described above, this bank is well-vegetated and partially armored with an asphalt-like material that would help protect against erosion and migration of the bank beyond the CFT.

Conclusion

The likelihood that future channel erosion will occur can be estimated based on the known history of creek bank migration and floodplain morphology, the presence of vegetation, the resistance of the bank material to shear stress and stream power, and the flow and sediment regimes.

From the historical topographic maps and aerial images, it can be determined that historic excessive bank erosion has not occurred within this reach of Cache Creek. Periods of low flow channel migration and in-channel sand and gravel bar transport and deposition are noted, but they did not result in bank erosion. Based on visual observations during our site visit, there is no evidence of any bank erosion even though the 2016/17 winter storms resulted in above average flows of 20,500 cfs (max daily mean flow) [3], which represents the third highest flow recorded in the last 20 years). Moreover, the well-vegetated bank, terraced slope configuration, and asphalt-like bank material within the upper terrace will all provide additional bank reinforcement and stabilization.

The maximum velocity and shear stress values shown in the HEC-RAS model along the bank do not exceed those estimated to cause erosion of a well-vegetated stream bank based on the FHWA reference. In addition, the bank alignment within the reduced setback area very closely follows the Channel Form Template (CFT) indicating the current bank location is situated at the proper location as modeled and approved by the Cache Creek TAC.

---

[3] From Cache Creek stream gauge in Town of Yolo.

Based on the research and analysis summarized above, it is our professional opinion that the risk of significant erosion of the southern stream bank in this reach is low. Therefore, no additional bank stabilization measures are required to ensure equivalent protection to a 700-foot setback from the channel bank. As required in the OCSMO, the channel must be annually monitored once mining begins and if minor lateral migration does begin to occur, additional plantings, armoring and/or a geotextile fabric may be incorporated along the southern stream bank within the reduced setback if necessary. If the lateral migration became significant, the embankment would require complete reconstruction that incorporates erosion protection along the embankment face.

Please contact us if you have any questions.

Sincerely,

Steve Greenfield, P.E., G.E,
Vice President
Cunningham Engineering Corporation

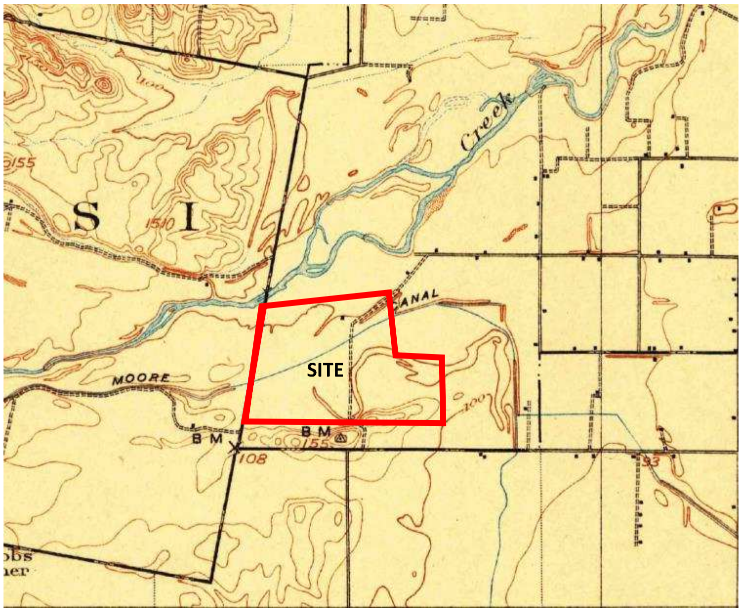
Attachments

A. Historical Topographic Maps and Aerial Imagery
B. Site Visit Photographs
C. HEC-RAS 2D model results
D. Literature References on Erosion
E. Map of Project Site with CFT
F. Meander Width Analysis, prepared by Teichert Aggregates, dated October 28, 2020

S:\Projects\1100\1129 Teichert Woodland\Memos, Meeting Minutes, Agendas\2019-11-05 Cache Bank Erosion Memo\2020-10-30 Updated Cache Creek Bank Erosion Memo.docx

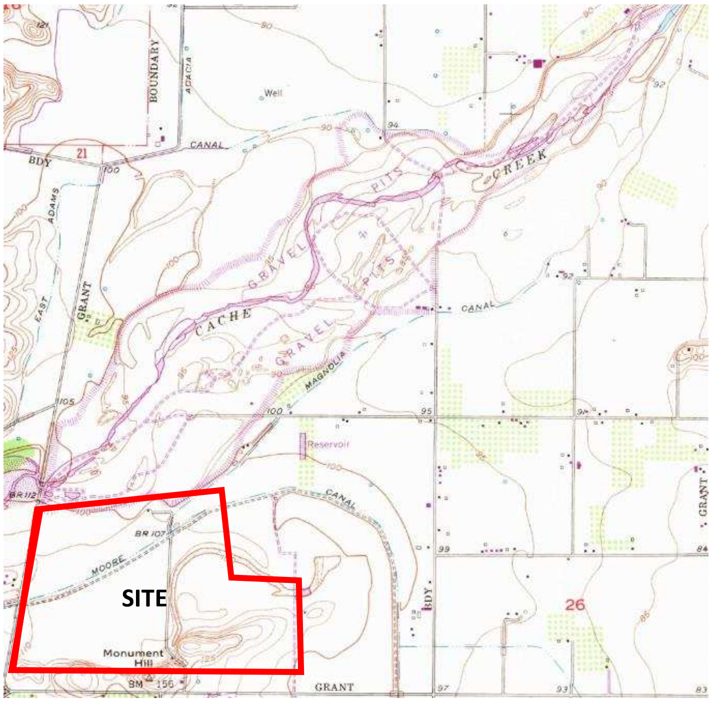
Attachment A – Historic Topographic Maps & Aerial Imagery

1907



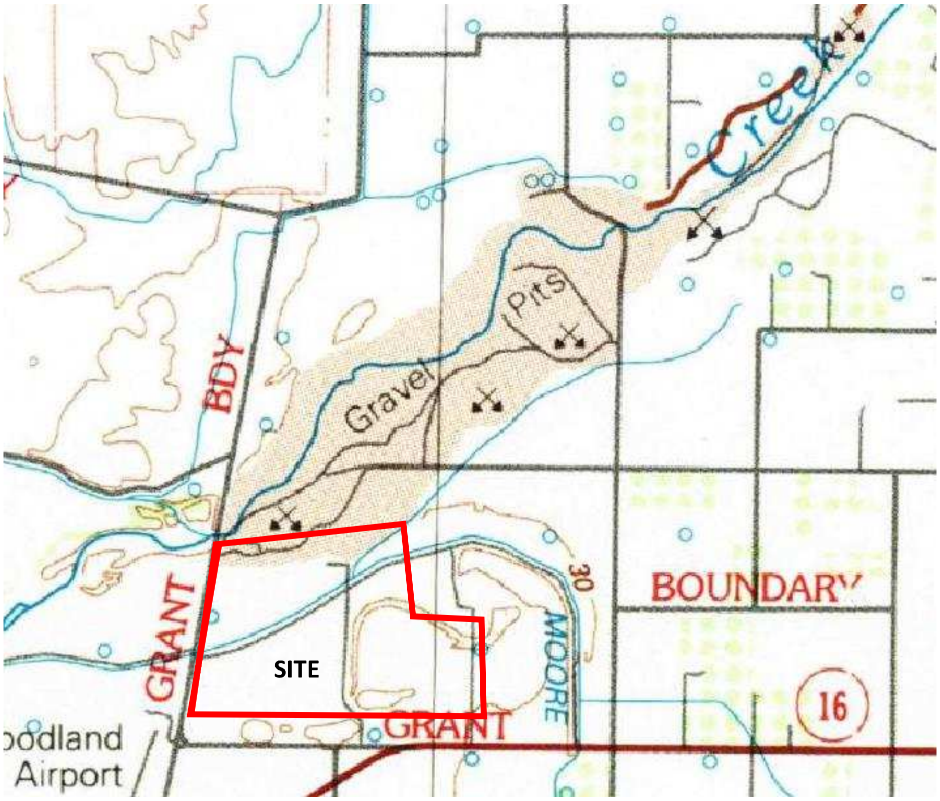
(source: USGS Woodland, California Quadrangle February 1907)

1968



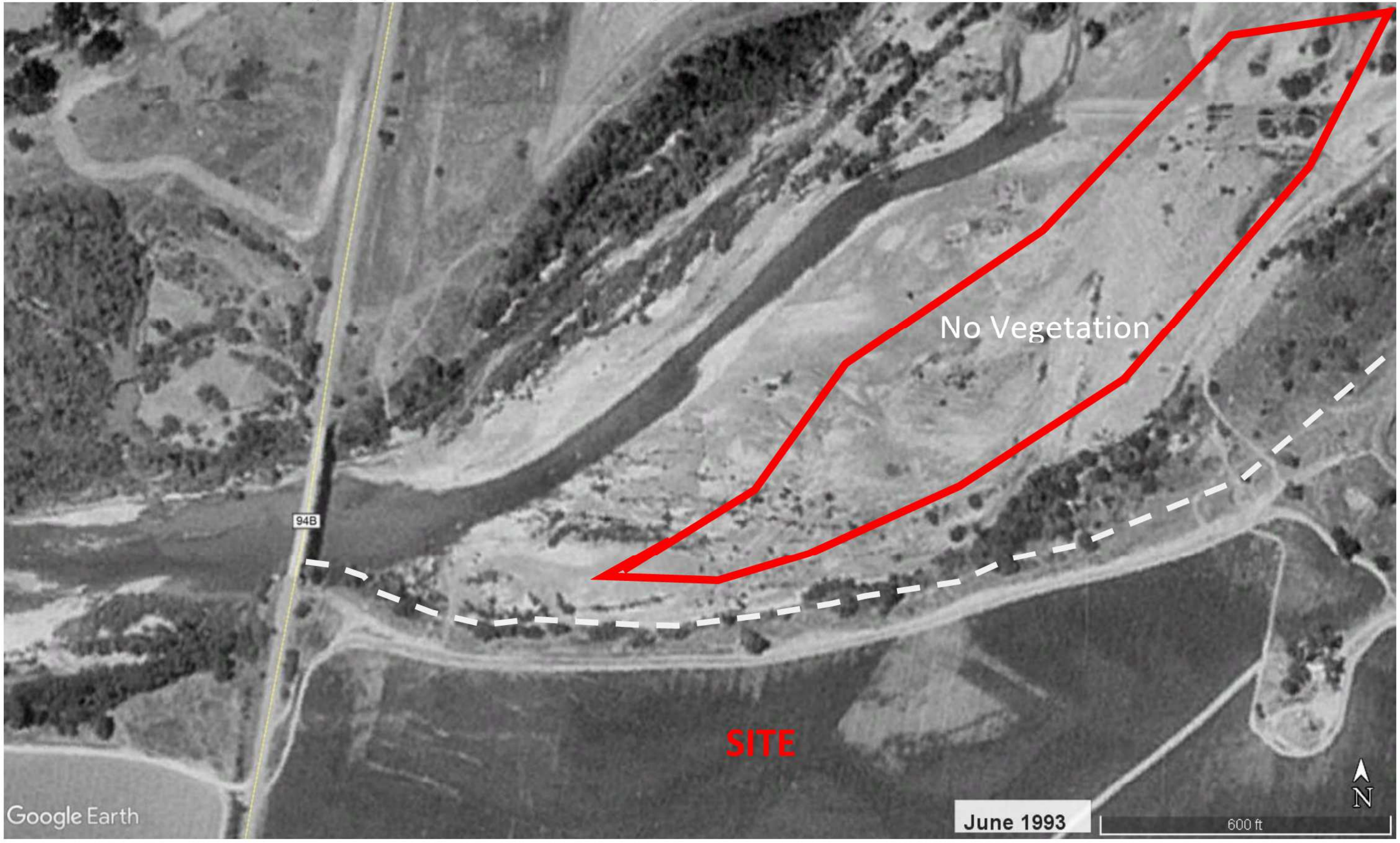
(source: USGS Woodland, California Quadrangle 1952 Photorevised 1968)

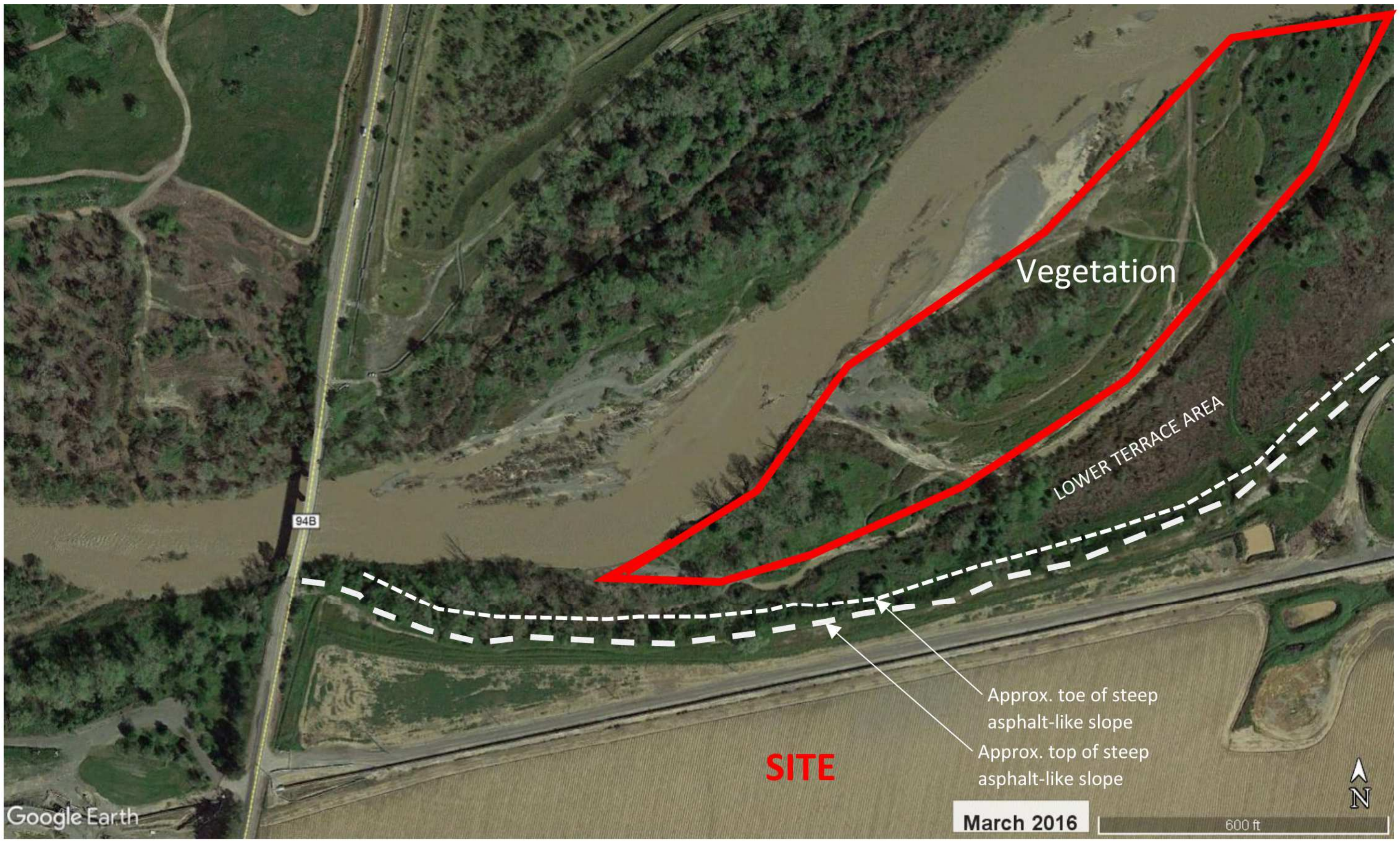
1994



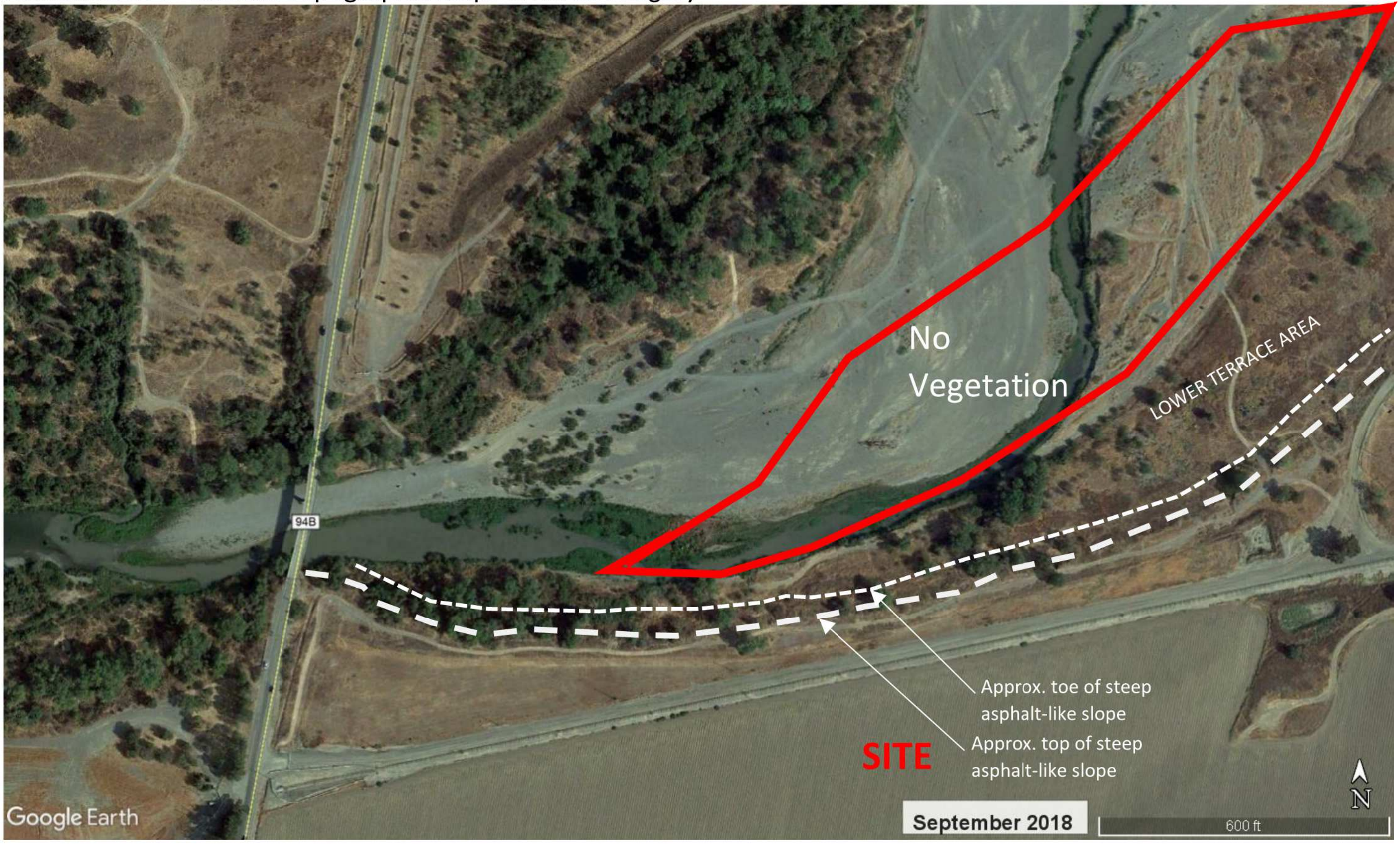
(source: USGS Quadrangle Sacramento, California 1994)

Attachment A – Historic Topographic Maps & Aerial Imagery



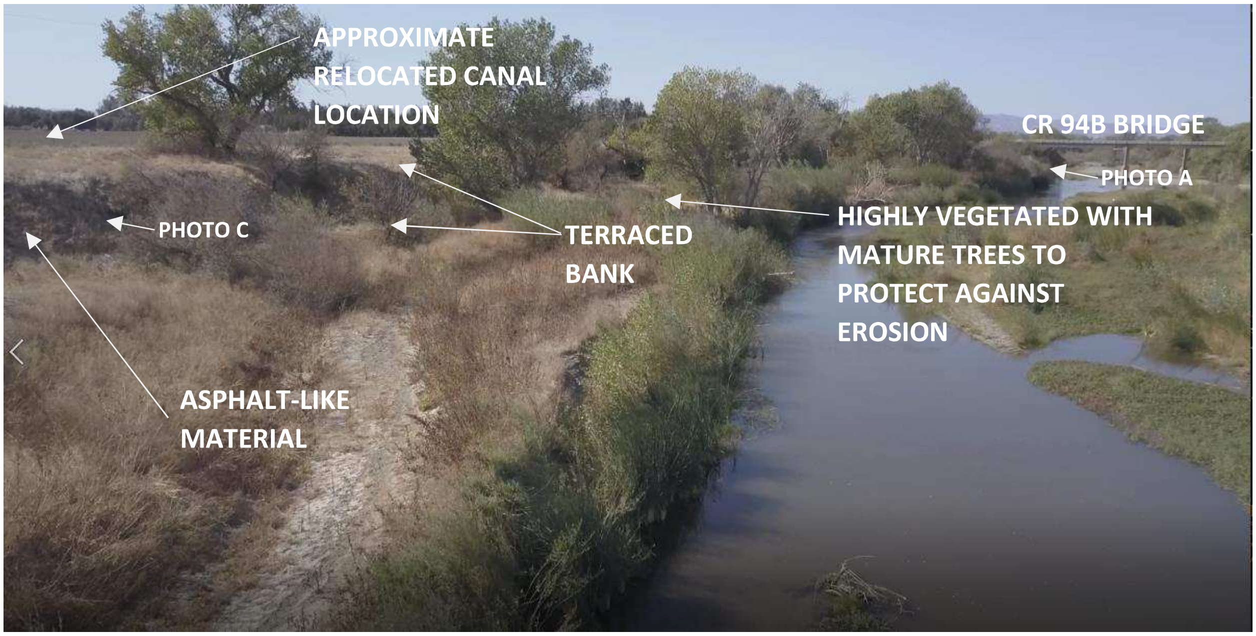


Attachment A – Historic Topographic Maps & Aerial Imagery

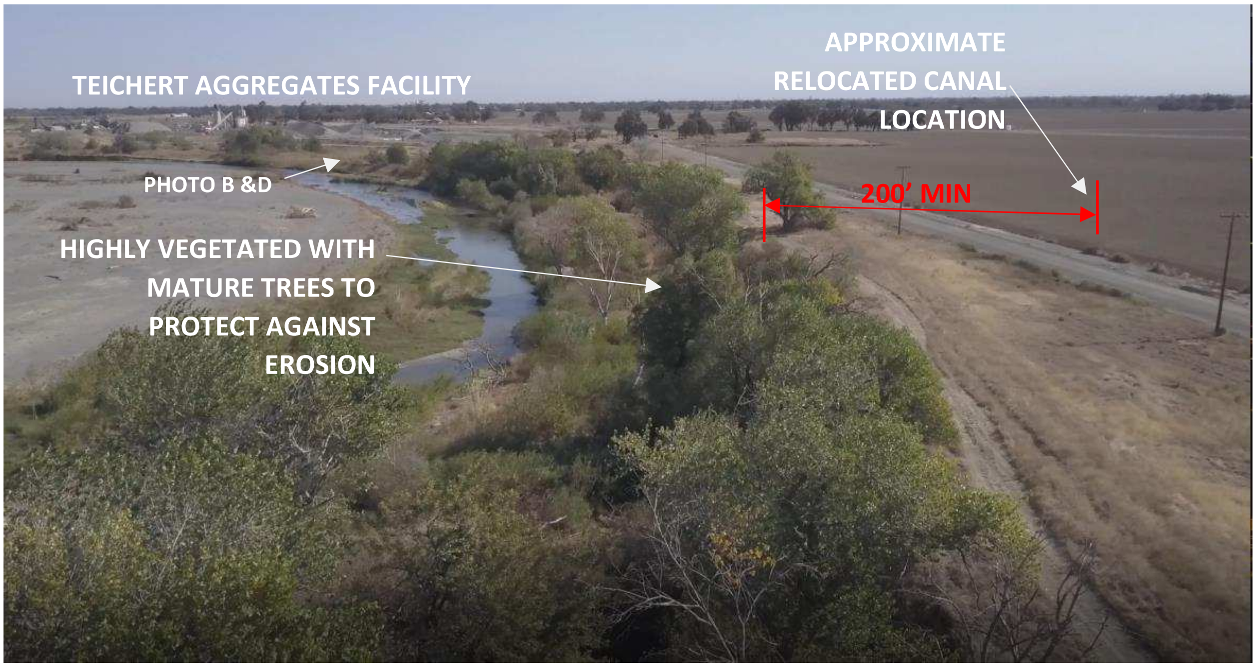


Attachment B – Photographs from November 2019 Site Visit

Drone Photograph 1 – Facing West



Drone Photograph 1 – Facing east

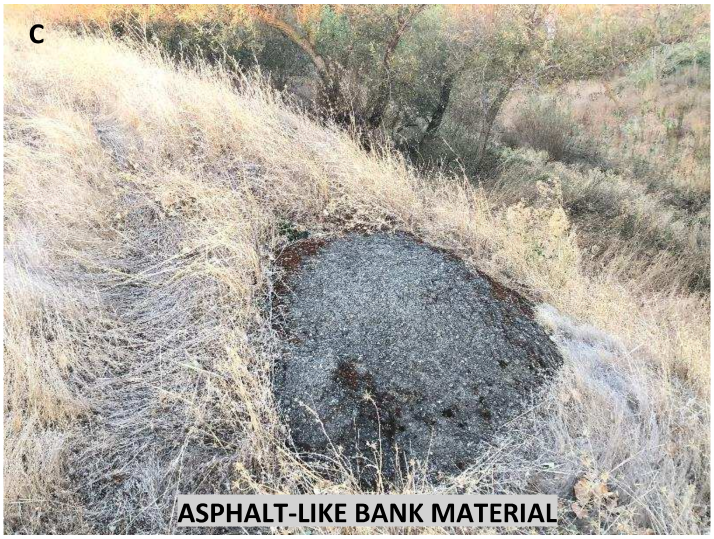


Attachment B – Photographs from November 2019 Site Visit

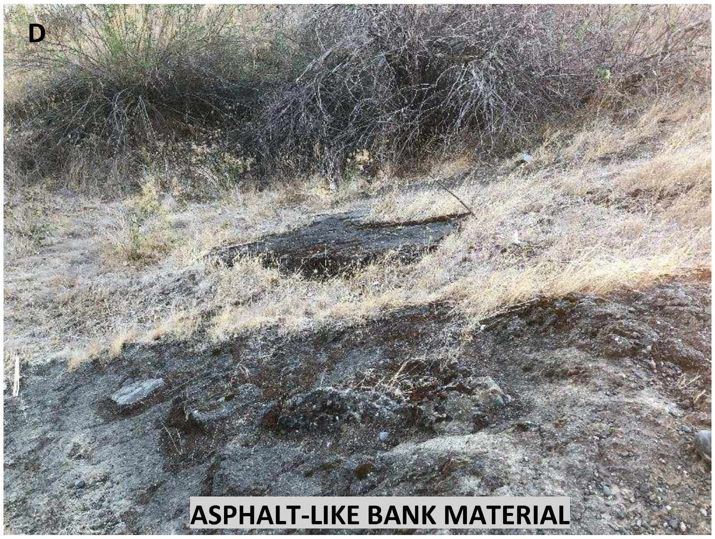
Photographs along Southern Bank

LOWER TERRACE SOUTH BANK NEAR CR94B BRIDGE

EVIDENCE OF SILT DEPOSITS FROM HIGH FLOW PERIOD

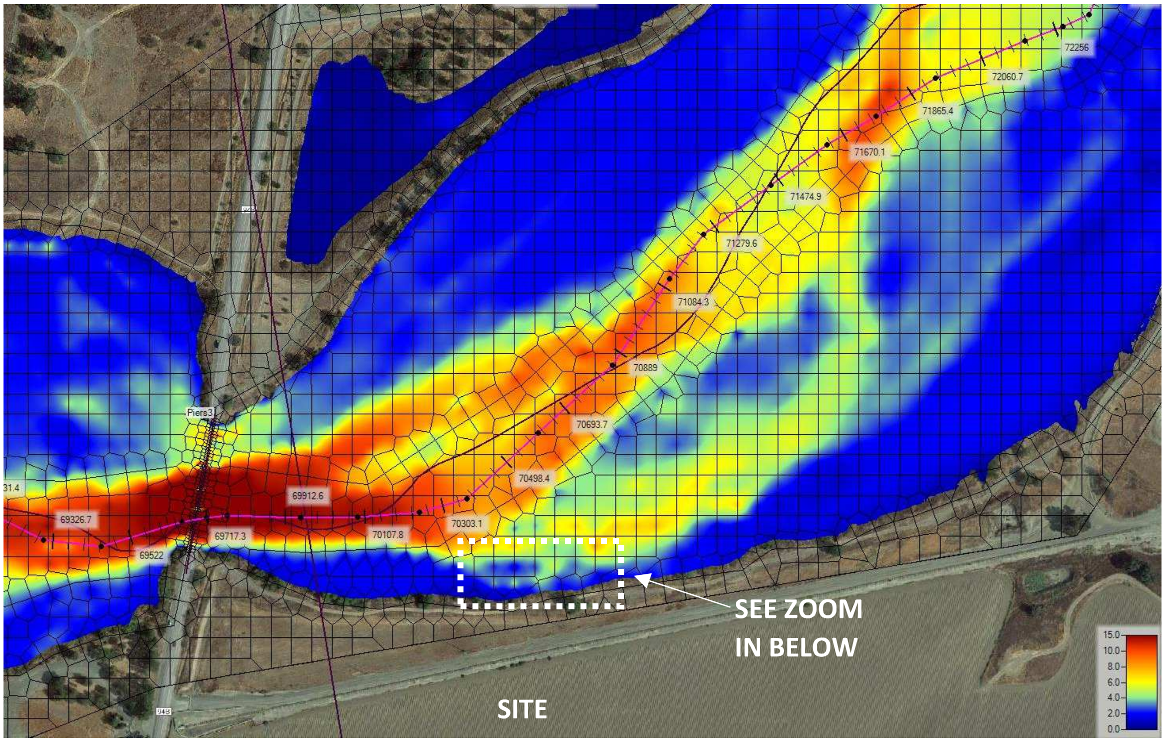


ASPHALT-LIKE BANK MATERIAL

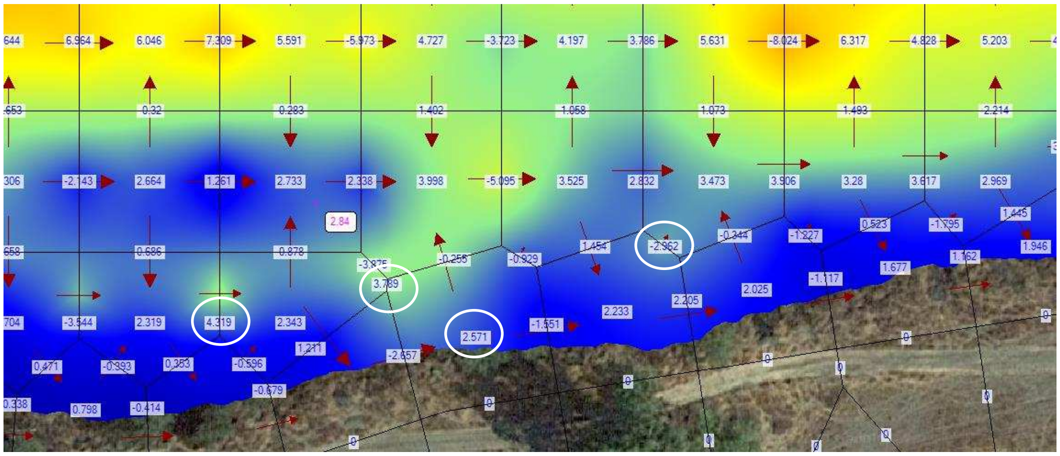


ASPHALT-LIKE BANK MATERIAL

2017 TERRAIN VELOCITY – 100-YR (FT/S)

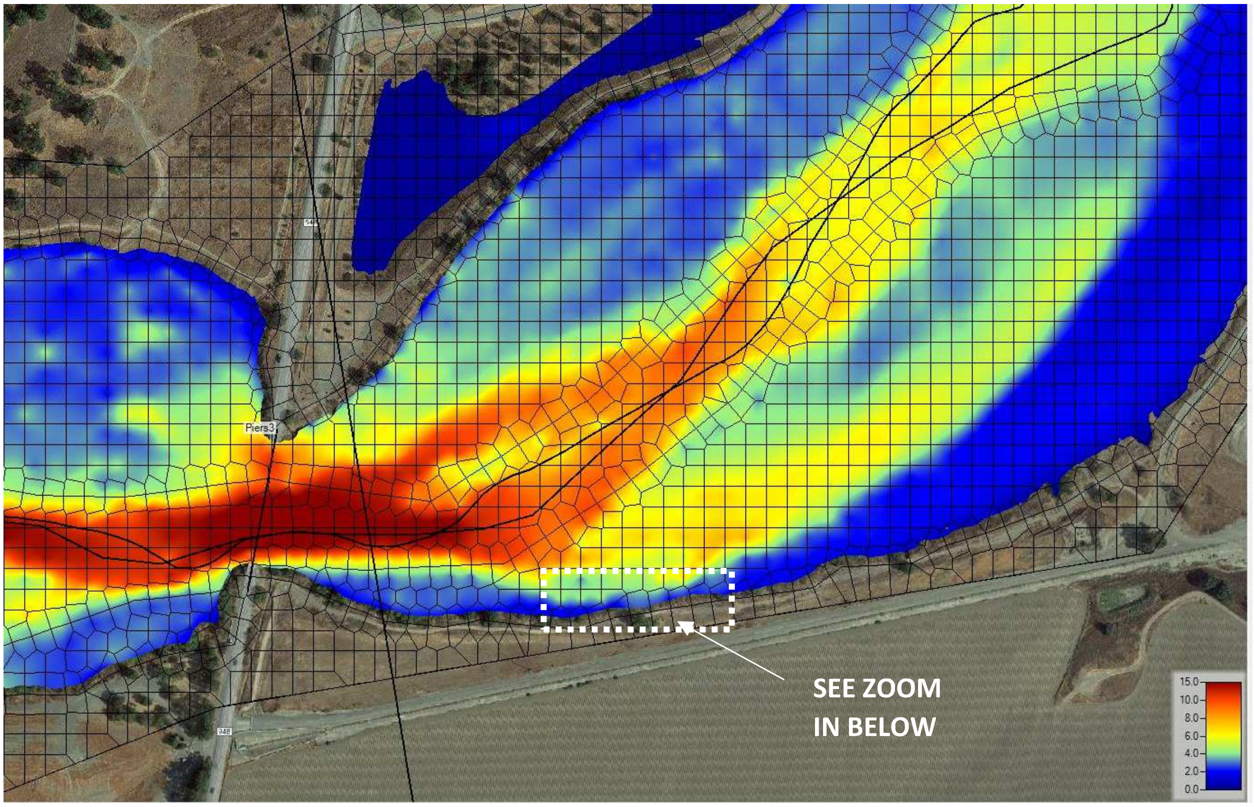


VELOCITY – 100-YR ZOOMED IN W/FACE VELOCITY VECTORS (FT/S)

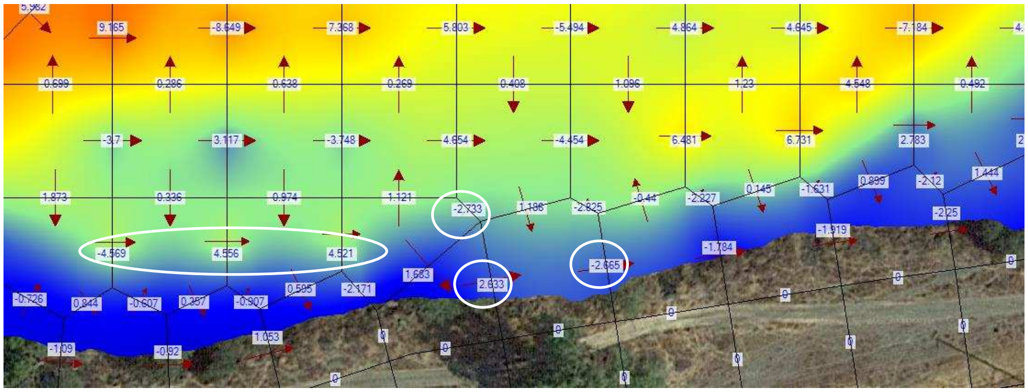


CIRCLED VALUES ARE MAXIMUM VELOCITY VALUES THAT COULD OCCUR NEAR THE CHANNEL BANK

2019 TERRAIN VELOCITY – 100-YR (FT/S)

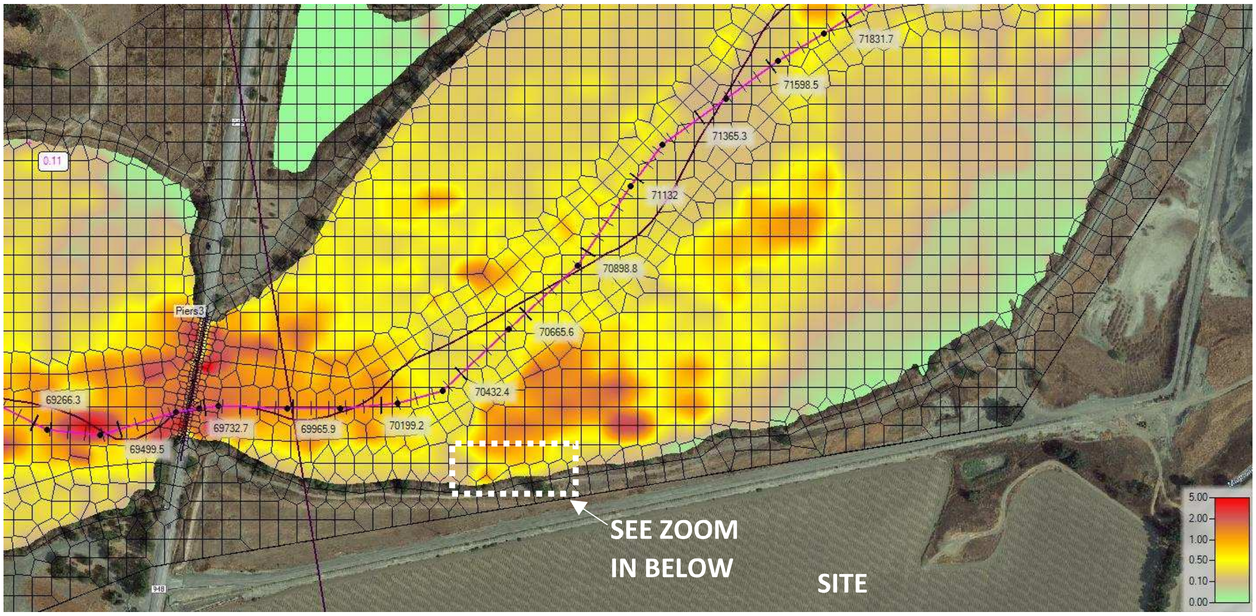


VELOCITY – 100-YR ZOOMED IN W/FACE VELOCITY VECTORS (FT/S)

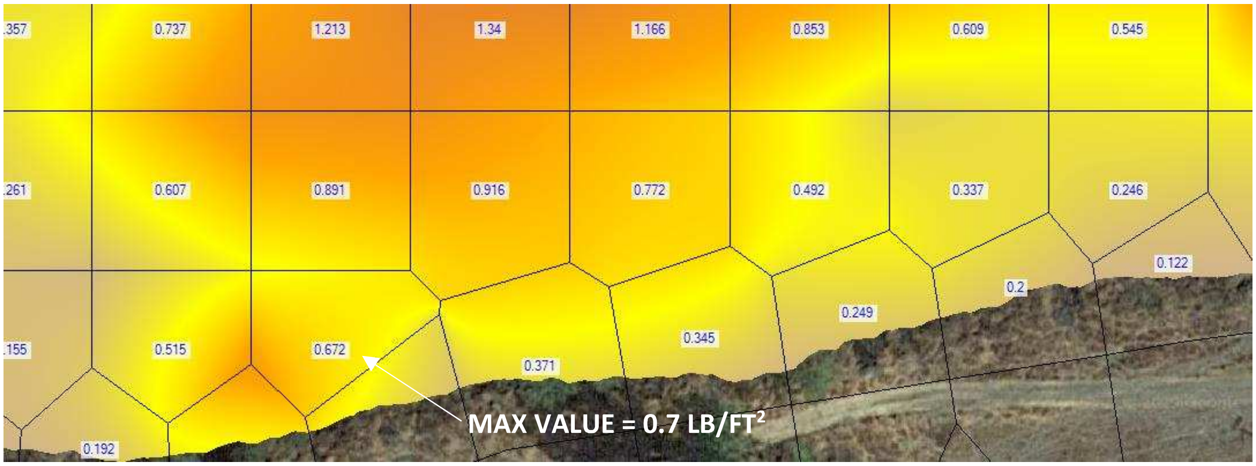


CIRCLED VALUES ARE MAXIMUM VELOCITY VALUES THAT COULD OCCUR NEAR THE CHANNEL BANK

2017 TERRAIN SHEAR STRESS – 100-YR (LB/FT^2)



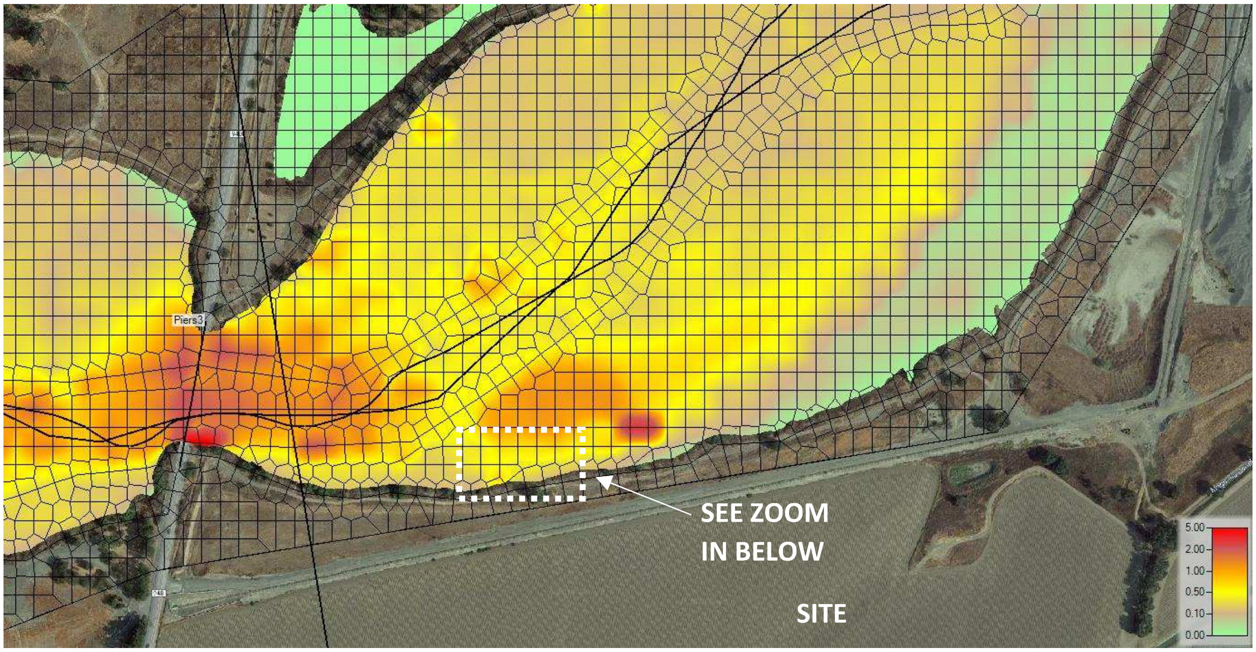
SEE ZOOM IN BELOW



MAX VALUE = 0.7 LB/FT^2

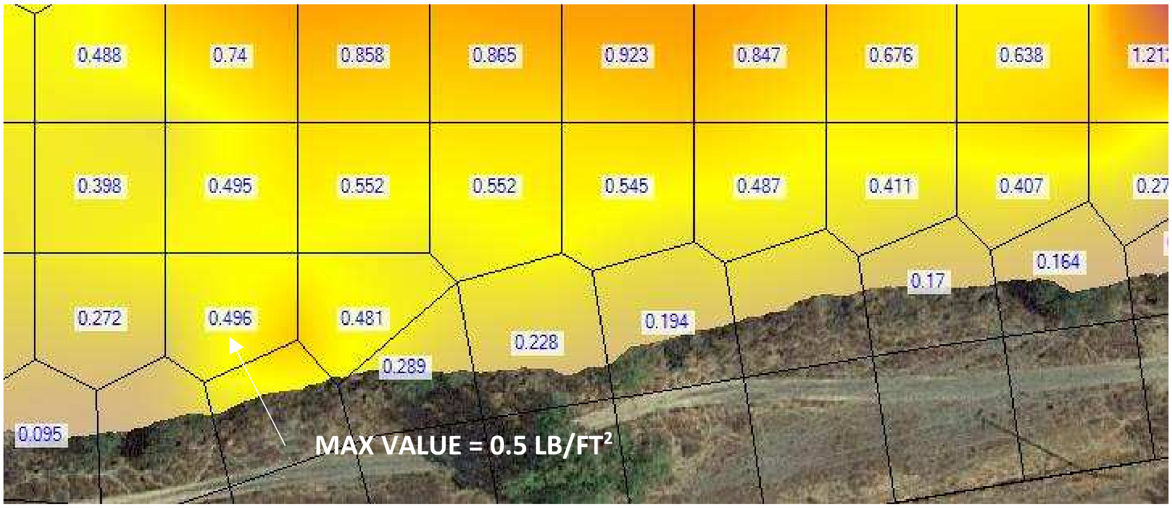
Attachment C – HEC-RAS 2D CACHE CREEK MODEL RESULTS

2019 TERRAIN SHEAR STRESS – 100-YR (LB/FT^2)



SEE ZOOM IN BELOW

SITE



MAX VALUE = 0.5 LB/FT^2

Critical Shear Stress

Source: (https://pubs.usgs.gov/sir/2008/5093/table7.html)

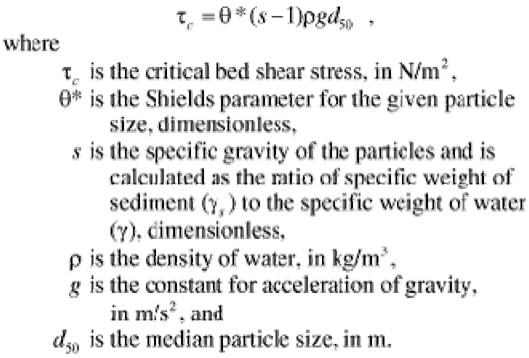
Table 7. Critical shear stress by particle-size classification for determining approximate condition for sediment mobility at 20 degrees Celsius.

[Modified from Julien, 1998, table 7.1. Sediment mobility for a given particle size occurs when the bed shear stress exceeds the critical shear stress. This only determines whether or not a given particle size is mobile.
Critical bed shear stress (τ_c) calculated from equation 4 using particle diameters from this table.
Abbreviations: φ, phi scale where φ = -log2 (diameter in mm); mm, millimeter; N/m2, Newtons per square meter]

Particle classification name	Ranges of particle diameters		Shields parameter (dimensionless)	Critical bed shear stress (τ_c) (N/m^2)
	φ	mm		
Coarse cobble	-7 – -8	128 – 256	0.054 – 0.054	112 – 223
Fine cobble	-6 – -7	64 – 128	0.052 – 0.054	53.8 – 112
Very coarse gravel	-5 – -6	32 – 64	0.05 – 0.052	25.9 – 53.8
Coarse gravel	-4 – -5	16 – 32	0.047 – 0.05	12.2 – 25.9
Medium gravel	-3 – -4	8 – 16	0.044 – 0.047	5.7 – 12.2
Fine gravel	-2 – -3	4 – 8	0.042 – 0.044	2.7 – 5.7
Very fine gravel	-1 – -2	2 – 4	0.039 – 0.042	1.3 – 2.7
Very coarse sand	0 – -1	1 – 2	0.029 – 0.039	0.47 – 1.3
Coarse sand	1 – 0	0.5 – 1	0.033 – 0.029	0.27 – 0.47
Medium sand	2 – 1	0.25 – 0.5	0.048 – 0.033	0.194 – 0.27
Fine sand	3 – 2	0.125 – 0.25	0.072 – 0.048	0.145 – 0.194
Very fine sand	4 – 3	0.0625 – 0.125	0.109 – 0.072	0.110 – 0.145
Coarse silt	5 – 4	0.0310 – 0.0625	0.165 – 0.109	0.0826 – 0.110
Medium silt	6 – 5	0.0156 – 0.0310	0.25 – 0.165	0.0630 – 0.0826
Fine silt	7 – 6	0.0078 – 0.0156	0.3 – 0.25	0.0378 – 0.0630

Max Shear stress along channel bank -
$0.5\ lb/ft^2 = 24\ N/m^2$

Equation 4

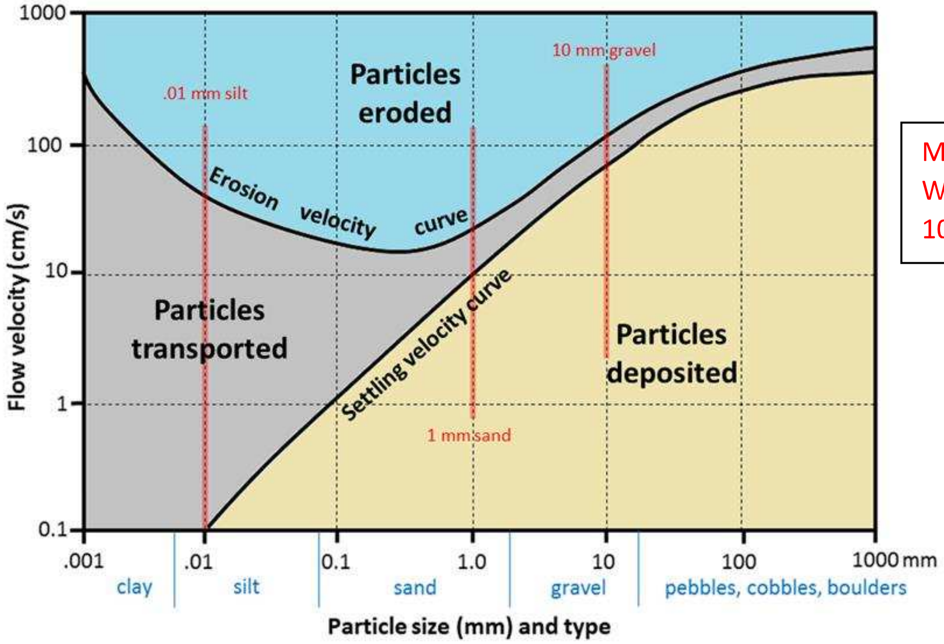


$$\tau_c = \theta^*(s-1)\rho g d_{50}\ ,$$

where

τ_c is the critical bed shear stress, in N/m^2,
θ^* is the Shields parameter for the given particle size, dimensionless,
s is the specific gravity of the particles and is calculated as the ratio of specific weight of sediment (γ_s) to the specific weight of water (γ), dimensionless,
ρ is the density of water, in kg/m^3,
g is the constant for acceleration of gravity, in m/s^2, and
d_{50} is the median particle size, in m.

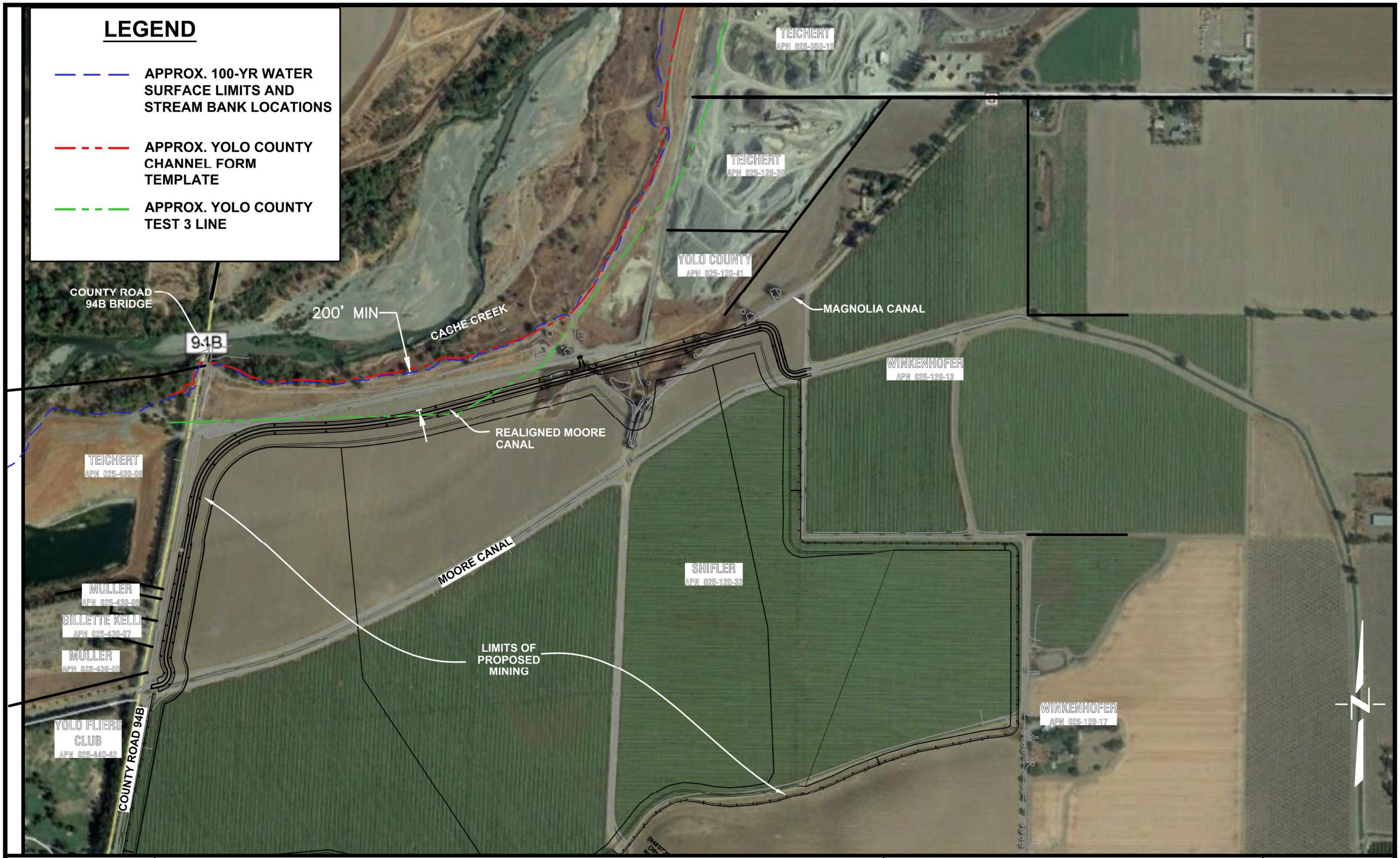
Velocity and Erosion



MIN VELOCITY WHERE GRAVEL WILL BEGIN TO ERODE IS 100 cm/s = 3.2 ft/s

The Hjulström-Sundborg diagram showing the relationships between particle size and the tendency to be eroded, transported, or deposited at different current velocities.

Source (https://opentextbc.ca/geology/chapter/13-3-stream-erosion-and-deposition/)



DESIGNED	JH
DRAWN	JH
CHECKED	SG
DATE:	12/10/19
JOB No:	1129

SHIFLER MINE
CACHE CREEK CFT AND BANK LOCATIONS
ATTACHMENT E

YOLO COUNTY CALIFORNIA

CUNNINGHAM ENGINEERING

CECWEST.COM

Project Planning ■ Civil Engineering ■ Landscape Architecture

Sacramento Office ■
2120 20th Street, Suite Three
Sacramento, CA 95818
(916) 455-2026

Davis Office ■
2940 Spafford Street, Suite 200
Davis, CA 95618
(530) 758-2026

SCALE
1"=800'

SHEET
1
OF
1

\\sac-file02\cec_tree\Projects\1100\1129 Teichert Woodland\AutoCAD\1129-20 SHF Mining and Reclamation Plan\EXHIBITS\Attachment E channel stability memo\Attachment E - Channel Alignment and CFT.dwg - Layout 12/10/2019 - 9:44AM Plotted by: jessie

Corporate Office
3500 American River Drive
P.O. Box 15002
Sacramento, CA 95851
(916) 484-3011 • Fax (916) 484-7012

TEICHERT MATERIALS

October 28, 2020

To: Steve Greenfield, PE
Cunningham Engineers
Davis, CA 95618

From: Bill Christner, PhD
Fluvial Geomorphologist
Teichert Materials

Re: Cache Creek Meander Analysis - Shifler Property Channel Setback

Meander Width Analysis

The meander width analysis is a tool for assessing the potential risk to property from river erosion while at the same time protecting the long term integrity of the watercourse and its aquatic habitats. Because Cache Creek is expected to move and change the boundaries of its meander width, development situated within the meander width could potentially, at some time in the future, be subject to erosion by the channel. A meander width analysis assists in defining the area in which natural river processes occur and may likely occur in the future.

The meander width analysis is not a substitute for floodplain delineation or setbacks based on geotechnical analyses to define the limit of development. However, where some types of development or activities are to be contemplated in proximity to a watercourse, the meander width can be an important planning tool.

The purpose of this meander width analysis is to assess the change in the meander width and location over an 81-year time period (1937 – 2018). The analysis assessed the meander width on Cache Creek in the vicinity of the proposed Shifler property using historic air photos from 1937 and 1957, and Google Earth images from 2018. These three time frames allow for a spatial and temporal assessment of the meander extent of Cache Creek.

Methods

An accurate meander width delineation and quantification is most often associated with the assessment of proposed development(s) near the river corridor. Delineating the boundary of the meander width is the first step in the assessment process.

Attachment F - Cache Creek Meander Analysis

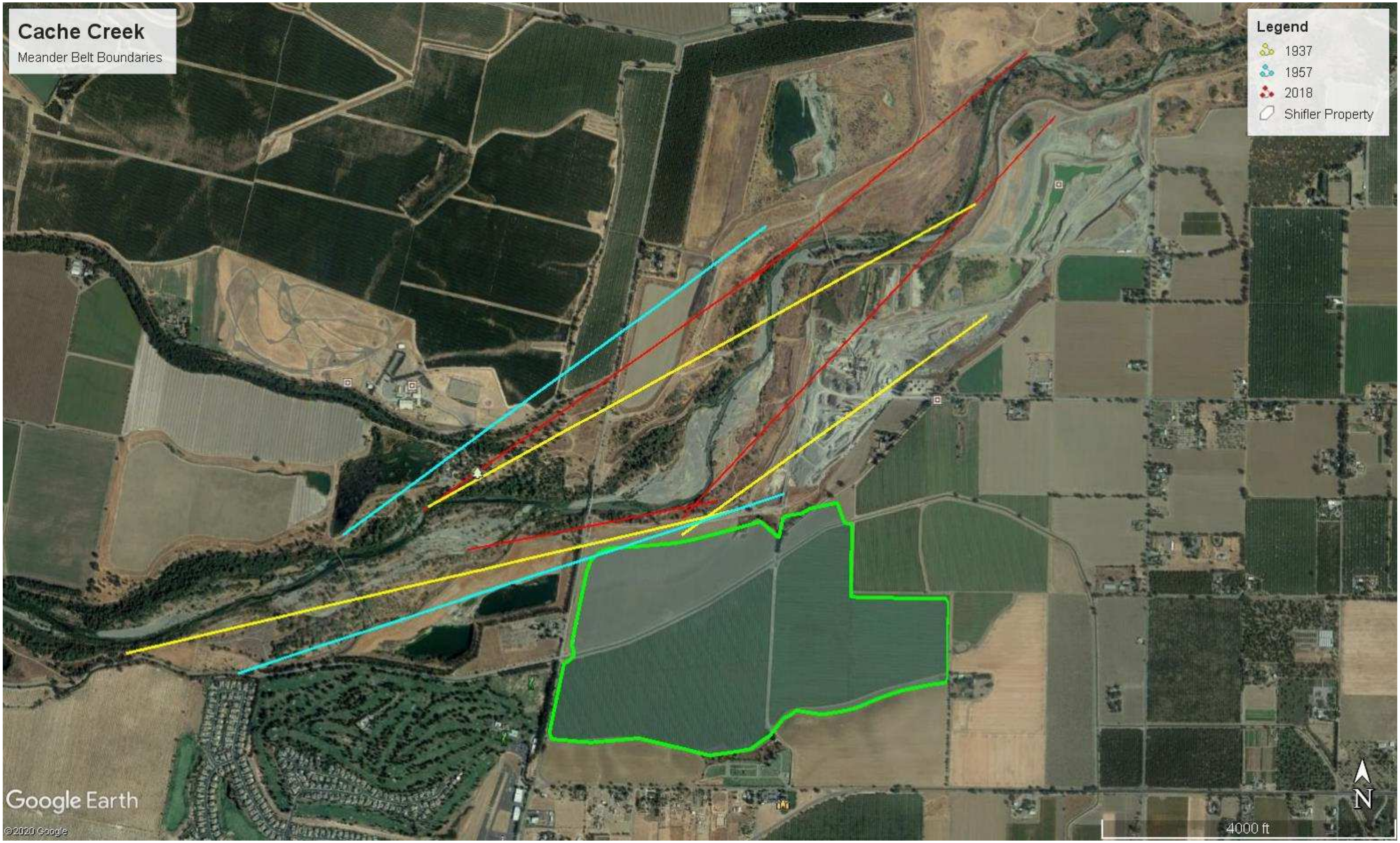


Figure 1. Meander width boundaries on Cache Creek for 1937 (yellow), 1957 (blue), and 2018 (red) and their location relative to Teichert's Shifler property (green).

Attachment F - Cache Creek Meander Analysis

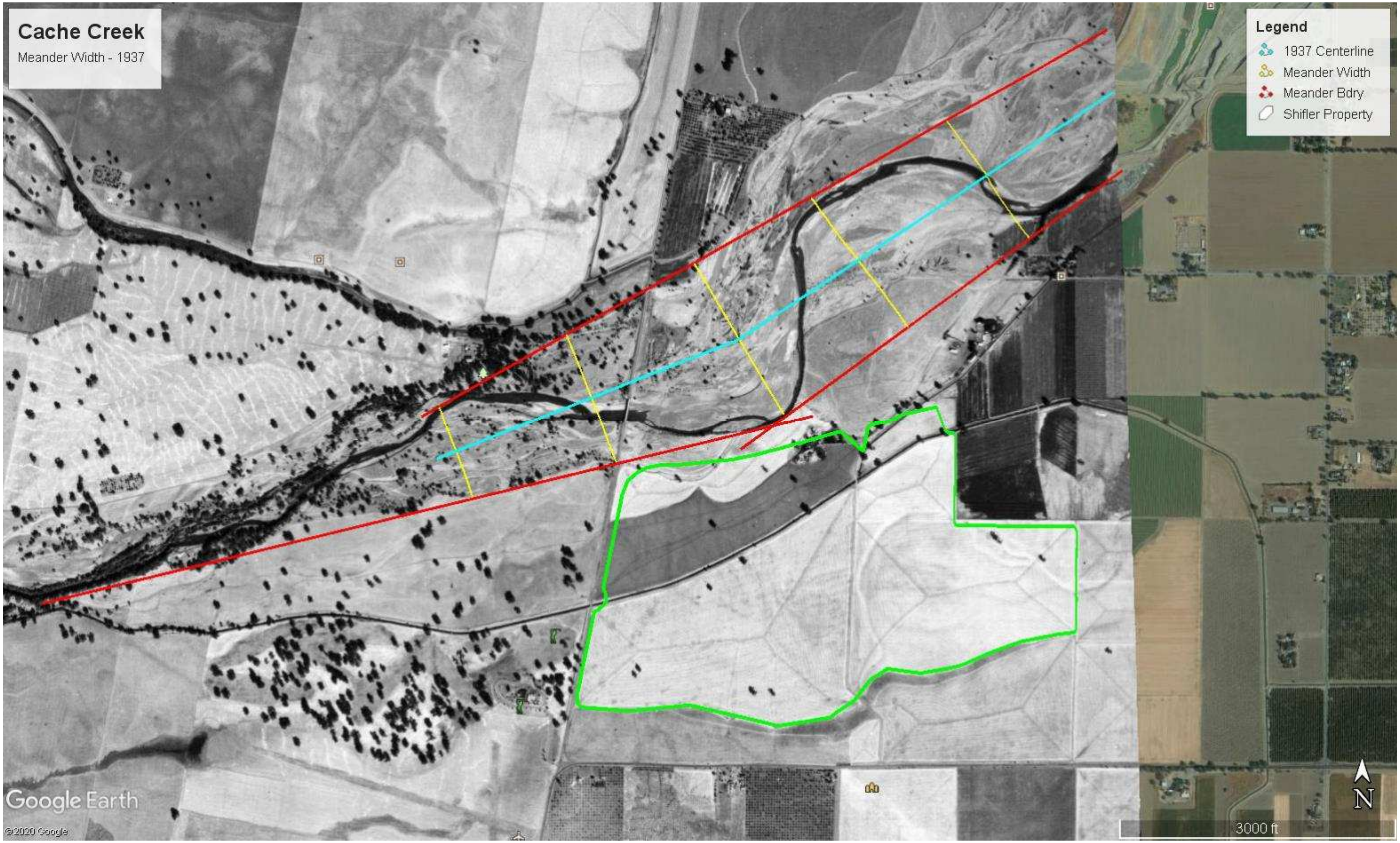


Figure 2. 1937 Cache Creek meander width boundaries (red) with meander widths (yellow) and their location relative to Teichert’s Shifler property (green).

Attachment F - Cache Creek Meander Analysis

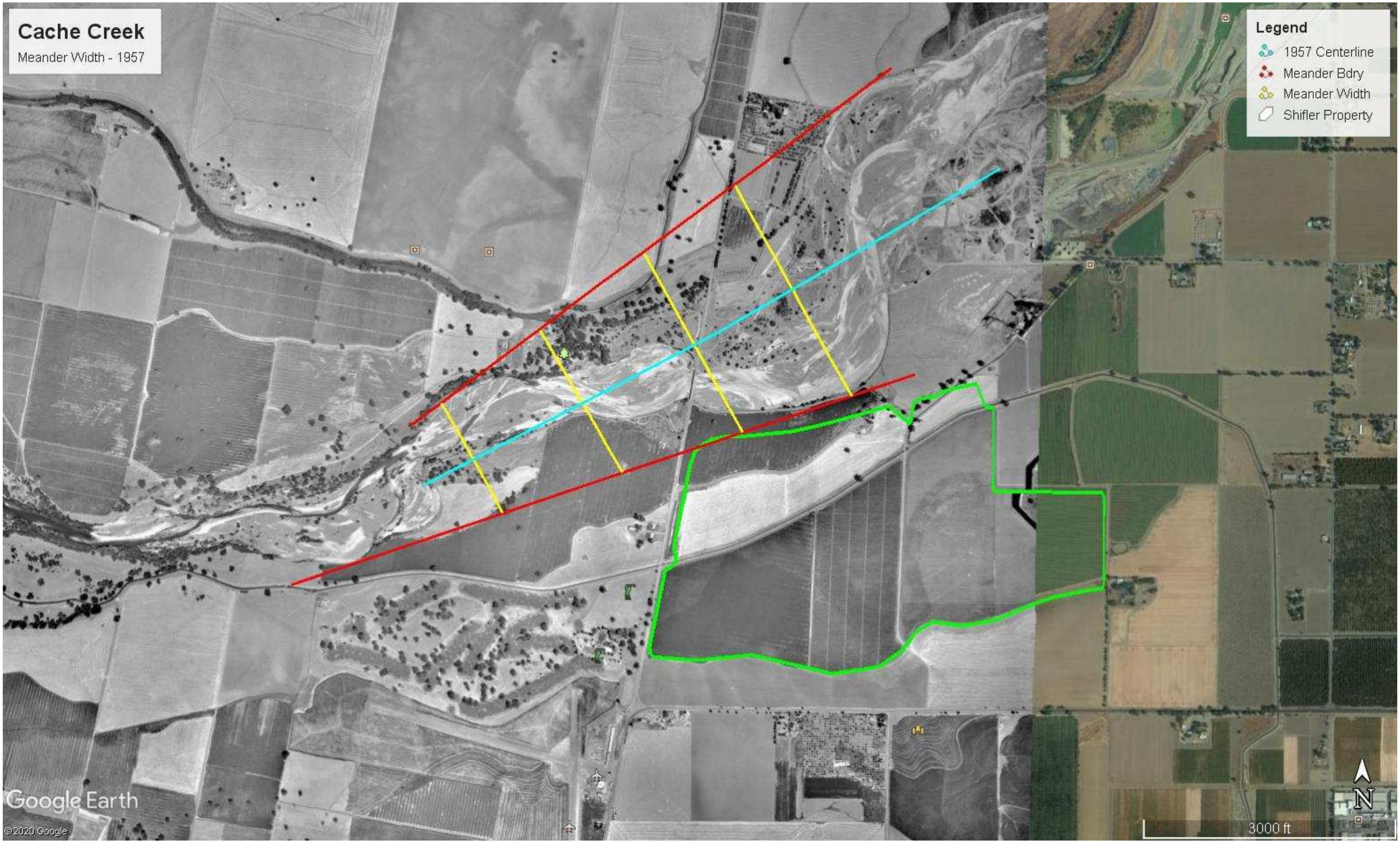


Figure 3. 1957 Cache Creek meander width boundaries (red) with meander widths (yellow) and their location relative to Teichert’s Shifler property (green).

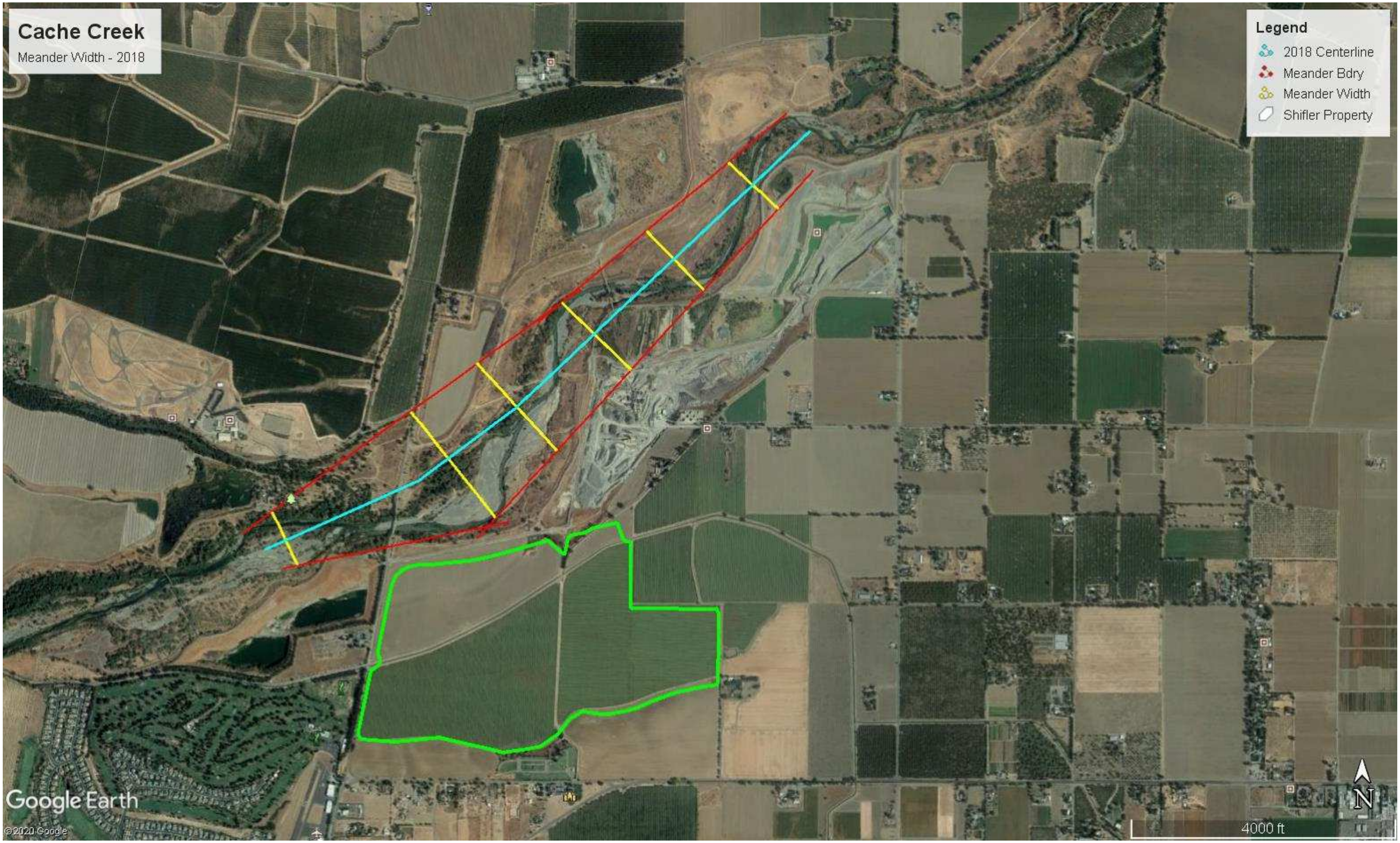


Figure 4. 2018 Cache Creek meander width boundaries (red) with meander widths (yellow) and their location relative to Teichert's Shifler property (green). 2018 Google Earth Image.

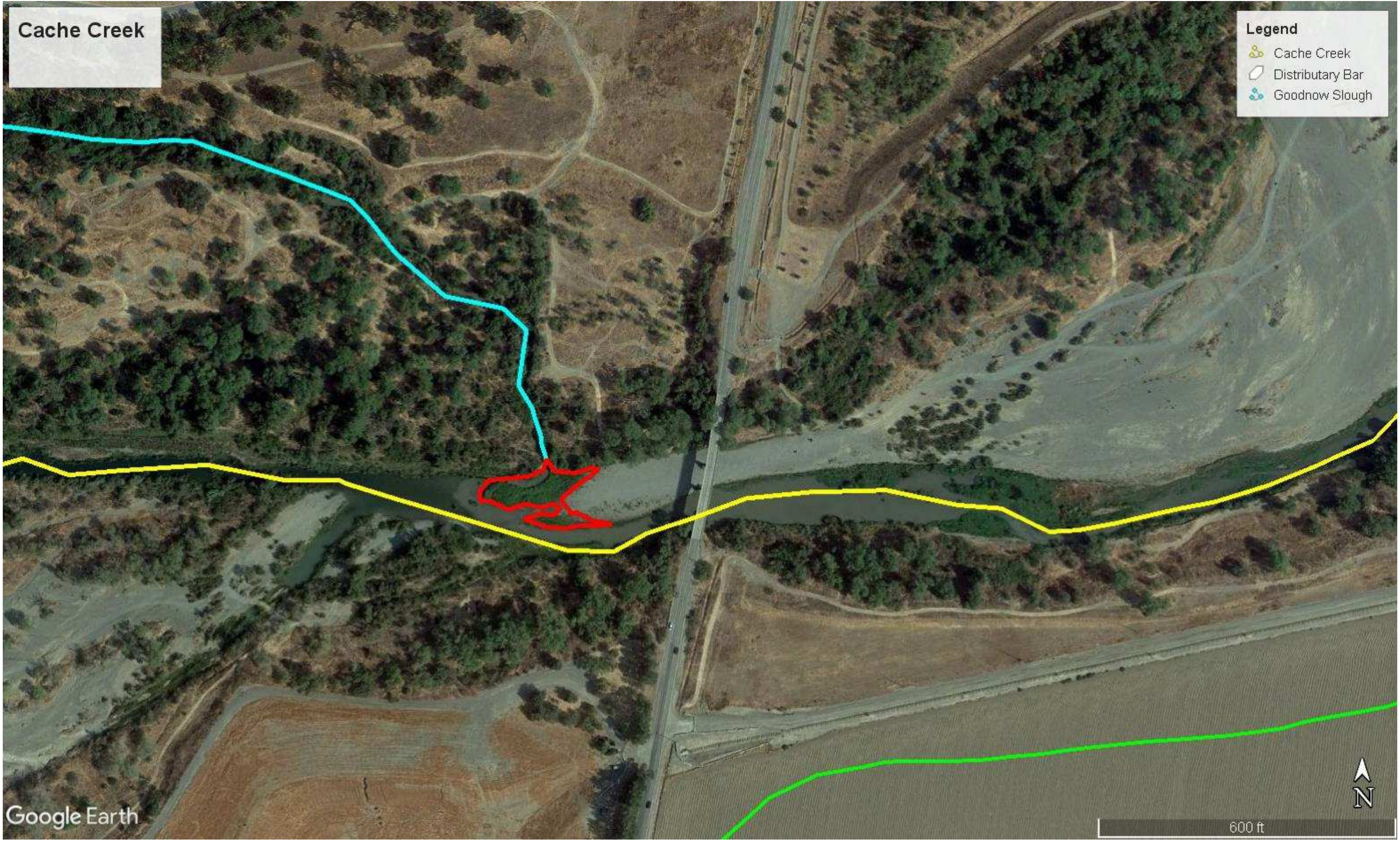


Figure 5. Gordon Slough, aka: Adams Canal, (blue) and its distributary bar (red) in relation to Cache Creek (yellow) and Teichert's Shifler property (green). 2018 Google Earth image.

The meander boundary for each year (1937, 1957, and 2018) was developed by drawing lines tangential to the outside meanders. While the linear length of the channel available for analysis in the historical air photos was limited by the aerial extent of the photo, they do provide sufficient channel length in the area of interest. Google Earth images allowed for a slightly longer meander analysis.

The boundaries of the meander width define the extent of channel migration at the moment in time the photos were taken. Areas within the meander width boundaries may someday be occupied by the watercourse; areas outside of the meander width boundaries would not. Meander widths were measured at intervals of 1500 feet along the meander axis (centerline). The meander axis is a conceptual line that indicates the general down-valley orientation of a meandering channel. The meander geometry of Cache Creek is considered partially confined due to the presence of multiple bridges which effectively “lock” the channel flow path into specific locations.

Meander Analysis Results

A review of the meander width boundaries indicate the meander pattern of Cache Creek has shifted over the course of the sampled years as illustrated in Figure 1. The furthest southern meander boundary is 1957. The 1937 meander width boundary is slightly north, and 2018 meander width boundary is the most northern.

The width of the meander boundary has also changed over the years. The widest meander width was observed in 1957 with an average meander width of 2,169 feet. The narrowest meander width is seen in 2018 with an average meander width of 1,404 feet. The average meander width in 1937 was 1,539 feet. It should be noted that the sample size in these years is limited due to the areal extent of the historic air photo. However, while the sample size is limited, the data provide solid evidence of the meandering tendencies of Cache Creek over the years in the area of Teichert’s Shifler property.

Differences in the relative location and size of the meanders on Cache Creek is attributed to the increased water diversions over the years and the presence, and subsequent termination, of in-channel mining activities. The meander widths from the three images illustrate that Cache Creek had a relatively narrow meandering corridor in 1937 which was prior to widespread in-stream gravel mining (Figure 2). By 1957 in-stream gravel mining was in full swing and resulted in a much larger meander width (Figure 3). After the prohibition of in-stream gravel mining activities in 1996 the meander width on Cache Creek narrowed as illustrated in the 2018 image (Figure 4). There is only a 9 percent difference between the average meander width in 2018 and the average meander width in 1937. However, there is 41 percent difference between the 1937 and 1957 average meander widths, and a 54 percent difference between the 1957 and 2018 average meander widths. These results indicate the current meander pattern on Cache Creek has achieved relative stability as reflected in the similarity of the 2018 meander width and the 1937 meander width. Both meander widths are the result of little/none in-stream gravel mining.

Gordon Slough (aka: West Adams Canal) tribes into Cache Creek from the north immediately upstream of the 94B Bridge (Figure 5). A small distributary bar has formed in Cache Creek from the Gordon Slough deposits. This deposit pushes Cache Creek to the south just west of the 94B bridge and effectively locks Cache Creek into this localized meander flow pattern. Cache Creek then meanders in a northeast direction, under the 94B bridge, immediately after being redirected by the Gordon Slough distributary bar. More importantly, the Gordon Slough distributary bar prevents Cache Creek from developing a meander bend on the north bank which could then flow back towards the southern bank of Cache Creek and the Shifler property. This is critical because without the meander bend on the north, Cache Creek will not develop a NW-SE flow pattern under the bridge towards the south bank along the Shifler property. This flow pattern is also illustrated in the Velocity and Shear Stress figures in HEC-RAS results (attachment C). The flow pattern is west-to-east. The 2017 and 2019 velocity vectors along the south bank on the west side of the 94B bridge are similar to those on the south bank along the Shifler property. High channel velocities are contained in the central portion of the Cache Creek channel and illustrate a west-to-east flow pattern. The west-to-east flow pattern is also illustrated in the 2017 and 2019 shear stresses. The shear stresses along the south bank on the west side of the 94B bridge are similar to those on the south bank along the Shifler property. High shear stresses are contained in the central portion of the channel and again, illustrate a west-to-east flow pattern. The west-to-east flow pattern is also visible in historic air photos. This suggests the flow pattern on Cache Creek is relatively stable through this reach due to the influences of Gordon Slough and the 94B bridge.

Conclusions

Cache Creek has meandered a bit from 1937, to 1957, to 2018. However, the extent of the meander widths appears to have been historically exacerbated by previous in-stream gravel mining activities. Cache Creek is not expected to meander towards the Shifler property due to the presence of the Gordon Slough distributary bar, and the 94B bridge. Together these combine to fix the location and flow pattern of Cache Creek at this location.

Bill Christn

Bill Christner, PhD. Fluvial Geomorphologist with 16 Years Professional Experience. His education includes a B.S. in Geohydrology and an M.S. in Soils, both from Montana State University-Bozeman. He obtained his doctorate in Water Resources from the University of Minnesota. His work experience includes stream and wetland restoration design, watershed analyses, sediment transport characterization, aquatic habitat enhancement/restoration, and soil analyses.