Stream Habitat Investigations and Assistance

Federal Aid Project F-161-R19

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Federal Aid in Fish and Wildlife Restoration

Job Progress Report

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Aquatic Wildlife Research Section

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The results of the research investigations contained in this report represent work of the authors and may or may not have been implemented as Colorado Parks & Wildlife policy by the Director or the Wildlife Commission.

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SEGMENT NARRATIVE

State: Colorado Project Number: F-161

Project Title: Stream Habitat Investigations and Assistance

Period Covered: July 1, 2012 through June 30, 2013

Principal Investigators: Matt C. Kondratieff and Eric E. Richer

Project Objective: To evaluate fishery response to stream aquatic habitat treatments; to evaluate the physical response of streams to aquatic habitat treatments and water development; to evaluate the barrier potential of in-stream obstacles; and to provide technical assistance for statewide aquatic habitat improvement projects and fish passage structure and barrier designs.

STUDY PLAN A: DESIGN, CONSTRUCTION AND EVALUATION OF STREAM HABITAT RESTORATION TREATMENTS AND IN-STREAM STRUCTURES

Job A.1. Fishery Response to Stream Aquatic Habitat Treatments

Job Objectives: Stream habitat improvements will be evaluated to quantify changes in salmonid biomass (quantity), individual fish size (quality), and fish utilization of habitat treatments in restored versus un-restored river segments. Before-After/Control-Treatment (BACT) studies will be conducted at appropriate site locations. A combination of field and theoretical results from this study will be used to evaluate the fishery response to stream habitat treatments. Research findings will generate useful information for quantifying how much improvement in the fishery can be expected from stream restoration projects. Results from this study will refine stream habitat restoration techniques to improve sport fisheries and benefit anglers.

Segment Objective 1: Develop list of candidate stream segments to conduct pre- and post-stream habitat improvement studies. Select appropriate study site location(s) for evaluation.

ACCOMPLISHMENTS

The list of candidate stream segments for conducting BACT studies of fish response to habitat treatments was updated to reflect new projects identified during the previous year (Table 1). Candidate sites for BACT monitoring studies must have the following characteristics: fish populations have stabilized post-whirling disease infection, at least two years of baseline fish data have been collected prior to stream restoration, Colorado Parks and Wildlife (CPW) leases or owns public fishing access, proposed restoration sites have been identified, prioritized and funded allowing adequate time to collect sufficient “before” data prior to construction, and CPW personnel will be able to work closely with contractors on design and implementation of habitat treatments (design-build).

Table 1. List of proposed stream segments for studying fish populations pre- and post- stream habitat improvements.

Stream	Construction Years	Project Status	Length (mile)	Primary Treatments	Treatment Reach*	Control Reach*	Project Description
South Platte River: Buckley Ranch	1991	Completed	0.4	Reduce channel width, excavate pools, enhance trout habitat	2/22	2/22	Upper Spinney SWA/Lower end of Badger Basin perpetual easement
South Platte River-Phase 1 & 2	1993 & 1998	Completed	0.6	Reduce channel width, increase adult fish cover (vegetative cover and deep pools), stabilize eroding banks and improve in-stream habitat complexity.	1/8	No control reach	South Platte River Downstream of Spinney Reservoir
Upper Conejos	2000	Completed	1.0	Reduce channel width, increase adult fish cover (vegetative cover and deep pools), stabilize eroding banks and improve in-stream habitat complexity.	TBD	TBD	Conejos River below town of Platoro
Tarryall Creek	2005	Completed	0.6	Increase trout biomass and number of quality-sized (> 14" TL) trout, stabilize eroding banks, reduce channel width, increase habitat complexity	2/2	No control reach	Tarryall Creek on Tarryall SWA
Rio Grande River	2006	Completed	4.4	Reduce channel width, excavate pools, enhance trout habitat	8/5	0/3	Wason and La Garita Ranches
Middle Fork of South Platte River: Badger Basin	2007-2011	Completed	2	Reduce channel width, excavate pools, enhance trout habitat	0/2	2/20	Upper Spinney SWA/Lower end of Badger Basin perpetual easement
Upper Arkansas River	2013-2014	In progress	3	Reduce channel width, excavate pools, enhance trout habitat	16/0	16/0	Upper Arkansas NRD project at Hayden Flats

South Platte River-Phase 5	2013-2015	In progress	1.5	Reduce channel width, excavate pools, enhance trout habitat	0/0	0/0	Lower Spinney SWA (Dream Stream)
Clear Creek, Twin Tunnels Project	2013-2014	Future Project	0.5	Reduce channel width, excavate pools, enhance trout habitat, floodplain connectivity	0/0	1/0	Twin Tunnels Project along Interstate 70 corridor
Gunnison River, Gunnison SWA	2014-2015	Future project	2.7	Improve diversion structures, enhance trout habitat, floodplain connectivity	TBD	TBD	Gunnison River SWA near Gunnison Colorado
Crystal River, Wexner Property	2014-2015	Future project	0.6	Improve diversion structures, enhance trout habitat	TBD	TBD	Wexner Property
North Platte River, Verner SWA	2015-2016	Future project	1.3	Stabilize eroding banks, reduce channel width, excavate pools, enhance trout habitat	TBD	TBD	Verner State Wildlife Area near Walden, Colorado
Tomichi Creek, Tomichi Creek SWA	2015-2016	Future project	4.4	Stabilize eroding banks, reduce channel width, excavate pools, enhance trout habitat	TBD	TBD	Tomichi Creek State Wildlife Area near Gunnison, Colorado
South Platte River	2015-2017	Future project	1	Reduce channel width, excavate pools , enhance trout habitat	0/0	0/0	River segment Downstream of Park Co. Rd 59
South Fork of South Platte River	Delayed	Future project	1	Reduce channel width, excavate pools, enhance trout habitat	2/0	2/0	River reach upstream of Badger Basin HQ - Lower end of Badger Basin perpetual easement
Hartsel Townsite	Delayed	Future project	0.6	Reduce channel width, excavate pools, enhance trout habitat	2/0	2/0	Hartsel Townsite between Highway 24 and Highway 9

*Years of fish data collected “Before” work started / Years of fish data collected “After” work completed

Segment Objective 2: During summer and fall months, conduct electrofishing sampling to determine salmonid biomass, densities and individual fish lengths in control and treatment study sites to serve as baseline for later comparison.

ACCOMPLISHMENTS

We collected fish sampling data on select pre- and post-treatment stream reaches to monitor fish response to aquatic treatments with assistance from area aquatic biologists and research scientists. Fish sampling was conducted at the following study locations:

Rio Grande River:

Boat electrofishing surveys were canceled for the Rio Grande River study site due to extreme low flows during fall 2012. Flows were insufficient for boat passage through the study reach. We plan to resume fish monitoring efforts for this study during fall 2013.

South Platte River:

Charlie Meyers SWA:
Fish sampling occurred on one historic stream electrofishing site located within Phase 1 and 2 (restored reach) below Spinney Mountain Reservoir which is just upstream of the proposed project reach. Data was collected by Jeff Spohn, CPW Fisheries Biologist and included fish population estimate data, length/frequency data, and fish species composition. A fish sampling station within the proposed treatment section will not be established due to potential for confounding issues related to flow releases from Spinney Reservoir. Instead, project evaluation will consist of conducting before and after studies using habitat surveys, ADCP flow mapping techniques, and creel surveys.

Buckley Ranch:
Historic monitoring sites: Data were collected for the Buckley Ranch including two sampling stations (treatment and control) during April and October 2012. Data collected included fish population estimate data, fish size by relative abundance data, and fish species composition. Fish sampling has been conducted nearly continuously since the fall of 1990 for these sites (Figure 1; Table 2).

Toe-wood sod mat site: The toe-wood sod mat treatment segment was sampled (approximately 200 linear feet of wood toe treated banks of the 1000 foot electrofishing station) during April and October 2012. Data collected included fish population estimates, fish size by relative abundance data, and fish species composition. Fisheries response data collected from this reach will be compared with data collected from the control/treatment reaches from the Buckley located just 0.15 miles downstream from the Badger Basin project boundary (Figure 1; Table 2).

Reference reach sites: We collected fish sampling data on Middle Fork of South Platte River on the Tomahawk SWA during the fall and spring of 2012. Data collected included fish population estimate data, fish size by relative abundance data, and fish species composition.

Fish biomass and density data collected from this site and one site upstream will serve as a "reference reach" and help us set target levels for expected fisheries response for treated (or restored) locations Downstream. Detailed habitat surveys from these locations along with fisheries data serve as reference conditions for impaired sites within the South Platte River basin (Figure 1; Table 2).

Table 2. Buckley Ranch Project brown trout biomass (lbs/acre) (± 95% C.I.) results for control, boulder treatment, wood-toe treatment and reference reaches pre-and post-project.

Year	Biomass (lbs/acre)			
	Boulder treatment	**Toe-wood treatment**	**Control**	**Reference**
1990	29 (±5)	N/A	69 (±4)	N/A
1991	44 (±9)	N/A	37 (±5)	N/A
	STREAM RESTORATION			
1992	40 (±3)	N/A	16 (±2)	N/A
1993	50 (±3)	N/A	11 (±1)	N/A
1994	103 (±39)	N/A	18 (±1)	N/A
1995	33 (±2)	N/A	30 (±5)	N/A
1996	66 (±5)	N/A	52 (±2)	N/A
2000	87 (±3)	N/A	35 (±1)	N/A
2002	N/A	N/A	N/A	130 (±16)
2003	51 (±4)	N/A	27 (±1)	215 (±10)
2004	49 (±3)	N/A	10 (±2)	289 (±3)
2007	N/A	N/A	N/A	484 (±6)
2009	41 (±4)	N/A	13 (±2)	204 (±7)
2010	58 (±7)	83 (±10)	24 (±2)	121 (±3)
2011	N/A	52 (±2)	N/A	95 (±2)
2012	N/A	59 (±4)	N/A	154 (±2)

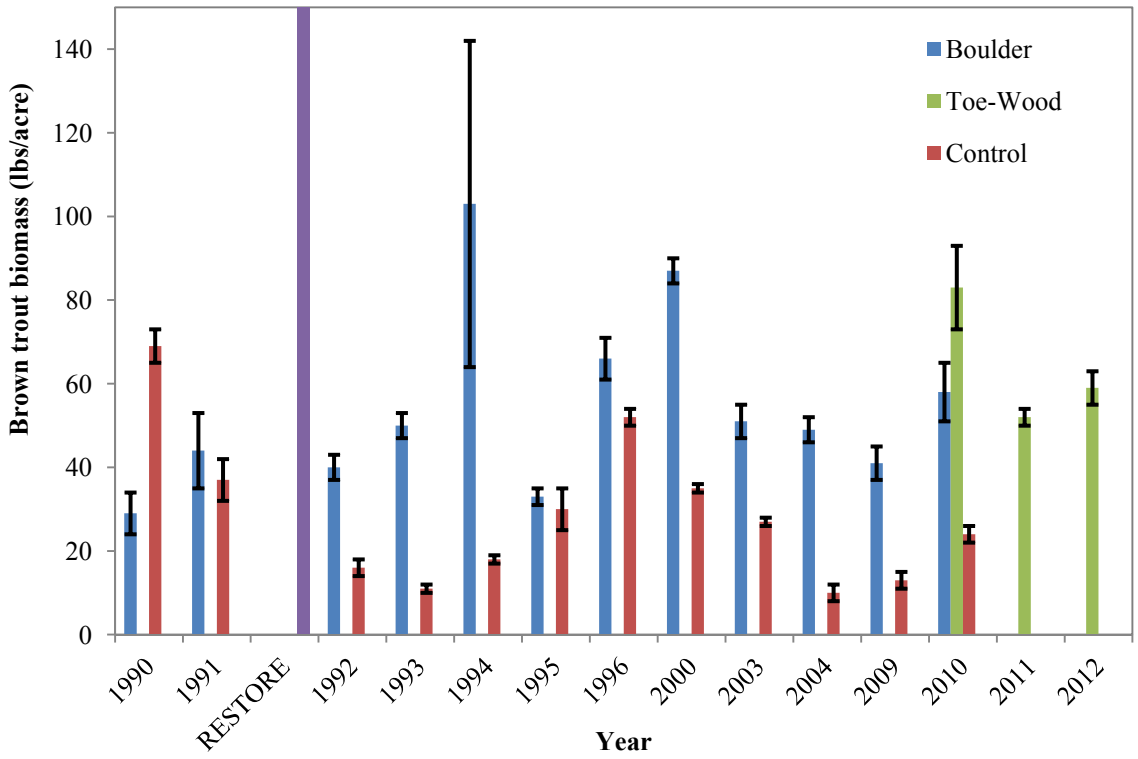

Figure 1. Fall fish sampling results for the Buckley Ranch Project. Brown trout biomass (lbs/acre) (± 95% C.I.) for control, treatment (boulder) and wood-toe treatment reaches located on the y-axis and sampling year for pre- (1990-1991) and post- (1992-2012) project completion on the x-axis.

Upper Arkansas River:

All fish monitoring sites in the Upper Arkansas River were sampled in August 2012 prior to instream construction activities during fall 2013. These data provide baseline information for comparison with fish population data after project implementation. This reach is unique in that some fish sampling sites have more than 16 years of baseline data collected prior to implementing the habitat enhancement project.

AR-4 is a historic monitoring site on private land that was previously considered a control site for the project. At the landowner's direction, the channel was altered and stream banks were hardened with large boulder treatments during 2011-2012 to minimize the risk of bank erosion. Due to these alterations, AR-4 is no longer considered a control site. Regardless, monitoring efforts will continue to evaluate the response of fish populations to bank treatments at this historical site.

Electrofishing surveys were used to collect length/frequency and species composition data for each site within the project extent (Table 3). Brown trout populations exhibited record numbers for many sites in 2012 due to improved water quality throughout the Arkansas River headwaters. If fish populations continue to improve following completion of the habitat enhancement project, many of these sites could meet Gold Medal criteria for Colorado streams.

Table 3. Brown trout monitoring results for the Upper Arkansas River from 2012. Brown trout density (#/acre), biomass (lbs/acre), and quality (# of fish of fish ≥ 14"/acre) were collected for seven sampling locations within the project reach.

Site	Density (#/acre)	Biomass (lb/acre)	Quality (# of fish ≥ 14"/ acre)	Control / Treatment
AR-4	687	353	188	Treatment
AR-Reddy	438	121	34	Treatment
AR-5	800	151	23	Treatment
AR-5b	565	266	86	Control
AR-6a	560	135	34	Control
AR-MH	410	89	17	Treatment
AR-6	602	144	24	Control

Clear Creek, Twin Tunnels Project:

The physical habitat characteristics of Clear Creek near Idaho Springs, CO have been highly modified from historic conditions. Most of the river has been channelized with rip-rap banks as the river runs parallel with a major Interstate highway (I-70). There are very few locations left that have any functional floodplain area. Primary project goals are to restore natural processes along a large existing river bend that will allow for better floodplain connectivity, establishment of deep lateral scour pools, and enhancement of additional trout habitat features that will provide benefits for anglers. Fish population data were collected during fall 2012 from the proposed treatment site to establish baseline conditions. This site will be monitored again during fall 2013. These sampling efforts will provide two years of baseline data prior to construction activities, which are scheduled for spring 2014.

Job A.2. Physical Response of Streams to Aquatic Habitat Treatments

Job Objectives: The physical response of streams to habitat improvements will be evaluated to quantify changes in channel morphology, sediment, and water temperature. Topographic and sediment surveys will be used to evaluate changes in longitudinal profile, cross-sections, sediment size, sediment transport, and habitat suitability. BACT studies will be conducted at appropriate site locations to evaluate changes in channel morphology and water temperature following habitat treatments. For select sites, an Acoustic Doppler Current Profiler (ADCP) will be use to evaluate hydraulic conditions and habitat suitability. Research findings will elucidate how habitat treatments improve channel form and function. Results from this study will help refine techniques to maximize the benefit of rehabilitation projects on stream processes and trout fisheries.

Segment Objective 1: Develop and maintain list of candidate stream segments for stream habitat improvement studies.

ACCOMPLISHMENTS

The list of candidate sites for stream habitat improvement studies was updated to include projects identified in the previous year (Table 4). The revised list includes 20 completed projects, 3 active or ongoing projects, and 11 proposed projects. This list will also be used to select sites for evaluating the longevity of different habitat treatments (see Job A.3, Segment Objective 2).

Table 4. List of candidate stream segments for habitat improvement and treatment longevity studies.

Number	Project	River	Status	Year
1	Buckley Ranch	South Platte River	Completed	1991
2	Dream Stream (Phase 1)	South Platte River	Completed	1993
3	Big Thompsom River	Big Thompsom River	Completed	1997
4	Dream Stream (Phase 2)	South Platte River	Completed	1998
5	Grape Creek	Grape Creek	Completed	1998
6	Antero	South Fork of South Platte River	Completed	1999
7	Upper Conejos River (Phase 1)	Conejos River	Completed	2000
8	Threemile Creek	Threemile Creek	Completed	2000
9	Dream Stream (Phase 3)	South Platte River	Completed	2001
10	Lefthand Creek	Lefthand Creek	Completed	2001
11	Knight-Impler	South Fork of South Platte River	Completed	2002
12	Hartsel	South Fork of South Platte River	Completed	2002
13	Aurora	South Platte River	Completed	2003
14	Dream Stream (Phase 4)	South Platte River	Completed	2004
15	Tarryall	Tarryall Creek	Completed	2005
16	Wason Ranch	Rio Grande River	Completed	2006
17	Badger Basin SWA	Middle Fork of South Platte River	Completed	2008
18	South Boulder Creek	South Boulder Creek	Completed	2011
19	Bear Creek SWA	Bear Creek	Completed	2012
20	Dolores River SWA	Dolores River	Completed	2013
21	Upper Arkansas NRD	Arkansas River	Ongoing	2013
22	Dream Stream (Phase 5)	South Platte River	Ongoing	2013
23	Upper South Boulder Creek	South Boulder Creek	Ongoing	2013
24	Hidden Mile	Conejos River	Proposed	2014
25	Verner SWA	North Platte River	Proposed	2014
26	Josh Ames Diversion	Cache la Poudre River	Proposed	2014
27	Gunnison River SWA	Gunnison River	Proposed	2014
28	Twin Tunnels	Clear Creek	Proposed	2014
29	Tomichi Creek SWA	Tomichi Creek	Proposed	2015
30	Wexner Property	Crystal River	Proposed	2015
31	Upper Conejos River (Phase 2)	Conejos River	Proposed	2015
32	West Plum Creek	Plum Creek	Proposed	2015
33	Windy Gap Enhancement	Colorado River	Proposed	2016
34	Little Hills SWA	Dry Creek	Proposed	2016

Segment Objective 2: Conduct topographic surveys to evaluate the dimension, pattern, and profile in control and treatment sites to provide baseline data for BACT studies. Surveys will be replicated after implementation to monitor and evaluate project goals and objectives. Topographic surveys will be collected on selected pre- and post-treatment stream reaches with assistance from area aquatic biologists/researchers.

ACCOMPLISHMENTS

Verner SWA, North Platte River:

We conducted a pre-treatment reach assessment for 1.2 river miles within the Verner State Wildlife Area (SWA) to evaluate causes of stream degradation. The proposed treatment reach was surveyed to characterize the longitudinal profile, cross-section dimensions, and sediment size. These data were used to produce a baseline habitat assessment and conceptual-level restoration design. The project site was impacted by decades of heavy grazing, which led to degraded riparian vegetation, bank erosion, a widening channel, and siltation of the stream bed (Figure 2). The objectives of the restoration project are to:

1) Stabilize eroding stream banks with bioengineering treatments;
2) Re-establish riparian vegetation;
3) Increase instream habitat for brown trout;
4) Reduce sedimentation;
5) Promote sediment continuity;
6) Reduce in-stream temperature;
7) Research the cost-effectiveness of different bank stabilization treatments.

The proposed project was presented to the North Platte Basin Roundtable in June 2013 for funding through the Water Supply Reserve Account. The Basin Roundtable elected not to fund the project due to concerns about project budget and treatment longevity. CPW is currently pursuing other funding opportunities for this project. Topographic survey data for this site are included in Appendix A. Site assessment and conceptual design drawings for this project are included in Appendix B.

Upper Conejos River:

The San Luis chapter of Trout Unlimited contacted CPW regarding a potential habitat enhancement project on the meadow section of the upper Conejos River just below the town of Platoro. The proposed treatment reach was surveyed to conduct a site assessment and develop a conceptual habitat enhancement design. Previous habitat enhancement treatments were completed above the proposed treatment site in 2000. A preliminary assessment of these structures was also conducted, but further survey work will be needed for a thorough analysis of the project. Preliminary data suggest brown trout populations have increased substantially since completion of the upstream habitat project in 2000, although there is evidence of accelerated stream bank erosion near some habitat structures. Past electrofishing surveys may have coincided with runs of spawning brown trout, which could have inflated population estimates.

Topographic survey data were collected for the 0.6 mile treatment reach. Survey data were used to configure and calibrate a HEC-RAS hydraulic model for the proposed treatment reach to aid in analysis and design. Sediment data were also used to configure the HEC-RAS model and perform preliminary sediment transport calculations. Preliminary results suggest the reach has aggraded due to decreased sediment transport capacity. There is evidence of meander shoot cutoffs which suggests the river is increasing its slope to offset the aggradation. In addition, cattle grazing has exasperated channel widening, which has further degraded fish habitat by creating an even wider and shallower channel (Figure 3).

Additional topographic surveys should be conducted during spring runoff to evaluate high flows above and below Platoro Reservoir. Reference reaches above Platoro Reservoir have been identified but have not yet been surveyed. Information gathered during high flow and reference reach surveys will be used to develop a conceptual rehabilitation and habitat enhancement design. However, funding for project implementation still needs to be procured. Topographic survey data for this site are included in Appendix A.

Twin Tunnels Project, Clear Creek:

Much of Clear Creek has been channelized to provide space for the I-70 corridor. Channelization has resulted in disconnected floodplains and degraded riparian areas (Figure 4). The Twin Tunnels construction project is managed by the Colorado Department of Transportation (CDOT) and will provide a third eastbound land to the east of Idaho Springs on I-70. During construction of the new tunnel, I-70 will be redirected onto to a temporary frontage road around the Twin Tunnels site. Once construction of the new tunnel has been completed, the temporary frontage road will be removed, providing a unique opportunity for riparian restoration within the I-70 corridor. The site will be graded to develop a riparian bench which should facilitate exchange of sediment and nutrients between the river channel and floodplain. In addition, instream habitat treatments will be used to provide velocity refuge and holding water for trout. The effects of establishing riparian connectivity and improving fish habitat will be evaluated by monitoring fish populations pre- and post-treatment.

Topographic surveys were conducted to develop a site assessment and conceptual rehabilitation design. CDOT and project consultants used the conceptual design to develop preliminary and final designs with input from CPW. The riparian restoration and habitat enhancement phases of the project are scheduled for spring 2014. Topographic survey data for this site are included in Appendix A. Site assessment and conceptual design drawings for this project are included in Appendix B.

Wexner Property, Crystal River:

The Wexner Property will provide 0.6 miles of public fishing access along Crystal River. The majority of the flows in the Crystal River are diverted during the growing season, leaving little in-channel habitat for fish. During low flow periods, water temperatures in the river elevate and diversion ditches can become more attractive habitat for fish. The goals of the habitat enhancement project are to:

1) Rehabilitate trout habitat throughout the reach;
2) Develop pools to provide temperature refuge during low flow periods;
3) Reconstruct a Downstream diversion structure to accommodate sediment, fish passage, and reduce maintenance frequency.

In fall 2012, we conducted a baseline survey including a longitudinal profile and cross-sections. Sediment data were also collected to help characterize the proposed treatment reach. Additional topographic data will be collected during fall 2013 before completing the site assessment and developing a conceptual rehabilitation plan. Topographic survey data for this site are included in Appendix A.

Gunnison SWA, Gunnison River:

Residential development along the Gunnison River has decreased the extent of riparian forests by 50%. In addition, agricultural water diversion structures have accelerated stream bank erosion, land loss, downstream sedimentation, and altered riparian plant communities. In response to these issues, the Gunnison SWA was identified as an ideal site for riparian rehabilitation and instream habitat enhancement. The goals of the Gunnison River and Riparian Rehabilitation Project are to:

1) Increase wild brown and rainbow trout biomass and densities;
2) Improve conditions for quality-sized adult trout;
3) Improve fishing access with a trail system;
4) Assist water rights holders in improving and/or relocating diversion structures to improve habitat, stability, and channel alignment;
5) Create deep in-channel pools to provide lower velocity holding areas;
6) Explore the potential for reconnecting the floodplain with the existing channel to improve river function, flood capacity, and aquifer recharge;
7) Assess aggradation and degradation near bridges;
8) Maintain the existing river planform to maintain property boundaries;
9) Incorporate in-channel habitat improvement structures while not raising flood stage on properties adjacent to and Downstream of the project area where floodplain connectivity is undesirable;
10) Planting native woody vegetation in riparian areas to improve river function and wildlife habitat;
11) Improve and manage boater access.

During spring 2013, a topographic survey was conducted for 2.7 river miles within the Gunnison SWA to develop a site assessment and conceptual rehabilitation design (Figure 5). The site assessment and conceptual design will be finalized during fall 2013 and presented to the Gunnison Basin Roundtable for funding. Topographic survey data for this site are included in Appendix A.

Charlie Meyers SWA, South Platte River:

The Charlie Meyers SWA on the South Platte River is a popular fishing destination, commonly referred to as the "Dream Stream". This reach of the South Platte is located between Spinney and Elevenmile Reservoirs. Riparian vegetation was the primary control on bank erosion along the upper South Platte River, but historical grazing activities removed most of the woody riparian vegetation along this reach. The combination of altered hydrology from operation of the upstream reservoir and degraded riparian vegetation have resulted in accelerated bank erosion and degraded river processes, including maintenance of later scour pools and point bars. Due to the economic benefit from fishing, Park County identified the Charlie Meyers SWA as an ideal site for stream rehabilitation and habitat enhancement. Previous habitat enhancement efforts were completed upstream of the site in four phases from 1993-2003. The Charlie Meyers SWA project will be the fifth and final phase of the Dream Stream project.

The project will be implemented in cooperation with the Vocational Heavy Construction Technology (VHCT) program. The VHCT program was formed in a cooperative effort between the Colorado Department of Corrections (CDOC), Colorado Parks and Wildlife (CPW), and Colorado Contractors Association (CCA) to rehabilitate degraded stream habitats while providing heavy construction training for inmates committed to changing the direction of their lives. This partnership provides a means to implement stream restoration projects with substantially reduced cost (up to 90%), while reducing recidivism rates for VHCT participants by 80% compared to other inmates in the Colorado penal system.

To monitor the effectiveness of habitat enhancement activities, an ADCP was used to collect data on channel morphology and velocity distributions in five pools prior to instream construction activities. The location of ADCP cross-sections is included in Appendix A. These sites will be resurveyed after construction is completed in fall 2014 to conduct a before-after comparison of physical habitat quality. Sediment gradation and fish populations will be monitored as well. Preliminary design drawings for this project are included in Appendix B.

Tomichi Creek SWA, Tomichi Creek:

The Tomichi Creek SWA was surveyed during fall 2012 to develop a site assessment and conceptual restoration design. The reach was heavy grazed in the past and many riparian areas were converted to hay meadows. This site is a candidate for stream rehabilitation and habitat enhancement, but funding for the project has not yet been procured. Project implementation is tentatively scheduled for 2015. Topographic survey data for this site are included in Appendix A.

Figure 2. Bank erosion and siltation at the Verner SWA on the North Platte River.

Figure 3. Example of over-wide channel condition along the upper Conejos River.

Figure 4. Example of trapezoidal channel that lacks riparian connectivity along Clear Creek.

Figure 5. CPW Aquatic Biologist, Dan Brauch, and Aquatic Researcher, Matt Kondratieff, conducting a topographic stream survey on the Gunnison River within the Gunnison SWA.

Segment Objective 3: Research theoretical techniques for evaluating the effectiveness of stream restoration treatments, including modeling (e.g., HEC-RAS, PHABSIM, River2D, MDSWIMS, IBMs), ADCP technology, and/or use of reference reach data to determine what methods are best for predicting changes in habitat suitability following stream habitat enhancement.

ACCOMPLISHMENTS

PHABSIM:

The Physical Habitat Simulation System (PHABSIM) is a component of Instream Flow Incremental Methodology (IFIM) that is used to develop relationships between streamflow and physical habitat for various life stages of aquatic organisms. PHABSIM was used to analyze many streams and rivers throughout Colorado. Revisiting these sites and conducting new PHABSIM analyses would provide valuable information regarding changes in habitat quality over time. To facilitate this study, a list of candidate sites in Colorado where PHABSIM analyses were previous conducted was compiled (Table 5). Select candidate sites will be visited during fall 2013 to identify a preliminary site for resumption of PHABSIM analyses in 2014. Other methods for measuring (e.g., ADCP) and modeling (e.g., River2D) habitat suitability will also be considered for comparison with PHABSIM results.

Table 5. Historical PHABSIM sites in Colorado.

Number	Site	Reference
1	Black Canyon of the Gunnison River	Nehring and Miller, 1987
2	Gunnison River, Duncan Trail	Anderson, 1984
3	Colorado River, Parshall	Anderson, 1984
4	South Platte, Cheesman	Anderson, 1984
5	South Platte, Trumbull	Anderson, 1984
6	South Platte, Waterton	Anderson, 1984
7	North Fork of the South Platte, Pine	Anderson, 1984
8	Cache la Poudre River, Lower Wild Trout	Anderson, 1984
9	St. Vrain Creek, Lyons	Anderson, 1984
10	South Fork of the Rio Grande, Park Creek	Anderson, 1984
11	Middle Fork of the South Platte, Tomahawk	Anderson, 1984
12	Coller SWA, Rio Grande River	Shuler and Nehring, 1994
13	Arkansas River	Nehring and Anderson, 1993
14	Blue River	Nehring and Anderson, 1993
15	Cache la Poudre River	Nehring and Anderson, 1993
16	Colorado River	Nehring and Anderson, 1993
17	Fryingpan River	Nehring and Anderson, 1993
18	Gunnison River	Nehring and Anderson, 1993
19	Rio Grande River	Nehring and Anderson, 1993
20	South Fork of Rio Grande	Nehring and Anderson, 1993
21	St. Vrain Creek	Nehring and Anderson, 1993
22	South Platte River	Nehring and Anderson, 1993
23	Taylor River	Nehring and Anderson, 1993

References:

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Nehring, R.B. and Miller, D.D. 1987. The influence of spring discharge levels on rainbow and brown trout recruitment and survival, Black Canyon of the Gunnison River, Colorado, as determined by IFIM/PHABSIM models. Proceedings of the Western Association of Fish and Wildlife Agencies and the Western Division of American Fisheries Society 67: 388-397.

Shuler, S.W. and Nehring, R.B. 1994. Using the Physical Habitat Simulation Model to evaluate stream habitat enhancement project. Rivers 4(3): 175-193.

Nehring, R.B. and Anderson, R.M. 1994. Determination of population-limiting critical salmonid habitats in Colorado streams using the Physical Habitat Simulation System. Rivers 4(1): 1-19.

River2D:

The Upper Arkansas River (UAR) Natural Resource Damages (NRD) project was identified as an ideal situation for conducting a BACT study on the effectiveness of habitat enhancement treatments. The UAR trout fishery was previously degraded due to the presence of historical mine tailings throughout riparian areas. These mine tailings have since been remediated by the EPA, leading to significant decreases in dissolved metals in the UAR (Figure 6). Fish populations have increased dramatically in response to the improved water quality (Figure 7). River2D is a two-dimensional, depth average hydrodynamic and fish habitat model developed for use in natural streams and rivers. Habitat modeling with River 2D will be conducted at historical fish monitoring sites in fall 2013, for a baseline assessment of habitat quality. These sites will be surveyed again in 2014, 2016, and 2018 to evaluate the effectiveness of habitat enhancement.

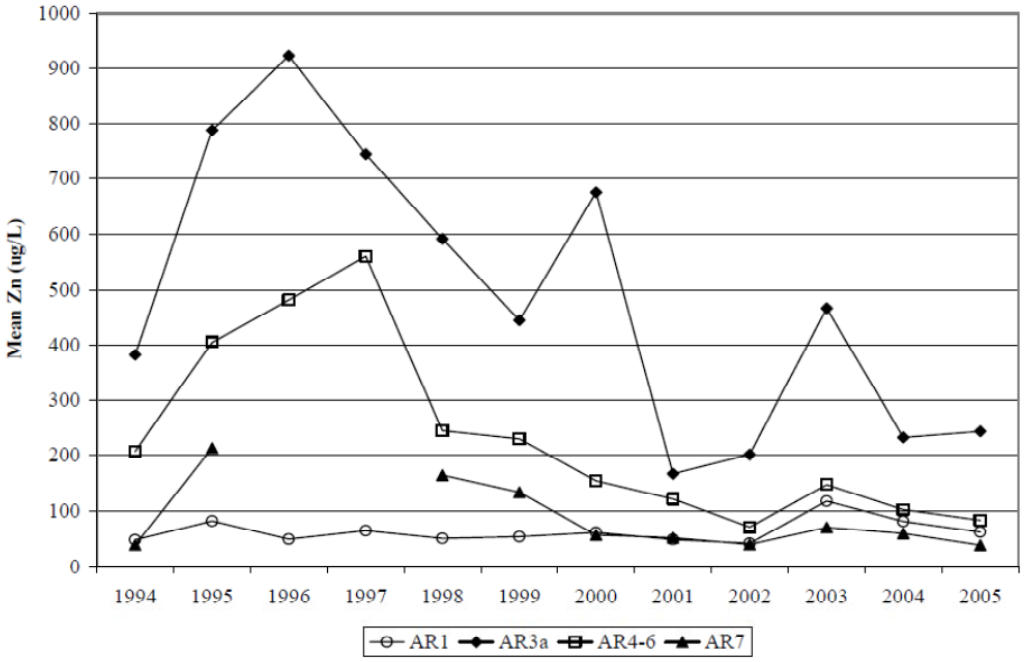


Figure 6. Mean dissolved zinc concentrations (µg/L) in the Arkansas River during spring runoff 1994-2005 (Brinkman et al., 2006).

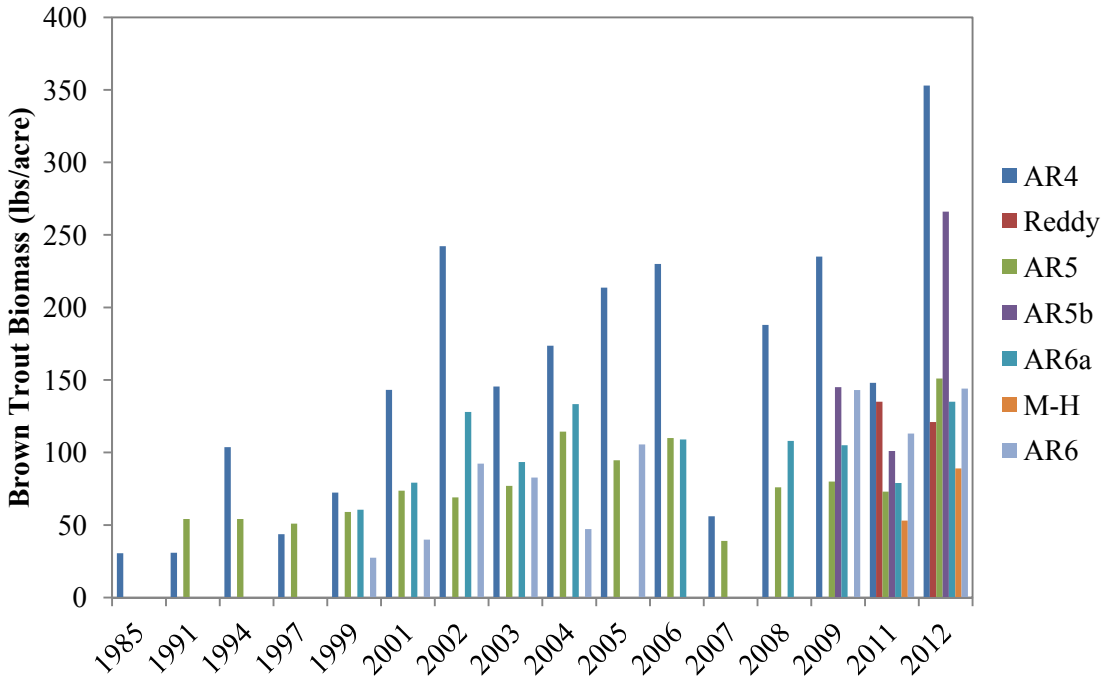


Figure 7. Brown trout biomass for historical fish monitoring sites along the Upper Arkansas River (Policky, 2012).

References:

Brinkman, S.F., Davies, P.H., Hansen, D., and Vieira, N. 2006. Arkansas River research study, final report for April 1994 to December 2005. Colorado Parks and Wildlife, Fort Collins, Colorado. 153 pp.

Policky, G. 2012. 2012 Fisheries Inventory: Upper Arkansas River Basin. Colorado Park and Wildlife, Salida, Colorado. 243 pp.

Acoustic Doppler Current Profiler (ADCP):

ADCP is being utilized at the Charlie Meyers SWA to evaluate changes in channel morphology and velocity distributions before and after implementation of the stream rehabilitation and habitat enhancement project. An ADCP was used to survey five pools within the project reach (see Appendix A for map of study pools). Five to six transects where taken for each pool. Irregular cross-section morphology and sediment deposition patterns were noted in the pools. Scour pools have developed on the inside of meander bends and fine deposition is occurring on the outside of meanders bends. Rehabilitation efforts will focus on stabilizing eroding banks, re-establishing lateral scour pools with point bars, and enhancing riparian plant communities.

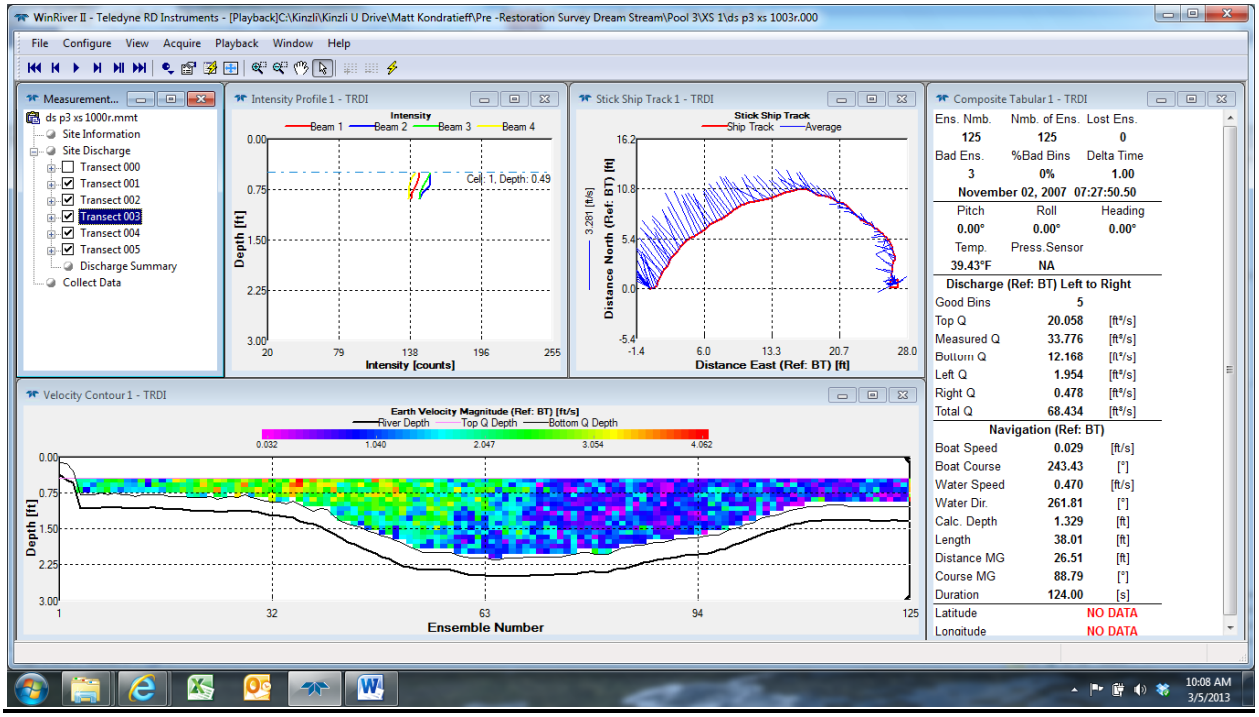


Figure 8. Velocity distribution data for pool 3 collected using an ADCP on the South Platte River, Charlie Meyers SWA.

Segment Objective 4: Monitor water temperature at rehabilitation sites where temperature has been identified as a limiting factor on trout fisheries. Temperature loggers will be deployed to evaluate the effects of stream rehabilitation and habitat enhancement on in-stream water temperature.

ACCOMPLISHMENTS

Badger Basin SWA, Middle Fork South Platte River:

The Badger Basin SWA experienced degradation of riparian vegetation due to historical grazing practices. The reach was selected for a rehabilitation and habitat enhancement project that was completed in 2011. One of the goals of the project was to stabilize eroding banks to facilitate re-establishment of woody riparian vegetation. To achieve this goal, eroding banks were stabilized with a variety of techniques and planted with a mixture of willow stakes and bare-root willow plantings. Pool habitat was also enhanced to provide deeper, and cooler, holding water for brown trout. We hypothesize the combination of improved shading from re-establishing willows and a deeper channel will result in cooler water temperatures. To test this hypothesis, we deployed temperature loggers directly upstream and Downstream of the project reach in the spring of 2013. Temperature data will be downloaded prior to winter and analyzed to evaluate changes in temperature as water move through the rehabilitated sites. Temperature loggers will be maintained at the site for at least three years to monitor the impact of willow growth on instream temperature.

Verner SWA, North Platte River:

The Verner SWA on the North Platte River experienced riparian degradation due to decades of heavy grazing. The reach is mostly devoid of woody riparian vegetation on the outside of meanders bends. This lack of bank stabilizing vegetation has led to substantial bank erosion, which in turn has created a wide and shallow channel with minimal shade. Irrigation practices in the area decrease streamflows during the growing season. The combination of decreased flows and wide channel can lead to increased water temperatures. As the reach is a candidate site for stream restoration and habitat enhancement, a water temperature logger was deployed on the upstream boundary of the site during spring 2013 to establish baseline water temperature conditions. Water temperature will monitored at this site to assess if riparian rehabilitation and habitat enhancement results in reduced water temperatures.

Segment Objective 5: Investigate the effects of water development and altered flow regimes on aquatic habitat.

ACCOMPLISHMENTS

Upper Conejos River:

Historical data were analyzed for the Upper Conejos River to evaluate the affects of reservoir operation on hydrology and channel morphology. Average daily discharge was analyzed for three periods: pre-dam (1937-1949), post-dam (1952-1964), and the last 30-years (1982-2011).

Annual peak flows have decreased by approximately 35% from pre-dam records when compared to the current flow regime. Bankfull discharge (i.e., return interval of 1.8-years) has decreased from 1010 cfs to 630 cfs (or 37%) (Figure 9).

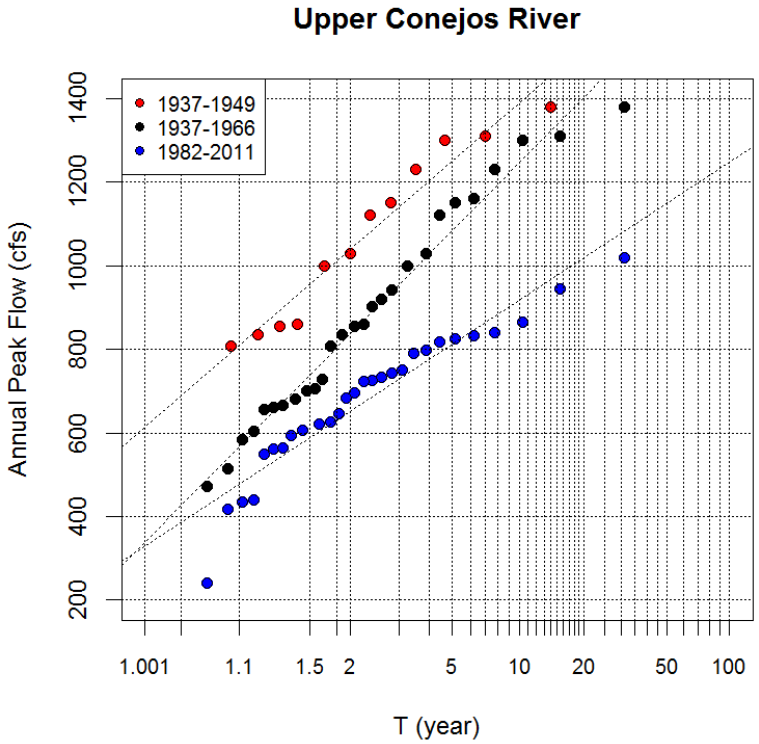


Figure 9. Flood-frequency analysis for Upper Conejos River comparing the magnitude of pre-dam (1937-1949), post-dam (1952-1964), and recent (1982-2011) flood events.

Hydraulic geometry was used to evaluate the effects of decreased flows on channel morphology (i.e., aquatic habitat). Estimates for bankfull discharge were used to calculate bankfull top width with equations from Torizzo and Pitlick (2004). The bankfull top width for the pre-dam flow regime was estimated at 70 ft. Survey data collected in September 2013 were used to configure and calibrate a HEC-RAS model for the proposed treatment section on the Upper Conejos River. The model was used to analyze existing conditions for the treatment reach. The existing bankfull top width for the channel is 90 ft, meaning the channel may have widened by 20 ft since construction of Platoro Reservoir. Channel widening is likely due to sediment aggradation from decreased transport capacity under the altered flow regime. Grazing of riparian vegetation may have exasperated channel widening by decreasing bank stability. Rapid drawdown of reservoir releases could also have contributed to bank failure and channel widening.

Stable channels in dynamic equilibrium are the most effective and sustainable means to create and maintain habitat for a variety of aquatic species and life stages. Cross-section geometry was estimated for a channel in dynamic equilibrium under the current flow regime. The desired top width for the Upper Conejos River was estimated at ~55 ft, meaning the channel would need to be narrowed by ~35 ft (or 39%) to achieve stable channel geometry for the existing flow regime.

Cache la Poudre River:

Historical hydrology was analyzed for three sites on the Cache la Poudre River to evaluate the effects of river regulation and water development on channel morphology. After flowing past the Canyon Mouth gauge, the river flows through the town of Fort Collins before reaching its confluence with the South Platte River just below the town of Greeley. Flood-frequency analysis was used to evaluate changes in magnitude and frequency of peak flows. Approximately 20% of the stream flow is diverted at the Canyon Mouth gauge, and an additional 70% is diverted by the Fort Collins gauge. This means that about 90% of flows in the Cache la Poudre have been diverted before the river reaches Fort Collins. Conversely, return flows from irrigation and municipalities lead to increased baseflows Downstream of Fort Collins (Figure 10). Hydraulic geometry was used to assess how much the river would need to be modified to achieve a more stable form under the current hydrology. Preliminary results suggest that the river may need to be narrowed by up to 40% around Fort Collins to achieve a stable geometry in dynamic equilibrium.

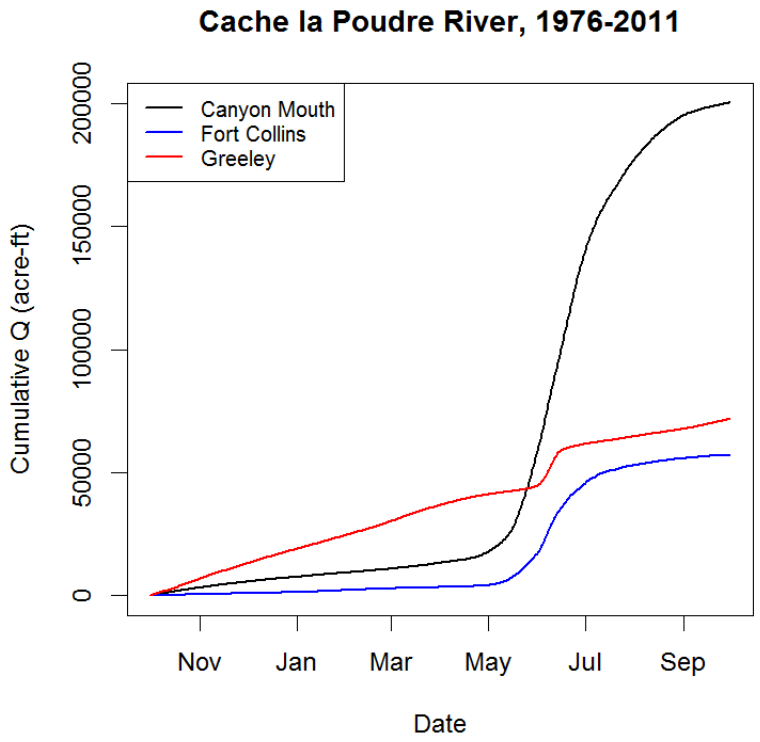


Figure 10. Average cumulative discharge for three sites along the Cache la Poudre River from 1976-2011.

Upper Colorado River:

Historical hydrology was analyzed for six sites within the Colorado River Headwaters. Some of the more dramatic changes in flows are evident at the Kremmling stream gauge (Figure 11). Trans-basin diversions that were developed from the 1930s to 1980s are largely responsible for

the altered hydrology in the Upper Colorado River. Additional water development is planned in the Colorado Headwaters, which could further exasperate poor habitat conditions in the river

Flood frequency analyses were performed for the Colorado River near Kremmling and Colorado River below Windy Gap to evaluate changes in bankfull discharge. The 1.8-year flow was assumed to representative of bankfull discharge and decreased by 73% at the Kremmling gauge between historical (1905-1918) and recent (1986-2011) periods. In addition, average annual peak flows decreased by 81% and water yield decreased by 52% at the Kremmling gauge over this same period. Hydraulic geometry equations were used to estimate the appropriate channel dimensions to maintain sediment continuity and habitat complexity under the modified flow regime. Preliminary results suggest the Upper Colorado River is over-wide in certain place. Topographic surveys will be conducted in 2013 to further analyze the effects of water develop on channel geometry and habitat quality in the Upper Colorado River.

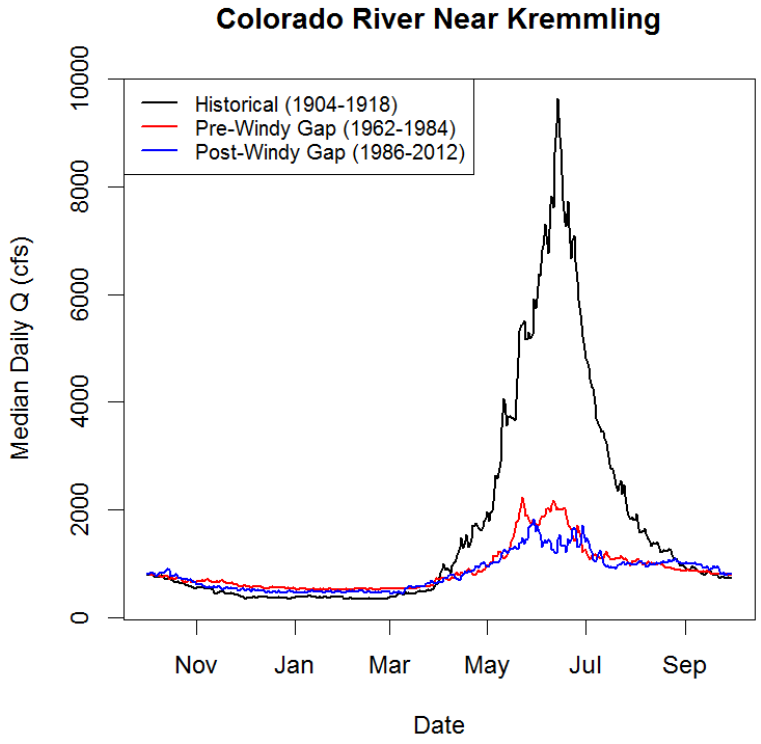


Figure 11. Average daily discharge for the Colorado River near Kremmling over three different periods.

References:

Torizzo, M. and Pitlick, J. 2004. Magnitude-frequency of bed load transport in mountain streams in Colorado. Journal of Hydrology 290: 137-151.

Job A.3. Effectiveness of Stream Aquatic Habitat Treatments within Functional Categories.

Job Objectives: The effectiveness of specific habitat treatments will be evaluated by addressing the following research questions: how do fish utilize the treatment, what is the life expectancy of the treatment, what maintenance is required to keep the treatment functioning properly, what is the initial cost in terms of labor and materials to install the treatment, and how immediate is a given treatment able to provide the desired benefit? A variety of methods will be tested (snorkel survey, underwater video and photography, PIT tag arrays, and electrofishing sampling) to determine how fish utilize specific treatments. Individual treatments and project cross sections will be surveyed, monitored and inspected over time to determine their life expectancies, maintenance costs and how quickly they are able to provide the desired benefits. The material costs and length of time to install particular treatments will be recorded to determine overall costs for installation of particular treatments. Various treatments will be compared within functional groups to assess their relative costs and benefits.

Segment Objective 1: Fish utilization of various treatment types

During summer and fall months, conduct pilot studies using a variety of potential fish monitoring techniques including some or all of the following: PIT tagging, radio telemetry, snorkel surveys and underwater video and photography for evaluating fish use of specific aquatic habitat treatments.

ACCOMPLISHMENTS

Ongoing studies using PIT tagging technology were initiated to investigate fish passage through WWP structures in Lyons on St. Vrain Creek and fish passage through engineered rock ramps (over diversion structures) on South Boulder Creek. Studies using PIT tagging technologies with fixed antenna systems were effectively applied in order to monitor fish movements within each of the these studies. PIT tagging shows promise as a possible technique to evaluate how fish utilize specific habitat treatments in future studies.

We began conducting pilot studies using underwater video during the fall of 2013. The method shows promise for evaluating habitat treatments from the fish's perspective. Pilot work with underwater video will continue through 2013 and 2014.

No pilot studies with radio telemetry, snorkel surveys, and photography techniques were used during this segment.

Segment Objective 2: Treatment longevity

Cross-sections at specific aquatic habitat treatment locations for which we have before, as-built and post-monitoring data will be re-surveyed to monitor treatment longevity and evaluate stability over time.

ACCOMPLISHMENTS

Dream Stream, South Platte River – Historical Cross Sections:

The Dream Stream is popular fishing destination on the South Platte River located between Spinney and Elevenmile Reservoirs. The reach has undergone four phases of stream restoration and habitat enhancement starting in 1993. Prior to Phase II, a series of monumented cross-sections were established in 1997. These cross-sections were surveyed after completion of habitat enhancement activities in 1998, and again in 2000. These cross-sections were located and re-surveyed in 2012 to evaluate changes in channel morphology (Figure 12). Graphical analysis of the cross-sections suggests that the habitat improvement project resulted in a stable channel that was narrower and deeper than the original channel (Figure 13). Additional analyses are planned to evaluate changes in cross-section area, top width, and bankfull depth in detail. There are additional sites throughout South Park that will be incorporated into the study following completion of the Dream Stream evaluation.

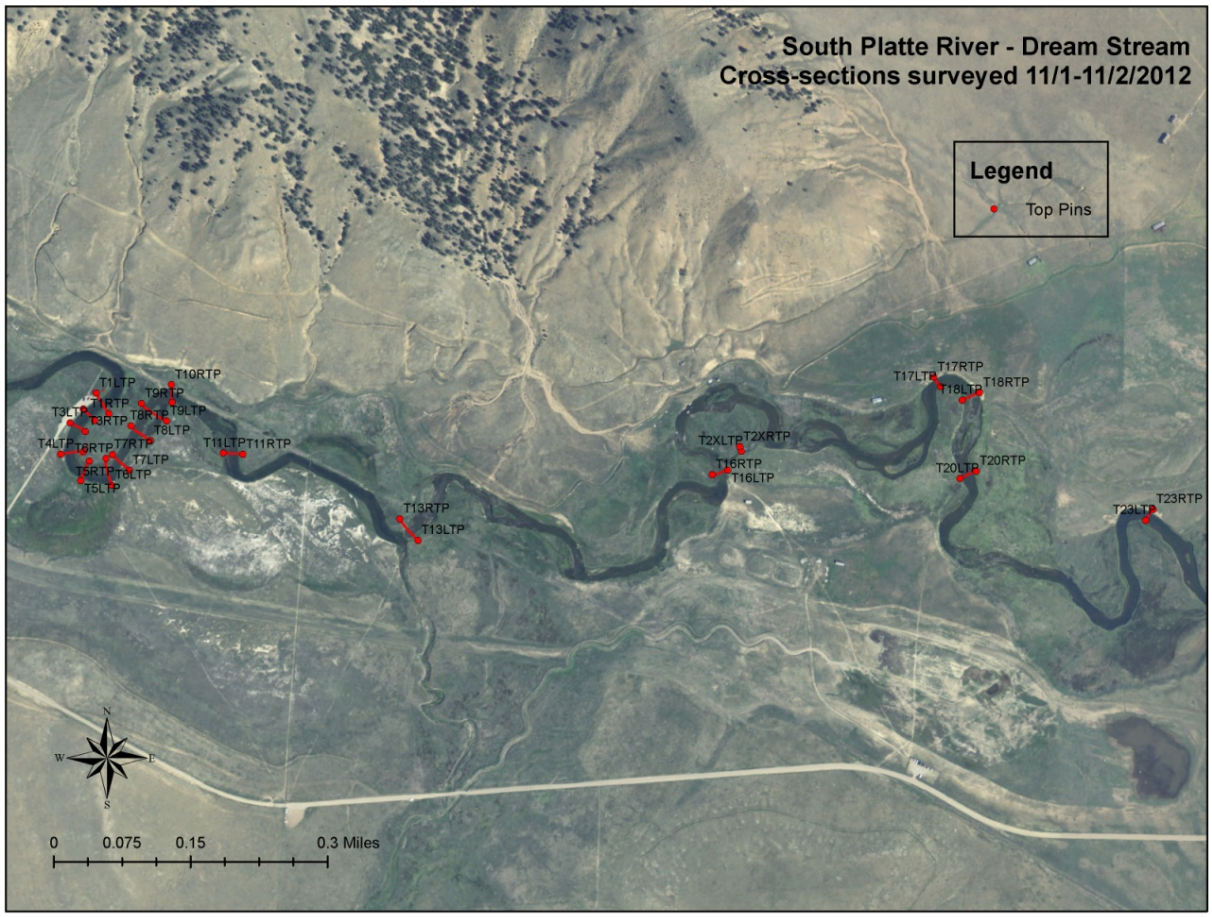


Figure 12. Map of 18 historical cross-sections along the South Platte River (i.e., Dream Stream) that were established in 1997 and re-surveyed in 2012.

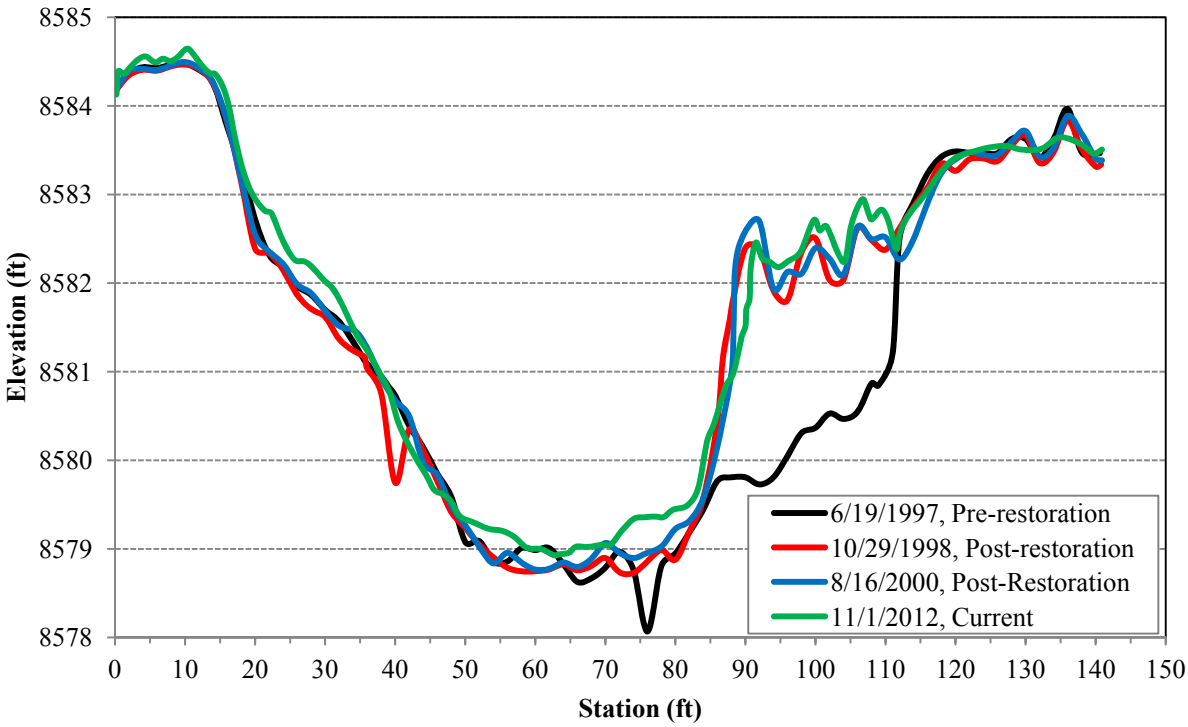


Figure 13. Example cross-section (T-1) on the South Platte River below Spinney Reservoir (i.e., Dream Stream) showing survey data pre-restoration (1997) and post-restoration (1998, 2000, and 2012).

Segment Objective 3: Treatment maintenance and costs

Past project restoration costs will be evaluated with the following criteria: material and labor costs for various habitat treatments, length of time to install specific aquatic habitat treatments, maintenance costs associated with specific treatments and how quickly specific habitat treatments provide their intended function. Various aquatic habitat treatments will be compared within functional groups to assess their relative costs and benefits.

ACCOMPLISHMENTS

Data collection on restoration costs from various CPW stream restoration projects is ongoing. We will continue to collect and analyze data related to treatment and maintenance to determine how various habitat treatments compare using a cost/benefit analysis. Treatment-specific costs were compiled using contractor bids for the Upper Arkansas River NRD project. Conservative cost estimates for contractor installed treatments are presented in Table 6. We should note that these costs were developed for a specific project and will vary with project location and availability of materials. Methods for evaluating the benefits of different treatment types will be developed to facilitate cost/benefit analyses.

Table 6. Estimated costs for contract installed treatment types. Note that costs were developed for a specific project and will vary.

Treatment	Cost	Unit
Cobble Toe with Sod Mat	$25	LF
Cobble Toe with Soil Lift	$40	LF
Brush Fascine with Sod Mat	$45	LF
Brush Fascine with Soil Lift	$60	LF
Coir Log with Sod Mat	$45	LF
Coir Log with Soil Lift	$60	LF
Horizontal Log with Sod Mat	$125	LF
Horizontal Log with Soil Lift	$140	LF
Root Wad with Sod Mat	$160	LF
Root Wad with Soil Lift	$175	LF
Log Vane	$3,000	EA
Bare Root Willow Plantings	$1.60	EA
Willow Stakes	$1.25	EA
Hardened Cattle Crossing	$1.25	SF
Enhance Pool	Included with bank treatment costs	
Grade Point Bar	Included with bank treatment costs	
Oxbow Development	Included with bank treatment costs	

Job A.4. Angler Use in Restored Versus Un-restored River Channels.

Job Objectives: Creel studies will be conducted to determine how angler use has changed in restored compared to un-restored river channels.

Segment Objective 1: Historic creel data

Aquatic biologists will be consulted to determine what data (if any) exist at proposed river restoration locations to quantify pre-restoration angler use.

ACCOMPLISHMENTS

Aquatic biologists were consulted for any existing creel data that might exist to quantify angler use in proposed river restoration reaches. No historical creel data were identified for use in evaluating changes in angler use for proposed river restoration reaches.

Segment Objective 2: Creel studies

ACCOMPLISHMENTS

Since no historic creel data exists, we will conduct creel surveys to quantify angler use specific to the un-restored river channel segment. Once stream restoration is completed, we will continue conducting creel studies to quantify angler use specific to the restored river channel segment for

comparison. Creel studies were planned in pre- and post- treatment stream reaches during spring/summer 2012.

Upper Arkansas River Project: Creel studies were planned and conducted successfully on the Upper Arkansas River to establish baseline data for comparing angler use and fisheries response pre- and post- restoration on the Upper Arkansas River basin from May 1, 2012 through October 30, 2012. Summary data on angler use will be useful in determining the economic benefits of habitat enhancement projects pre- and post- construction once the Upper Arkansas Habitat Improvement project is completed.

South Platte Basin Projects: A 3-month creel was completed from April 1, 2013 through June 30, 2013 on the South Platte River between Spinney Mountain Reservoir and Elevenmile Canyon Reservoir (Dream Stream). The entire reach was been broken into three discreet segments including: Segment 1, a 2.0 mile treated reach below Spinney Mountain Reservoir Dam to the end of the treated section; Segment 2, a 1.5 mile proposed project reach from the end of the treated section to County Rd 59; and Segment 3, a 2.0 mile control reach between County Rd 59 and the confluence of the South Platte River with Elevenmile Canyon Reservoir. These data will be useful in comparing angler use before and after completion of the Charlie Meyers SWA habitat enhancement project.

An additional future creel study on the South Platte would include the reference reach (Tomahawk SWA), completed project reach Badger Basin SWA (Middle Fork of South Platte below Badger Basin Headquarters), proposed project reach Badger Basin SWA (South Fork of South Platte above Badger Basin Headquarters) and completed project reach Buckley Ranch (South Platte River). Ongoing creel studies for additional proposed sections within South Park will be contingent on future budget amounts.

Job A.5. Identification, Evaluation and Development of Fish Barriers for Protecting Colorado Fishes.

Job Objectives: Develop field and theoretical techniques for evaluating the barrier potential of in-stream obstacles. This study will involve multiple years of data collection statewide. Specific projects will result from consultations with aquatic biologists requesting assistance with measuring the barrier potential of in-stream structures. Examples include evaluation of fish barrier function to protect cutthroat trout populations from whirling disease or non-native salmonids, evaluation of native sucker and sport-fish passage through white water park (WWP) structures and evaluation of diversion, low-head dam and culvert structures for passage of various Colorado fishes. Data collected from field sites will be useful in developing species-specific fish passage criteria, evaluating existing in-stream obstacles, refinement of monitoring techniques for fish passage at potential barrier sites and improvement of theoretical techniques for evaluating fish passage.

Segment Objective 1: Continue working with aquatic biologists to evaluate the barrier potential of in-stream obstacles to Colorado fishes. Develop publishable fish passage criteria for correcting potential barriers (i.e., culverts, diversions, WWP structures). Conversely, continue

evaluations to assist with new barrier designs or modification of existing barriers to protect native Colorado sportfish from downstream threats.

ACCOMPLISHMENTS

Evaluation and Development of Fish Passage Designs:

Techniques to modify existing diversion structures that will allow upstream and downstream migration for various trout species are being evaluated. This project includes an ongoing PhD study to determine the effectiveness of existing fishways (such as engineered rock ramps) for passage of salmonids, refine techniques for monitoring fish movement at potential barriers, and evaluate impacts of artificial in-stream structures, such as water diversion structures, on fish movement. The PhD student, Ashley Ficke, has completed field and laboratory data collection and is in the process of synthesizing results for her dissertation.

Physical habitat alterations have been identified as one of the primary causes leading to declines and extinctions of fishes over the past century. Stream habitat alterations that limit sport fish dispersal and connectivity between populations include diversions, structures installed at road-stream crossings, and impoundments. For this study, suitable sites for deploying antennae arrays were identified on South Boulder Creek in Boulder with cooperation from City of Boulder Open Space. Movements of PIT tagged fish were monitored using a pair of antennae placed upstream and Downstream of a diversion that was modified to facilitate fish passage. The antenna system was successfully used to monitor movements of wild salmonid fishes. Topographic habitat surveys of three locations within the study reach were conducted on South Boulder Creek including McGinn Ditch, South Boulder Canyon Ditch, and a control reach located in between both diversions. In addition, detailed hydrologic and hydraulic measurements have been completed at these field sites. The physical habitat data were used to design and construct scale models of rock ramp structures to evaluate performance of existing structures at the CSU Engineering Research Center (ERC) laboratory during 2012 (Figure 14).

CPW has provided funding, project oversight and assistance with data analysis, study design, equipment purchases, and research supplies. In addition, CPW assisted with collecting fish (including brown and rainbow trout) as well as PIT tag array installation and maintenance. The following project components have been completed:

1) Field study and data analyses in Program MARK;
2) Predictive swimming performance model trials (CAT tests);
3) ERC rock ramp construction and hydraulic measurements;
4) ERC tests of fish passage success;
5) Swimming performance data analyses;
6) ERC rock ramp data analyses;

The following project components are should be finalized in 2013:

7) Submission of final report to CPW;
8) Publication of dissertation and professional papers.

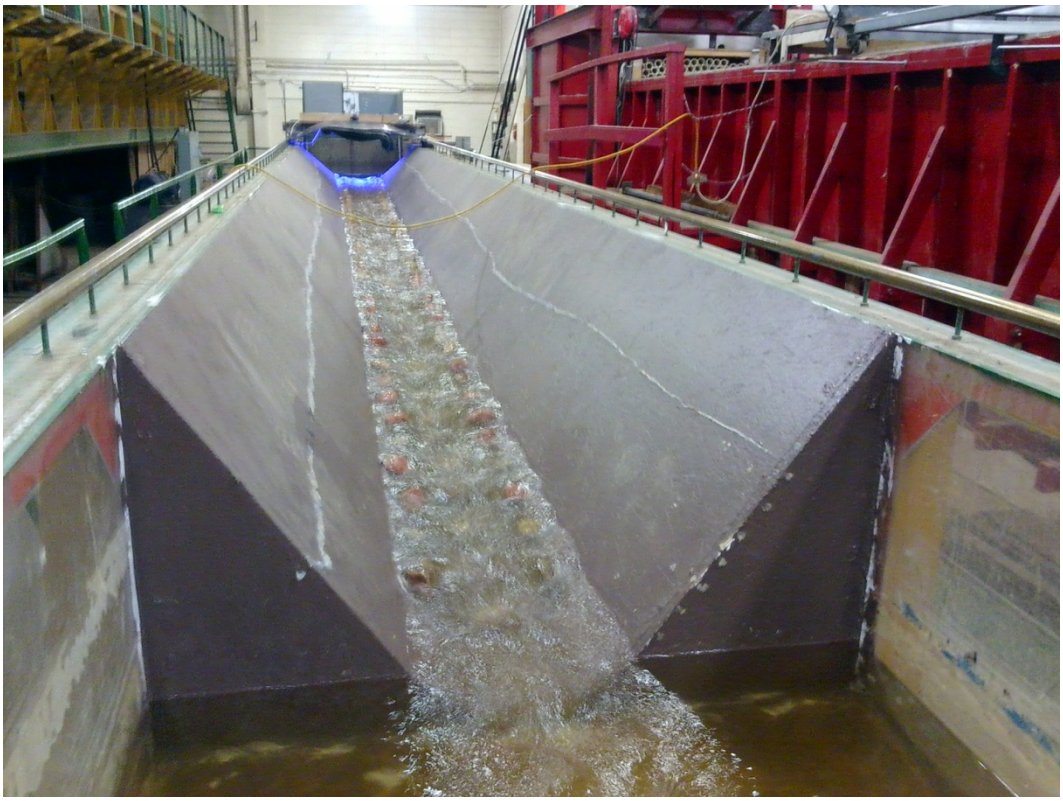


Figure 14. Rock ramp model being tested at the CSU Engineering Research Center laboratory.

Fish Passage in Colorado White Water Parks:

With more white water parks (WWP) than any other state, Colorado is the epicenter for white water park design and construction. WWPs contribute to local communities by providing revenue from tourism, promoting public interest in rivers and creating exciting new recreational opportunities. However, no comprehensive studies have been completed to assess the effects of WWPs on fisheries and river ecology. To better understand the effects of WWPs, CPW initiated a pilot study to monitor a small number of WWPs in Colorado. This study identified a number of concerns, including:

1) Impaired fish passage;
2) Loss of aquatic and riparian habitat;
3) Disruption of natural river processes;
4) Angler and boater conflicts.

These concerns were developed through observations of altered habitat and hydraulic conditions at WWPs. Field measurements of high velocity zones within WWP structures indicated that flows may exceed the swimming ability of fish, which could limit upstream fish passage. In addition, the turbulent flow patterns below WWP structures could create undesirable habitat conditions. To better understand the effects of WWPs on fish movement and habitat, CPW funded and initiated a comprehensive research project in cooperation with Colorado State University (CSU) to study a WWP in Lyons, Colorado (Figure 15). Although this project is still ongoing, the following updates from Fox et al. (2013) are included as a brief synopsis:

I. Fish Passage Study

We used a Passive Integrated Transponder (PIT) telemetry system to track fish movement and directly assess the effects of WWPs on upstream fish movement. PIT telemetry is a type of passive radio frequency identification (RFID) with the capability to detect uniquely coded radio tags that pass within the vicinity of fixed antennas. Because PIT tags are small (<32mm) and operate without batteries, they are ideal for studies involving a number of individuals over relatively long time periods.

Approximately 2,500 individual fish including brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*), longnose sucker (*Catostomus catostomus*) and longnose dace (*Rhinichthys cataractae*) were tagged and released within the vicinity of the project (Figure 16). A total 12 fixed PIT antennas were installed to monitor upstream movement across three WWP and three control sites.

Figure 15. White water park structure in Lyons, Colorado.

Figure 16. Inserting a PIT tag into a brown trout to assess fish movement in white water parks.

For this study, we collected PIT telemetry data that included over 10 million individual detections of tagged fish. Results show that this WWP is not a complete barrier to upstream movement, but differences in WWP and control movement may indicate a partial barrier. Proportions of fish moving upstream differed by up to 30 percent based on 359-494 individuals observed at each sampling location. Maximum water velocities observed in the chutes of WWP structures exceeded 3 m/s in some instances, while those within the control reach were typically below 1 m/s.

Further analysis is currently underway to assess this difference in movement rate and how it may be related to the hydraulic conditions at the WWPs. We are using the PIT data and a mark-recapture statistical model to assess differences in movement probability between the WWP and control sites. We will also be assessing the effects and interactions between species, body length and hydraulic conditions using the FLOW-3D® modeling results. The results of this analysis will assist future research needed in developing design guidelines to optimize the recreational and ecological benefits of WWP structures.

II. Hydraulic Model Development

FLOW-3D® is a commercially available hydraulic modeling software package. This model outputs a dataset of detailed information on flow velocity, direction and depth, which can be used to evaluate fish passage and habitat at relevant spatial scales over a range of flow conditions.

To build the model for each WWP reach and control reach, we collected detailed channel bed and bank topography, upstream and downstream flow conditions, and a channel bed roughness to approximate the effects of boulders and cobbles in the stream to be specified in the computer model. We validated the accuracy of the model by comparing predicted velocities and depths with field measurements. Multiple simulations were performed at different of flow rates that matched the low, medium, and high flow conditions for each of the study sites (Figure 17).

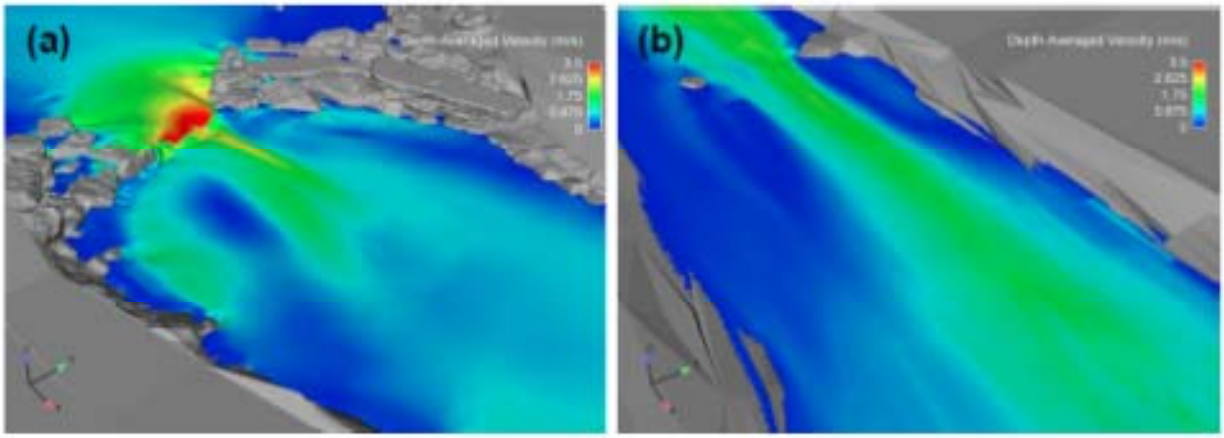


Figure 17. Results from FLOW-3D model showing velocity patterns in (a) white water park structure and (b) control pool (Kolden, 2013).

III. Fish Habitat Study

We used the output of the FLOW-3D® models to calculate predicted habitat quality in the WWP pools and control pools. Habitat suitability equations were used for this process, which relate the 2-D hydraulic variables depth and depth-averaged velocity to habitat suitability for specific fish species and life stages. Predicted habitat suitability in the WWP pools based on these equations was on par with control pools for all species and life stages; however, CPW conducted fish biomass estimates in the same WWP pools and control pools and found more adult brown trout and rainbow trout biomass per volume in the control pools during two years of surveys, which directly contradicts the prediction of habitat suitability models for these species.

This contradiction suggests that the habitat suitability analysis is not accurately predicting habitat suitability in the WWP pools, and there are many possible explanations for the discrepancy. First, the habitat suitability equations are based solely on the 2-D variables of depth and depth-averaged velocity. It is clear from the FLOW-3D models of the WWP pools that there is substantial flow complexity in the vertical direction, and this 3-D flow complexity could affect fish habitat in a way that is not reflected in the habitat suitability equations. Secondly, the predictions take into account only hydraulic conditions, while there are many other factors that affect habitat quality including competition, predation, food availability, water quality, and recreational use.

The results of this habitat analysis show that more research is needed to understand the specific ways that WWPs affect aquatic habitat quality. 3-D modeling has the potential to be very useful

in this research, especially as we increase our understanding of how habitat quality is correlated to 3-D hydraulic variables such as turbulence, vorticity, and circulation.

IV. Summary

CPW is still collecting data on WWPs and their influence on fish passage, fish habitat quality, natural stream processes, and potential conflicts between boaters and anglers. We have collected a substantial amount of preliminary information on each of these topics to provide evidence of the negative impacts of WWP structures. Research findings are in the process of being synthesized and published. This study has supported two graduate students, Brian Fox and Nell Kolden, in the Department of Civil and Environmental Engineering at CSU. Nell Kolden has successfully defended and published her thesis (see publications below). Brian Fox has successfully defended his thesis and is expected to publish his thesis in 2013. We hope that information from this study will aid in developing WWP designs that do not impede fish passage, degrade fish habitat, or impair river processes.

Publications:

Fox, B., Kolden, E., and Bledsoe, B. 2013. 3-D modeling of fish passage in Colorado whitewater parks. Colorado Water 30(3): 12-14.

Kolden, E. 2013. Modeling in a three-dimensional world: Whitewater park hydraulics and their impact on aquatic habitat in Colorado. M.S. Thesis, Department of Civil and Environmental Engineering, Colorado State University. 67 pp.

STUDY PLAN B: TECHNICAL ASSISTANCE

Job B.1. Stream Restoration Assistance to CPW Personnel and other State and Federal Agencies.

Job Objectives: To provide expertise, consultation, evaluation and training related to stream habitat restoration project identification, selection, design and permitting to CPW and other state and federal personnel as requested.

Segment Objectives: CPW and other state and federal personnel are frequently in need of technical assistance related to stream habitat restoration projects. Technical assistance related to stream habitat restoration project identification, selection, design, evaluation, and permitting will be provided to CPW and external agencies. Technical assistance includes review of stream restoration project designs for aquatic biologists and district wildlife managers (DWMs), site visits to proposed stream restoration locations, consultations with various agencies on stream restoration opportunities associated with highway and bridge improvement projects, project management of aquatic habitat treatment construction during highway bridge replacements or Fishing is Fun (FIF) projects, consultations and technical support related to stream mitigation work for 404 permit violations, technical and physical assistance related to fish barrier design and construction, and teaching at various technical training sessions for CPW and other state and federal personnel.

Job activities included: presentations to CPW (internal) and non-CPW (external) personnel, technical assistance to CPW area biologists and DWMs, technical assistance to non-CPW external government agencies and private consultants, technical assistance related the Upper Arkansas NRD (Natural Resource Damage) project, technical assistance to the Upper Colorado Wild & Scenic Stakeholder Group, technical assistance related to design, construction, and monitoring of fish barriers, providing training to CPW personnel and acquiring additional technical expertise and professional job skills.

ACCOMPLISHMENTS

Presentations, CPW (Internal)

Presentations to CPW personnel were delivered with the goal of increasing interactions and communication with Regional CPW staff (i.e. local Area meetings) and providing current research finding to the CPW Aquatic Section (Aquatic Biologists and Senior Aquatic Staff).

Kondratieff, M.C. 2013. River Restoration Benefits and Impacts of White Water Parks. Northeast Region Biology Days, Colorado Parks and Wildlife, Denver, CO. January 31, 2013.

Kondratieff, M. C. 2013. Enhancing Stream Habitat for Fisheries in Colorado. Colorado Parks and Wildlife Commission Meeting, Greeley, CO. March 7, 2013.

Kondratieff, M.C. 2013. River Restoration Benefits and Impacts of White Water Parks. Southeast Biology Days, Colorado Parks and Wildlife, Pueblo, CO. April 18, 2013.

Richer, E.E., Kondratieff, M.C., and Kittel, T. 2013. Colorado Parks and Wildlife Stream Rehabilitation Team. Annual CPW Aquatic Biologist Meeting, Steamboat Springs, CO. January 24, 2013.

Presentations, non-CPW (External)

Presentations to non-CPW personnel were delivered with the goal of communicating recent research findings to interested parties and educating students and professionals on river restoration techniques.

Kondratieff, M.C. 2012. Introduction to Fluvial Geomorphology-Course 1: Stream Fish Habitat Concerns. USDA Natural Resources Conservation Service (NRCS), Keystone, CO. August 1, 2012.

Kondratieff, M.C. 2012. Charlie Meyer SWA stream habitat enhancement project. Land and Water Trust Fund (LWTF) meeting, Park County Board of County Commissioners, Bailey, CO. August 2, 2012.

Kondratieff, M.C. 2012. Limiting factors analysis: Integrating salmonid spatial needs in Natural Channel Design. Implementation of Geomorphic Restoration Structures - Course 5, USDA Natural Resources Conservation Service, Kremmling, CO. October 3, 2012.

Kondratieff, M.C. 2013. Whitewater parks and their influence on fish habitat quality. Colorado/Wyoming Chapter of the American Fisheries Society 2013 Annual Meeting, Fort Collins, CO. February 26, 2013.

Kondratieff, M.C. 2013. Whitewater parks and their influence on fish habitat quality. Colorado State University Student Group Chapter of the American Fisheries Society, Colorado State University, Fort Collins, CO. March 13, 2013.

Kondratieff, M. C. 2013. Restoring Colorado Rivers and Introduction to Fisheries Science and Management. Wildlife Management Short Course 2013, Colorado State University, Colorado State University, Fort Collins, CO. March 26, 2013.

Kondratieff, M.C., Fox, B., and Kinzli, K. 2013. Are White Water Parks Good Fish Habitat? International Conference on Engineering & Ecohydrology for Fish Passage, Oregon State University, Corvallis, OR. June 27, 2013.

Richer, E.E. 2013. Effects of river regulation on hydrology and aquatic habitat. Guest lecture for WR304, Principles of Watershed Management. Colorado State University, Fort Collins, Colorado. February 21, 2013.

Richer, E.E. 2013. Effects of river regulation on hydrology and aquatic habitat: Three Colorado case studies. 2013 Annual Meeting, Colorado/Wyoming Chapter, American Fisheries Society. Fort Collins, CO. February 27, 2013.

Technical Assistance, CPW Staff (Senior Biologists, Area Biologists, Engineers, property technicians, DWMs, and AWMs)

We provided technical assistance to CPW internal staff as requested. Technical assistance included work related to evaluating fish passage at white water parks, culverts and other potential barriers, writing CPW position papers on a variety of fish habitat-related topics (e.g., white water parks), reviewing habitat restoration construction plans related to river restoration and trout habitat enhancement as part of the ACOE 404 permitting process, assisting with physical habitat surveys and equipment, assisting various property technicians on how to manage CPW properties with rivers in mind (e.g., appropriate locations for water gaps for cattle grazing), designing and reviewing fish barrier construction designs to protect native cutthroat trout populations, assisting Army Corps of Engineers (ACOE) staff and CPW water specialists to develop a new ACOE 404 permit (Regional General Permit 12) specifically for stream habitat improvement projects with fisheries-related goals for Colorado, providing aquatic biologists with cost estimates for specific habitat treatments to enhance sport fish populations in streams, providing technical expertise related to fish passage, providing technical expertise related proposal review and selection of stream habitat restoration firms, writing grants to generate funding for future habitat improvement projects, providing field consultation services to CPW staff related to potential stream habitat improvement projects and providing technical expertise related to river impacts from large-scale water development projects in Colorado (i.e., Windy Gap and Moffat Firming Project).

Technical Assistance, non-CPW external government agencies and private consultants

We provided technical assistance to non-CPW external government agencies and consultants as requested. Technical assistance included developing monitoring plans for evaluating stream habitat projects in South Park, CO, presenting fisheries concerns associated with WWP development, assisting with fish barrier designs and developing conceptual ideas for trout habitat improvement. Technical assistance to non-CPW external government agencies included the Army Corps of Engineers (ACOE), Colorado Department of Transportation (CDOT), Colorado Springs Utilities, Michigan Department of Natural Resources (DNR), and USFS. Assistance was specifically related to potential impacts of White Water Parks to fisheries, creation of a new ACOE 404 permit for stream restoration projects, developing plans to enhance trout habitat in Clear Creek in conjunction with an I-70 highway expansion project, assistance in writing and developing a white paper on the potential harm of WWP development on fisheries in Michigan and serving as a stream restoration expert assisting with development of restoration options for Armstrong Creek as part of a large-scale stream restoration project in the Steamboat Springs area.

Technical Assistance, Upper Arkansas NRD Project

We provided technical assistance to various agencies and organizations involved in the Upper Arkansas NRD project as requested. Technical assistance included: participation in Upper Arkansas Project trustees coordination meetings, LCOSI (Lake County Open Space Initiative) meetings and I-team meetings, technical and logistical planning with Brian Bledsoe (CSU Engineering Professor), Rod Van Velson (retired CPW Aquatic Researcher), Tracy Kittell (CPW Design Engineer), and Greg Policky (CPW Aquatic Biologist). Review of publications, reports, and other relevant literature related to the Upper Arkansas River NRD project and presenting information regarding river restoration plans and research monitoring to interested publics and CPW staff as requested.

Technical Assistance, Upper Colorado Wild & Scenic Stakeholder Group

The Upper Colorado Wild & Scenic Stakeholder Group was formed as a collaborative effort to protect and enhance the outstandingly remarkable values (ORVs) of the upper Colorado River in ways that coordinate with federal agency management. The group represents a variety of interests groups, including American Whitewater, Aurora Water, Blue Valley Ranch, Colorado Parks and Wildlife, Colorado River Outfitters Association, Colorado River Water Conservation District, Colorado Springs Utilities, Colorado Water Conservation Board, Colorado Whitewater Association, Denver Water, Eagle County, Grand County, Northern Colorado Water Conservancy District, Northwest Colorado Council of Government, Summit County, The Wilderness Society, and Trout Unlimited. As a member of the Channel Maintenance Work Group, we assisted with developing recommendations for a suite of channel maintenance flows, including flushing flows, channel maintenance flows, and riparian maintenance flows.

Technical Assistance: Design, Construction, and Monitoring of Fish Barriers

1) Assist area aquatic biologists to monitor fish barrier performance at existing sites.

No assistance was requested during this segment period.

Training to CPW personnel

CPW publication titled “Colorado Rivers” will be updated with new techniques and fish passage and barrier assessment materials. This is a work in progress. Kay Knudsen (CPW librarian) is assisting to acquire necessary permissions to publish material from copyrighted materials in “Colorado Rivers” handbook so that it can be more widely (electronically) distributed to CPW and non-CPW personnel for training and educational purposes.

Continuing Education: Training to gain additional technical expertise and professional job skills.

Colorado/Wyoming Chapter, American Fisheries Society. Attended continuing education workshop on “Instream Flow Principles and Water Law Concepts for Fishery Managers”. Fort Collins, CO. February 25, 2013.

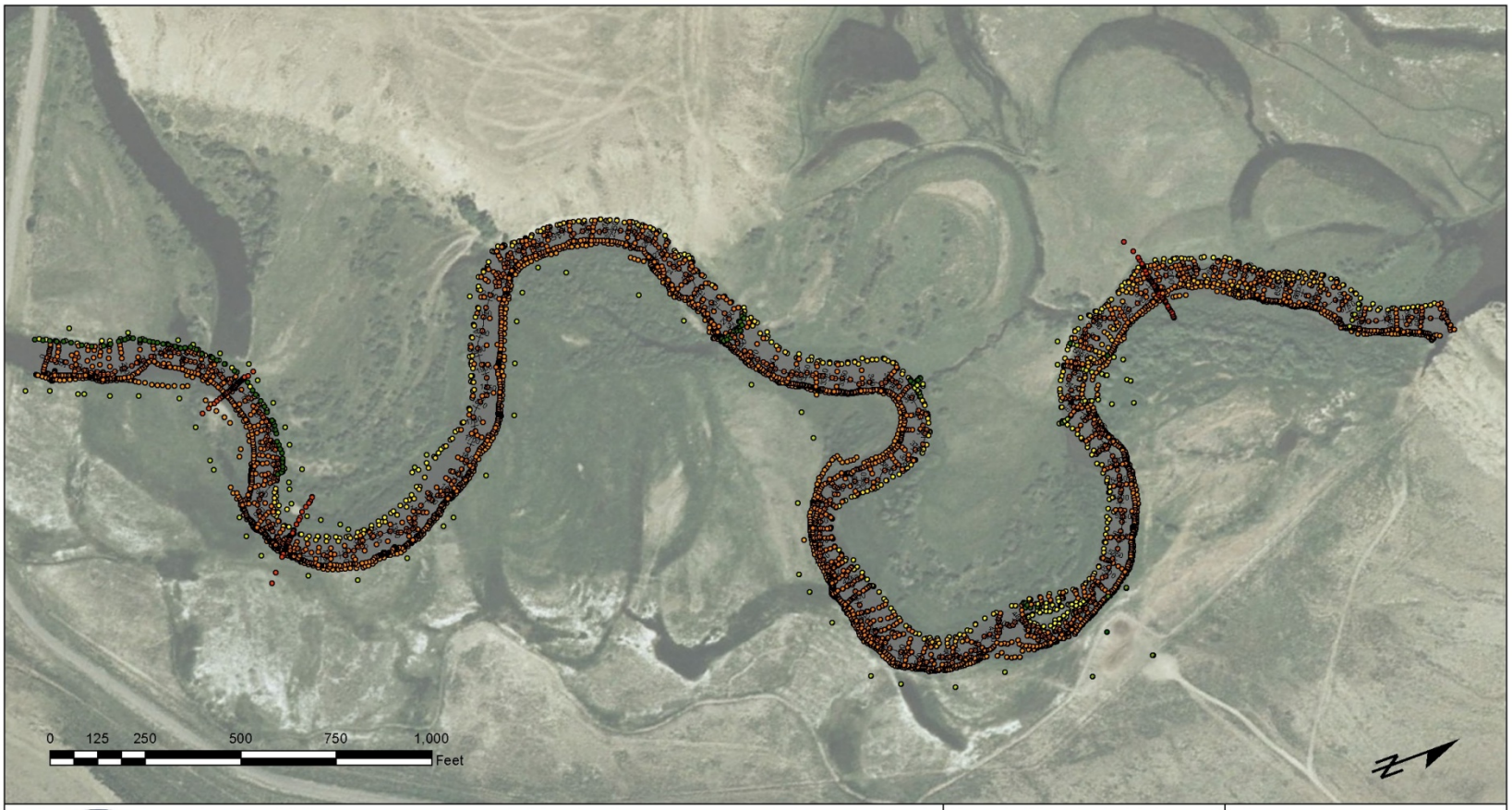
Oregon RFID. Attended training on application of PIT tag technology for monitoring fish behavior and movement. Fort Collins, CO. February 29, 2013.

SonTek. Attended training on streamflow measurement using the SonTek RiverSurveyor, FlowTracker, and SonTek-IQ. Denver, CO. April 23-24, 2013.

Bureau of Land Management. Attended training on "Assessing Proper Functioning Condition of Riparian Areas". Denver, CO. June 11-12, 2013.

Appendix A

Topographic Surveys for Stream Rehabilitation and Habitat Enhancement Projects



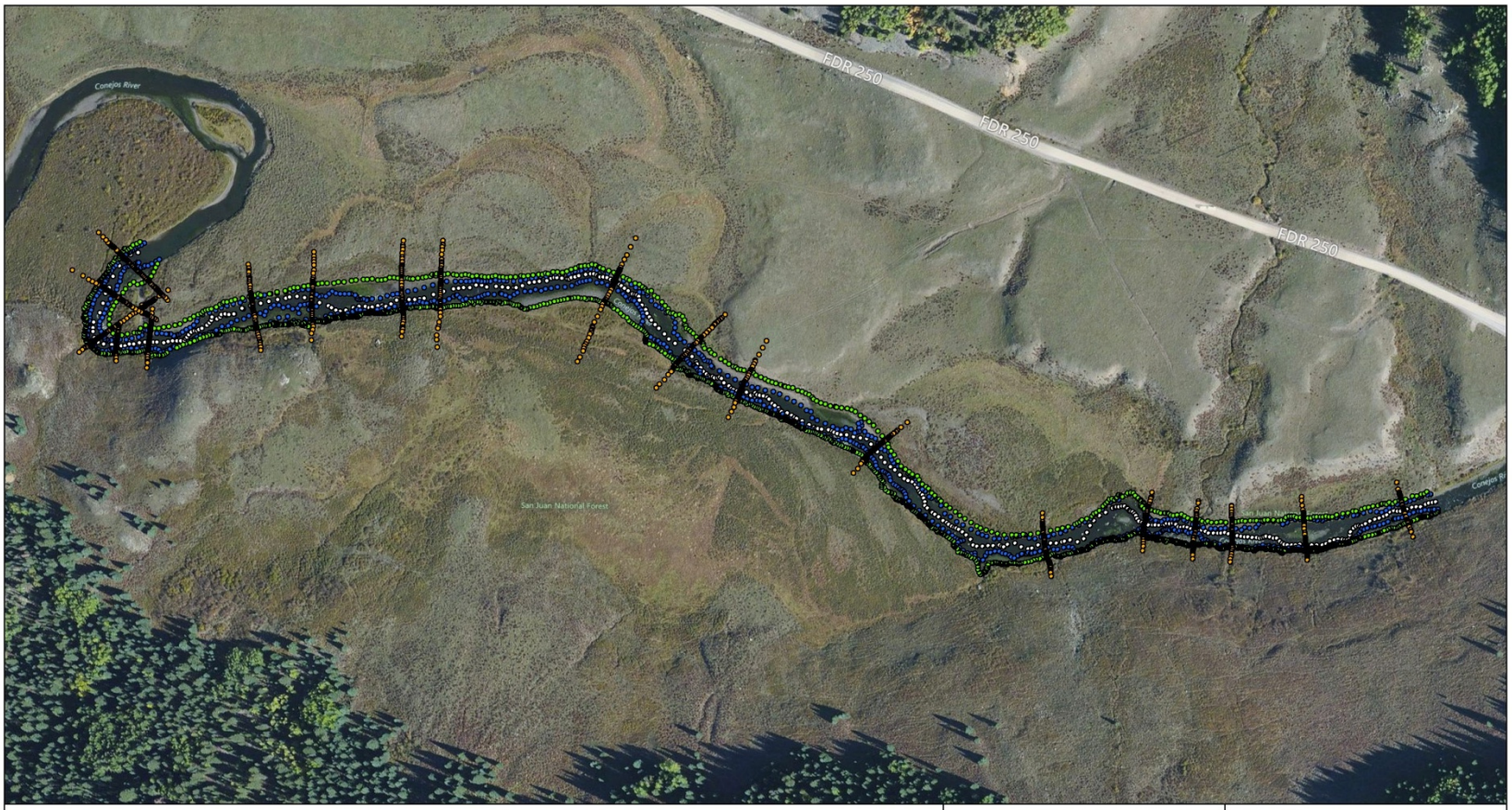
Legend

Stations	BD	CKPT	FLDPLN	LB	PBEV	SB	XS2	
Thalweg	BEAVERDAM	CP	FX	LBF	PBEW	THL	XS3	
BASE	BM	CP1	GRND	LBTOE	PIN	THLP		
BB	BT	CP2	ISLBB	LEW	RB	THLRI		
BBL	BTR	EW	ISLBT	PB	RTOE	XS1		

SURVEY DATA	
DRAWN: ERICHER	8/23/2013
CHECKED:	
APPROVED:	
SHEET: 1 OF 1	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

NORTH PLATTE RIVER VERNER SWA



Legend

- Cross Sections
- Edge of Water
- Thalweg
- Top of Bank

0 60 120 240 360 480 Feet

N

SURVEY POINTS	
DRAWN: ERICHER	8/23/2013
CHECKED:	
APPROVED:	
SHEET: 1 OF 1	

STATE OF COLORADO
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CONEJOS RIVER
UPPER MEADOW SECTION

Survey Data

BASE · CP · BANK · WS · THL · BKF · XS · GRND · ISLAND · EFFLUENT

0 45 90 180 270 360 Feet

N

SURVEY POINTS	
DRAWN: ERICHER	4/2/2013
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APPROVED:	
SHEET: 3 OF 10	

STATE OF COLORADO
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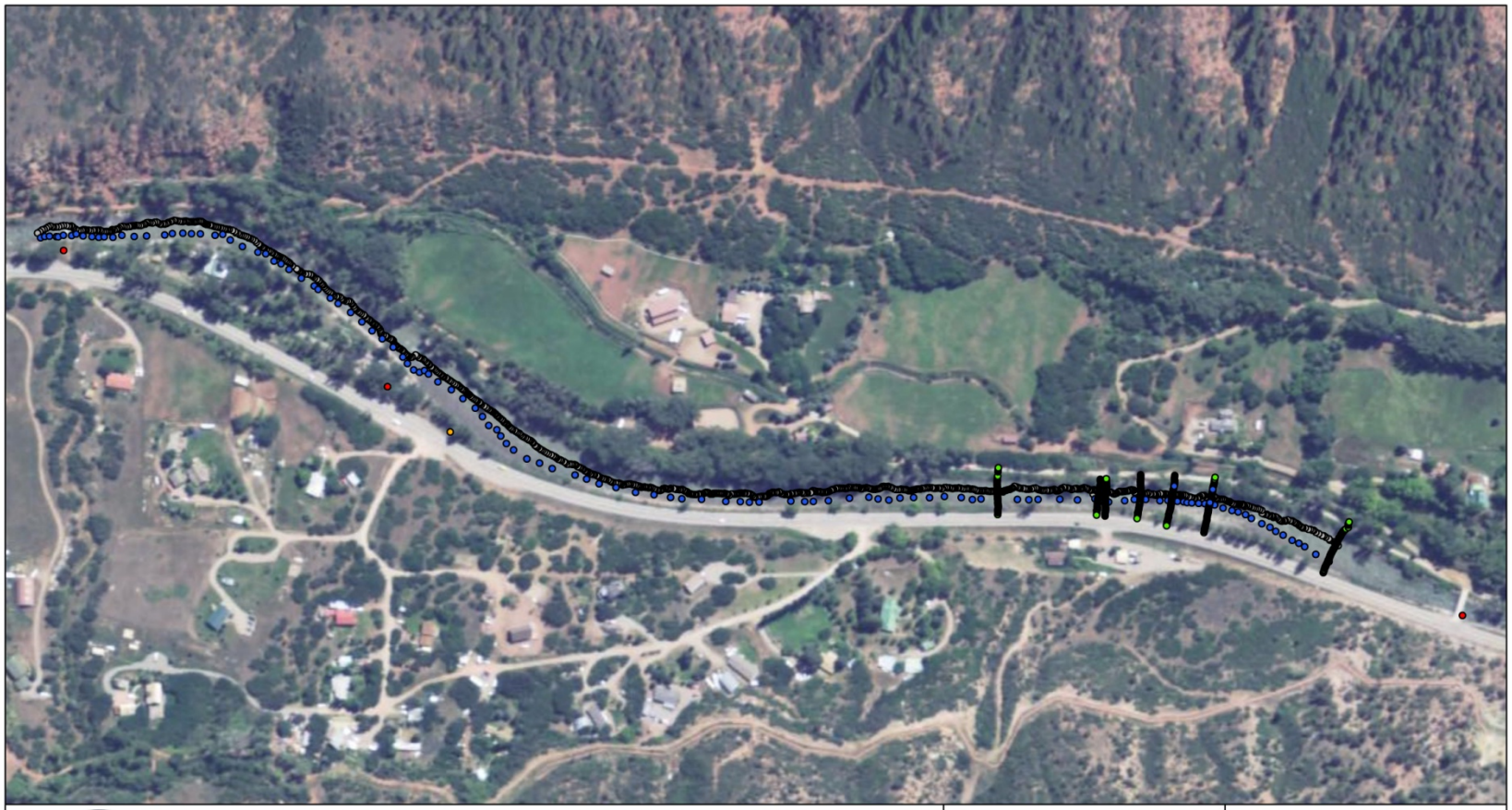
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

TWIN TUNNELS PROJECT
CLEAR CREEK
SITE ASSESSMENT



Survey Data (11/16/2012)

BKF	CP2	THL
BM	CP3	WS
CP1	LEW	XS

0 65 130 260 390 520 Feet

N

SURVEY DATA	
DRAWN: ERICHER	2/8/2013
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APPROVED:	
SHEET: 2 OF 2	

STATE OF COLORADO
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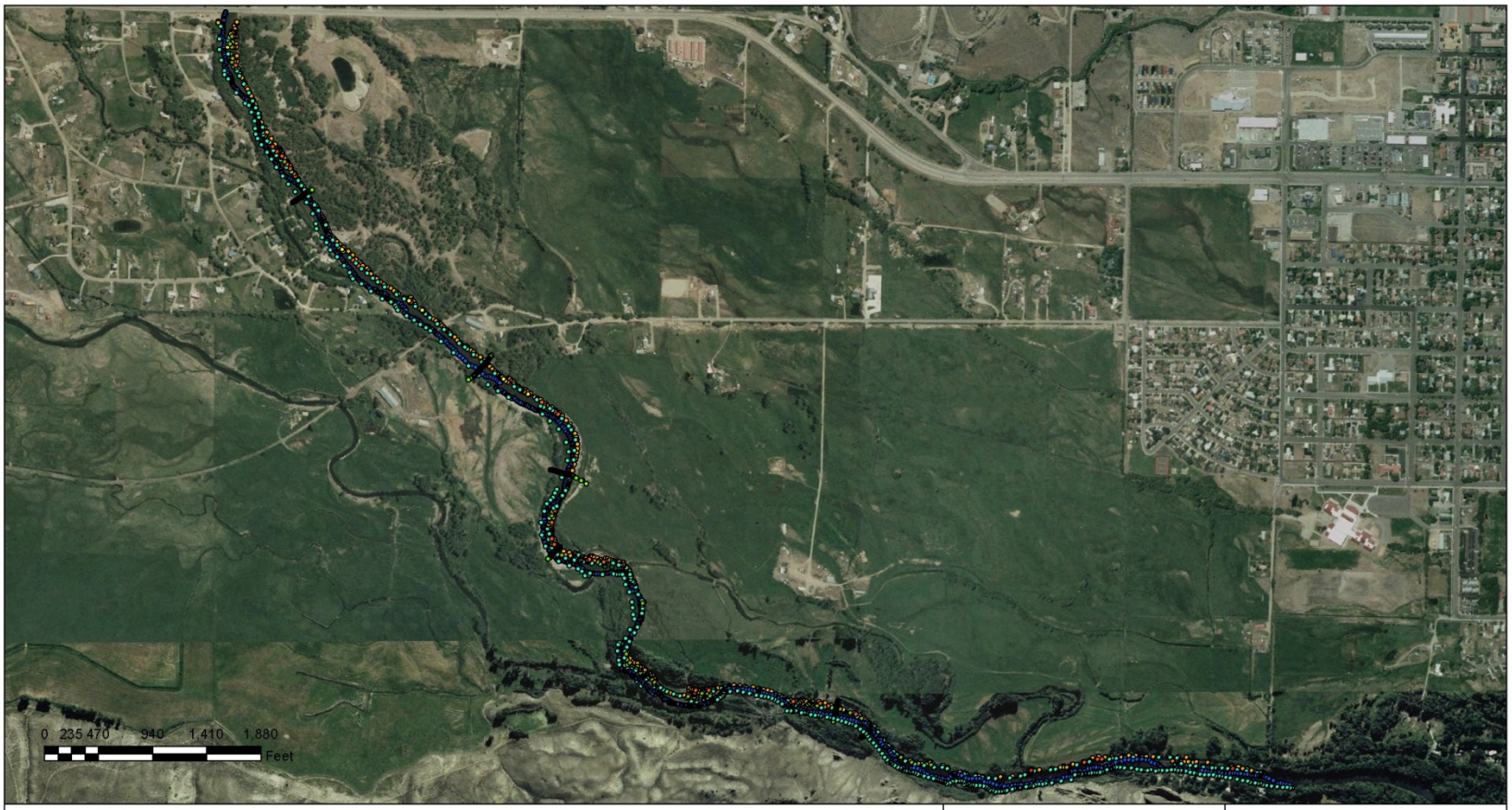
FORT COLLINS, COLORADO

CRYSTAL RIVER
WEXNER PROPERTY
PLAN VIEW



Legend

BASE	BTL	DIVGRADE	SB	bkf	x
BBL	CP	DIVRET	THL	div	xs
BKF	DIKE	EW	XS100	line	
BRIDGE	DIV	PB	base	test	

SURVEY DATA	
DRAWN: ERICHER	4/12/2013
CHECKED:	
APPROVED:	
SHEET: 1 OF 1	

STATE OF COLORADO
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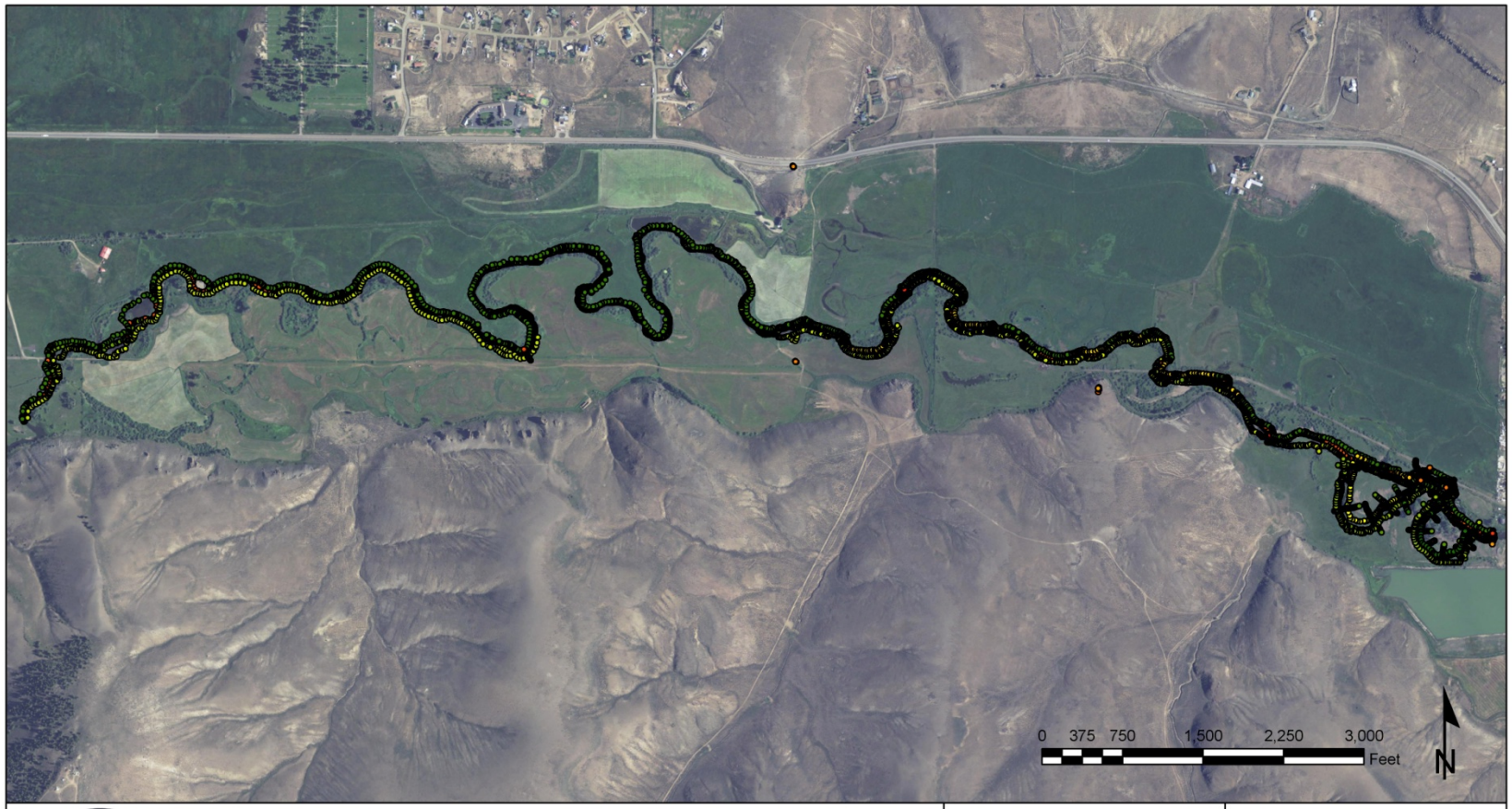
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

GUNNISON RIVER SWA
PLAN VIEW



SURVEY DATA (2012)

	BMHWY	REW	XS-REW	XS-THL		diversionberm
BASE	DIVERSION	THL	XS-SIDE	XSECT		lb
BKF	LB	THL-SIDE	XS-SIDE RB	XSECTWS		thw0926
BM	LB-SIDE	XS	XS-SIDELB	XSSIDE		thwpluspt5
BMAIRPORT	RB	XS SIDE	XS-SIDERB	XSTREATMENTM		
BMBRATTON	RBSIDE	XS-LEW	XS-SIDETHL	XSTREATMENTMWS		

SURVEY POINTS	
DRAWN: ERICHER	2/8/2013
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APPROVED:	
SHEET: 1 OF 1	

STATE OF COLORADO
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FORT COLLINS, COLORADO

TOMICHI CREEK
TOMICHI CREEK SWA
PLAN VIEW

Legend

ADCP Cross-Sections

0 50 100 200 300 400 Feet

N

CROSS-SECTION LOCATIONS	
DRAWN: ERICHER	8/5/2013
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APPROVED:	
SHEET: 1 OF 6	

STATE OF COLORADO
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COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

SOUTH PLATTE RIVER CHARLIE MEYERS SWA ADCP SURVEY

Appendix B

Site Assessment and Design Drawings for Stream Rehabilitation and Habitat Enhancement Projects

COLORADO PARKS AND WILDLIFE

North Platte River Stream Restoration: Verner State Wildlife Area

Site Assessment and Conceptual Design Drawings

Prepared for:
Colorado Water Conservation Board
Water Supply Reserve Account Grant Application
North Platte Basin Roundtable

Prepared by:
Colorado Parks and Wildlife
Wildlife Research Center
317 W. Prospect Road
Fort Collins, CO 80526

June 3, 2013

STATE OF COLORADO
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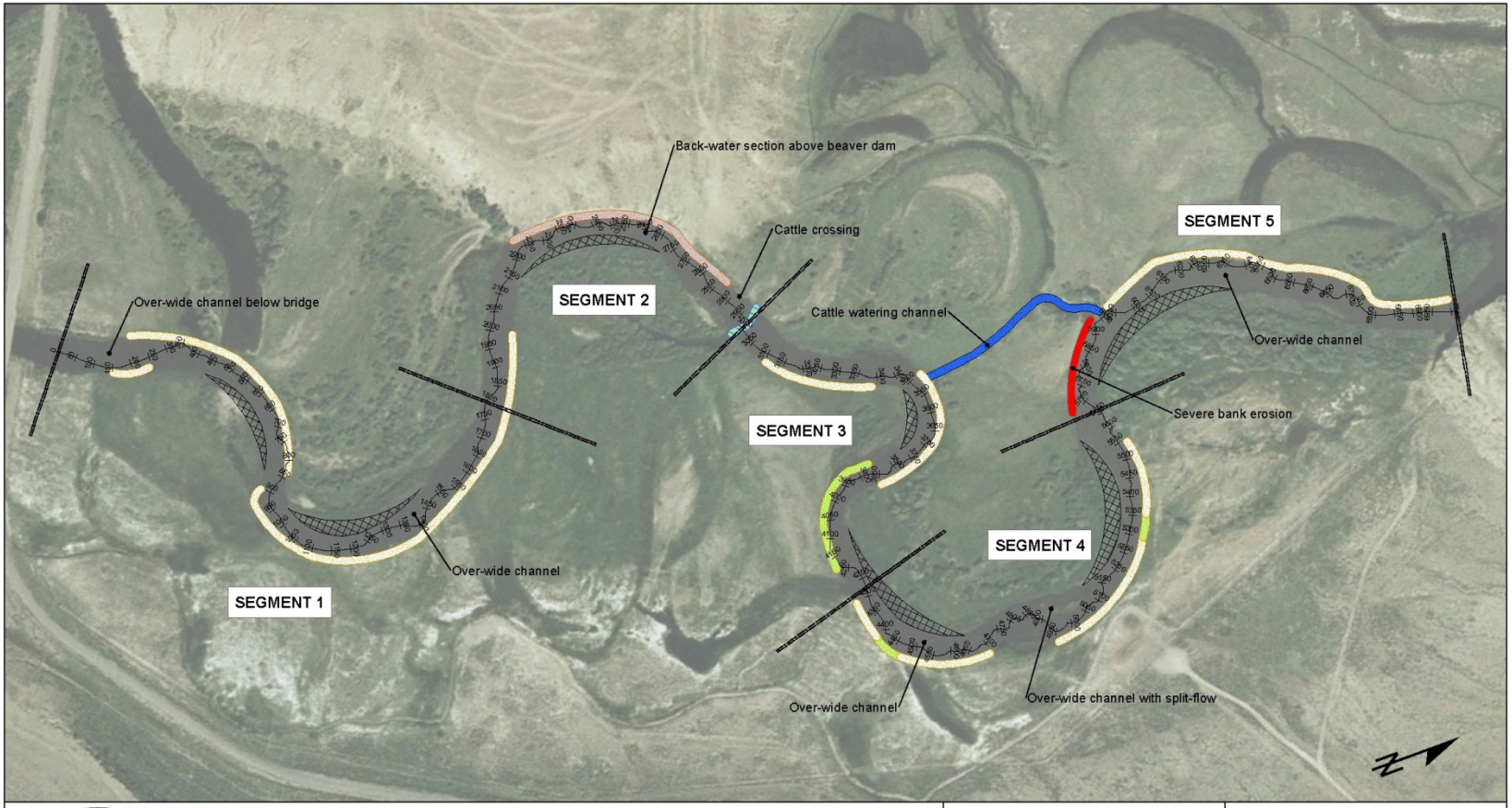


Legend

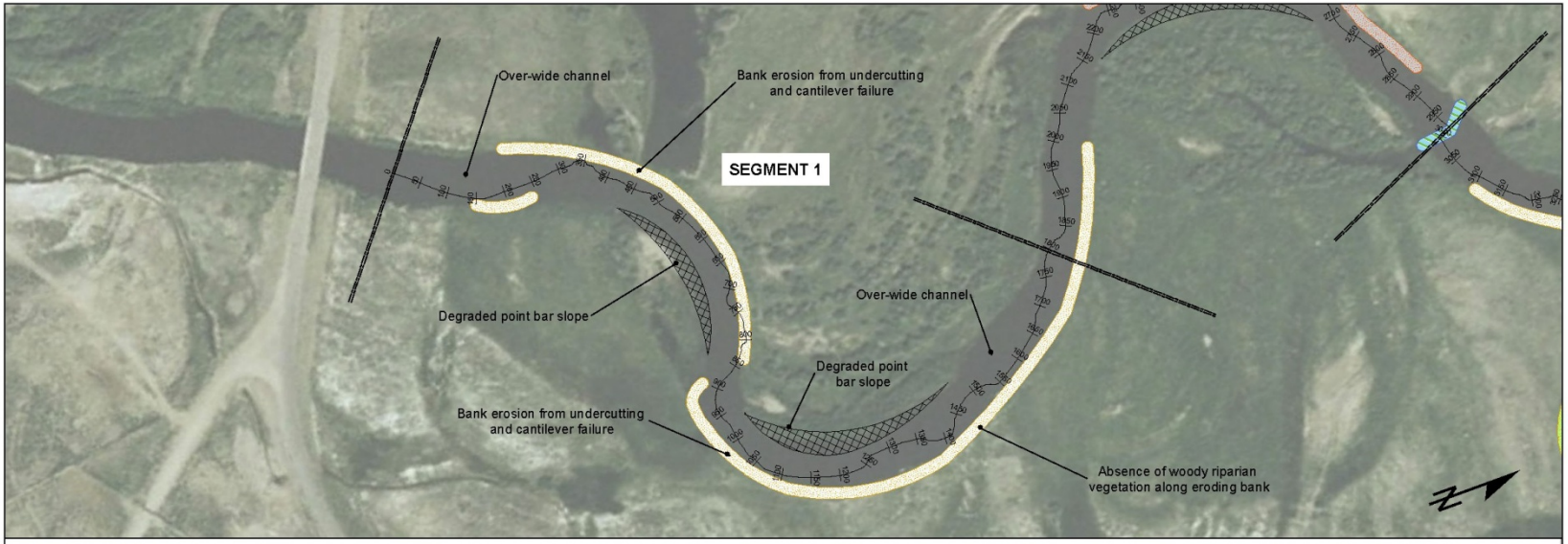
- Segment Breaks
- Thalweg
- Bank Erosion
- Bank Erosion (Bluff)
- Bank Erosion (Recovering)
- Bank Erosion (Severe)
- Degraded Point Bar
- Watering Channel
- Beaver Dam

0 50100 200 300 400 Feet

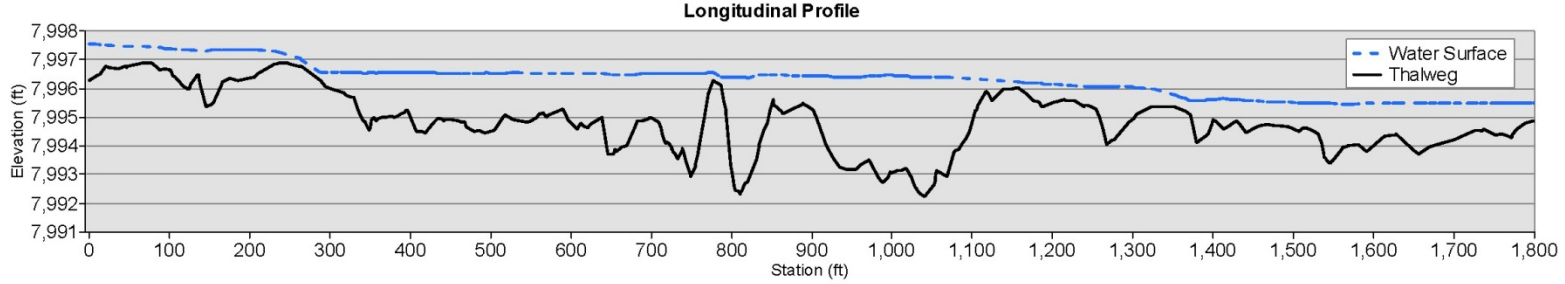
SITE OVERVIEW	
DRAWN: ERICHER	6/3/2013
CHECKED:	
APPROVED:	
SHEET: 1 OF 6	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

NORTH PLATTE RIVER VERNER SWA SITE ASSESSMENT



Longitudinal Profile



Legend

Segment Breaks
Thalweg
Bank Erosion
Bank Erosion (Bluff)
Bank Erosion (Severe)
Bank Erosion (Recovering)
Degraded Point Bar
Watering Channel
Beaver Dam

0 30 60 120 180 240 Feet

SEGMENT 1	
DRAWN: ERICHER	6/3/2013
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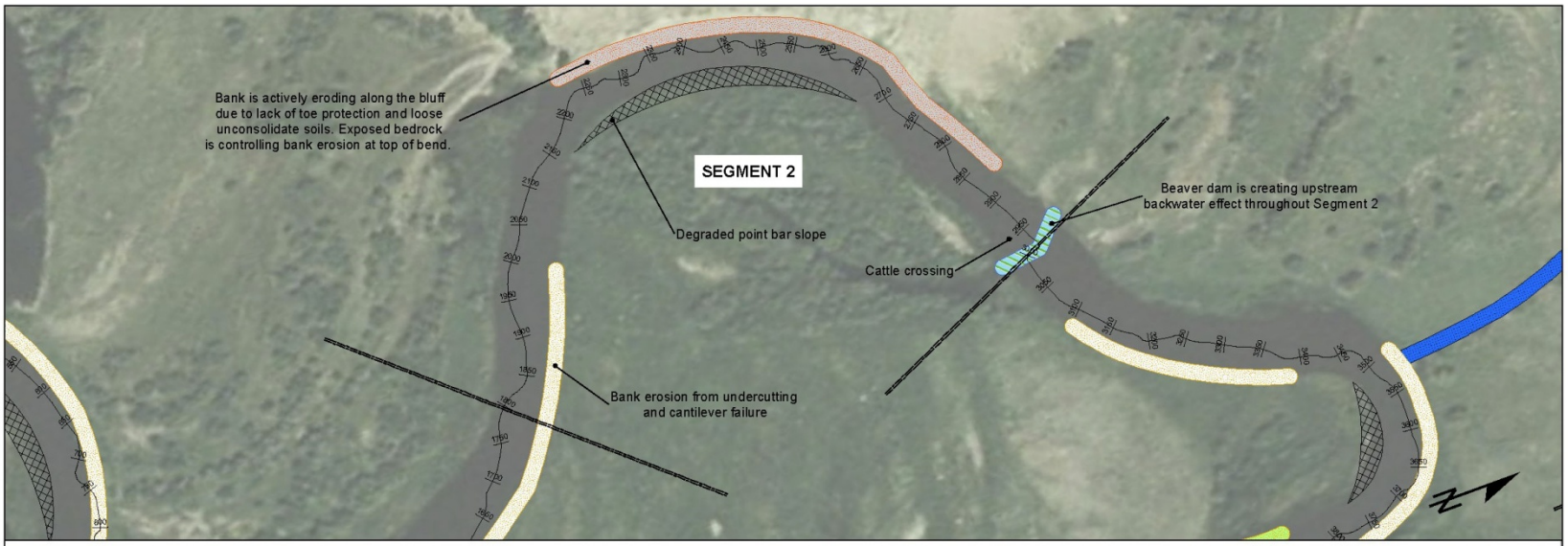
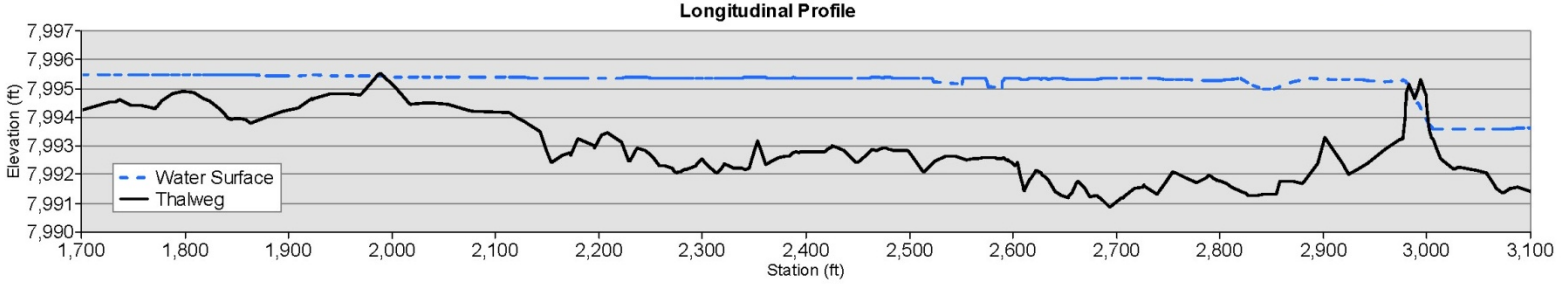
SHEET: 2 OF 6	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

NORTH PLATTE RIVER
VERNER SWA
SITE ASSESSMENT



Longitudinal Profile



Legend

- Segment Breaks
- Thalweg
- Bank Erosion
- Bank Erosion (Bluff)
- Bank Erosion (Recovering)
- Bank Erosion (Severe)
- Degraded Point Bar
- Watering Channel
- Beaver Dam

0 25 50 100 150 200 Feet

SEGMENT 2	
DRAWN: ERICHER	6/3/2013
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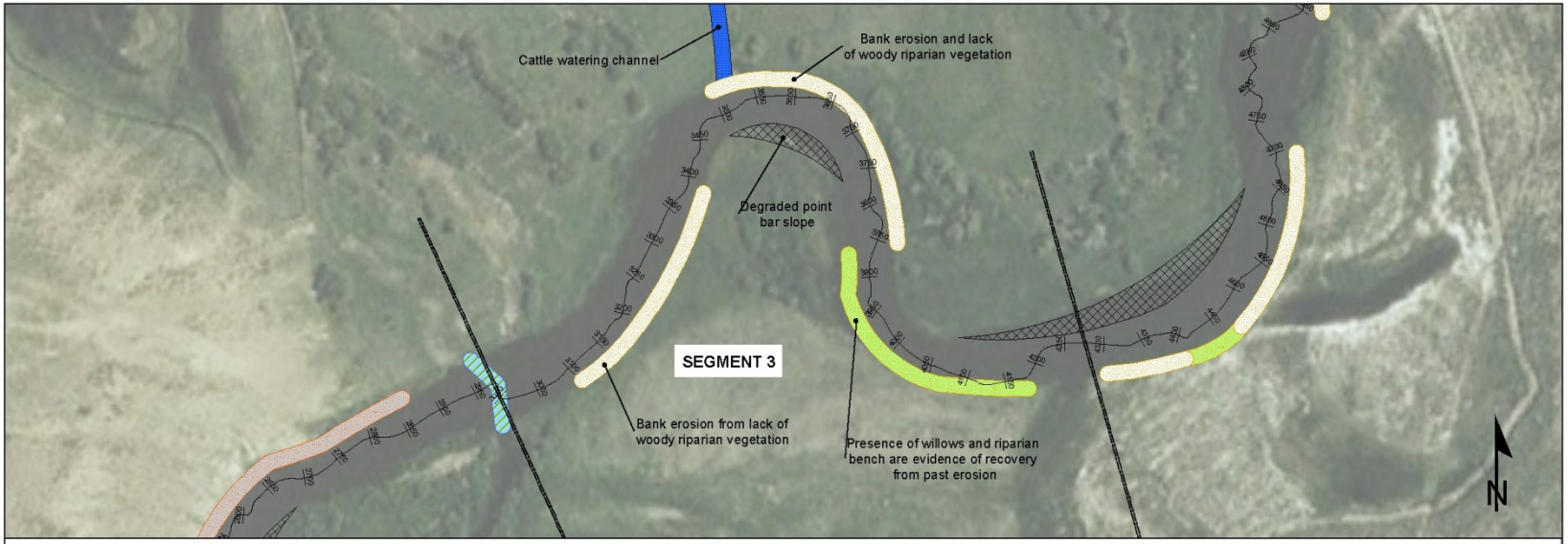
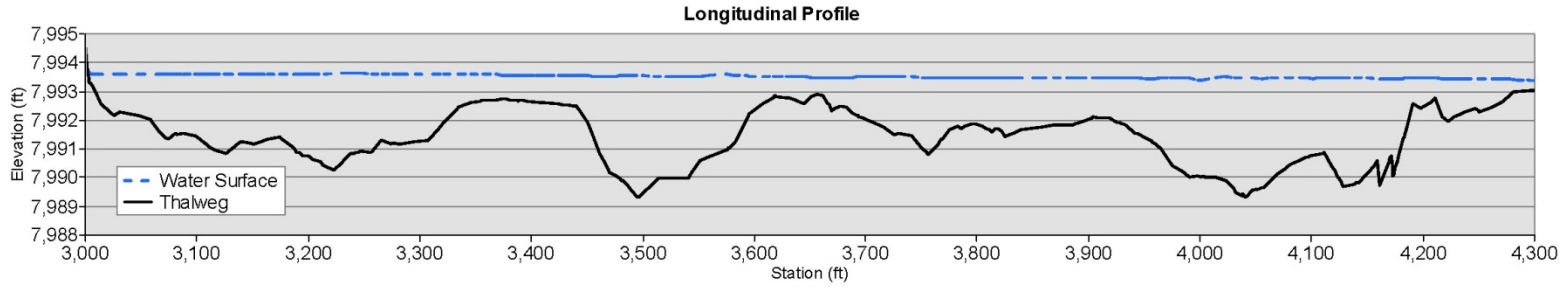
APPROVED:	
SHEET: 3 OF 6	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

NORTH PLATTE RIVER
VERNER SWA
SITE ASSESSMENT





Legend

- Segment Breaks
- Thalweg
- Bank Erosion
- Bank Erosion (Bluff)
- Bank Erosion (Recovering)
- Bank Erosion (Severe)
- Degraded Point Bar
- Watering Channel
- Beaver Dam

0 25 50 100 150 200 Feet

SEGMENT 3	
DRAWN: ERICHER	6/3/2013
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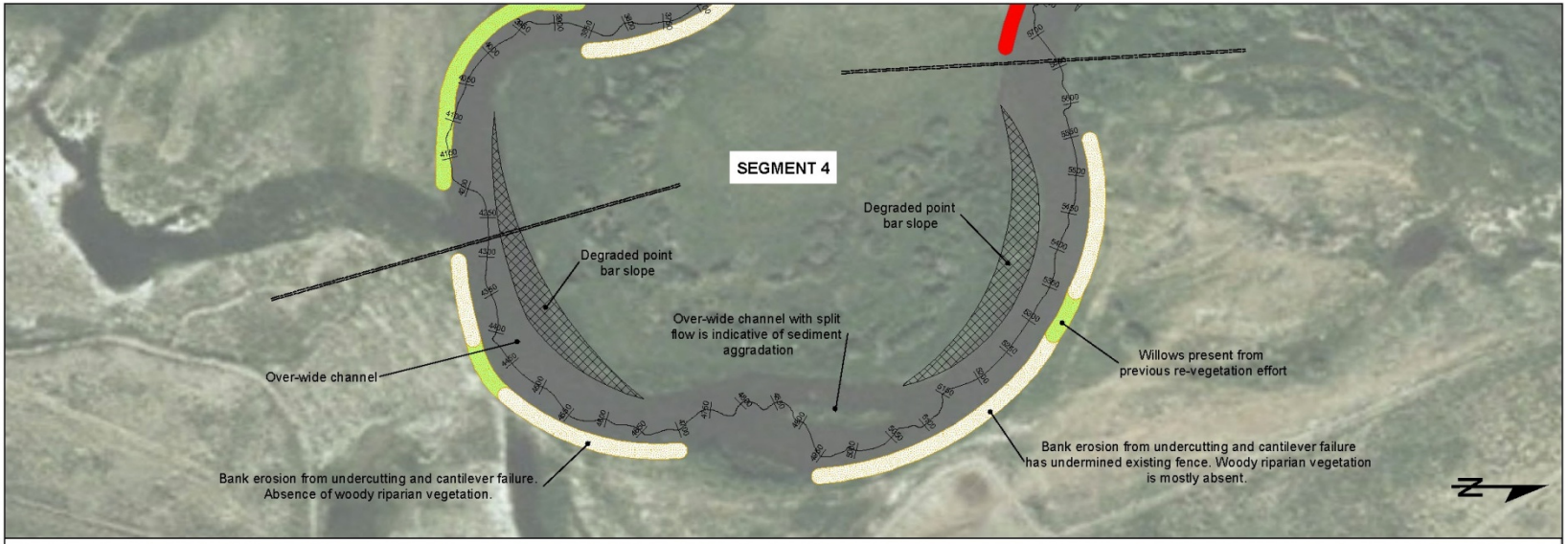
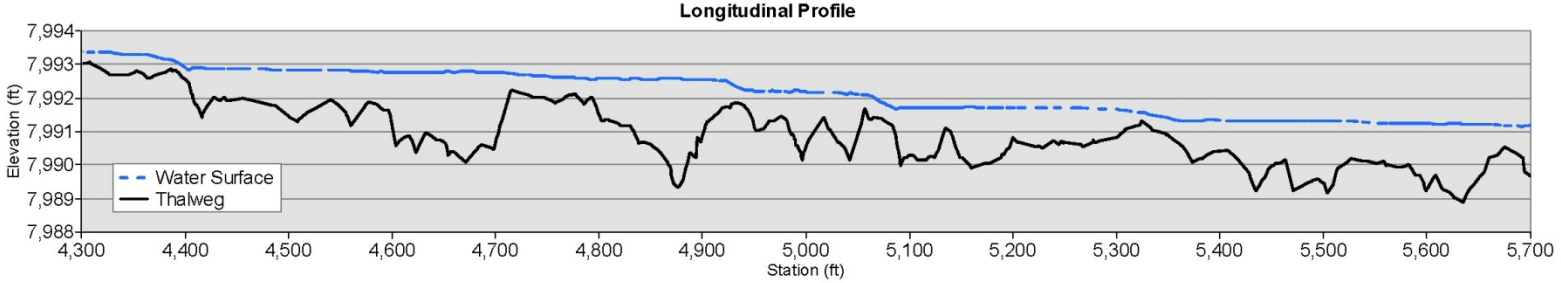
APPROVED:	
SHEET: 4 OF 6	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

NORTH PLATTE RIVER
VERNER SWA
SITE ASSESSMENT



Longitudinal Profile



Legend

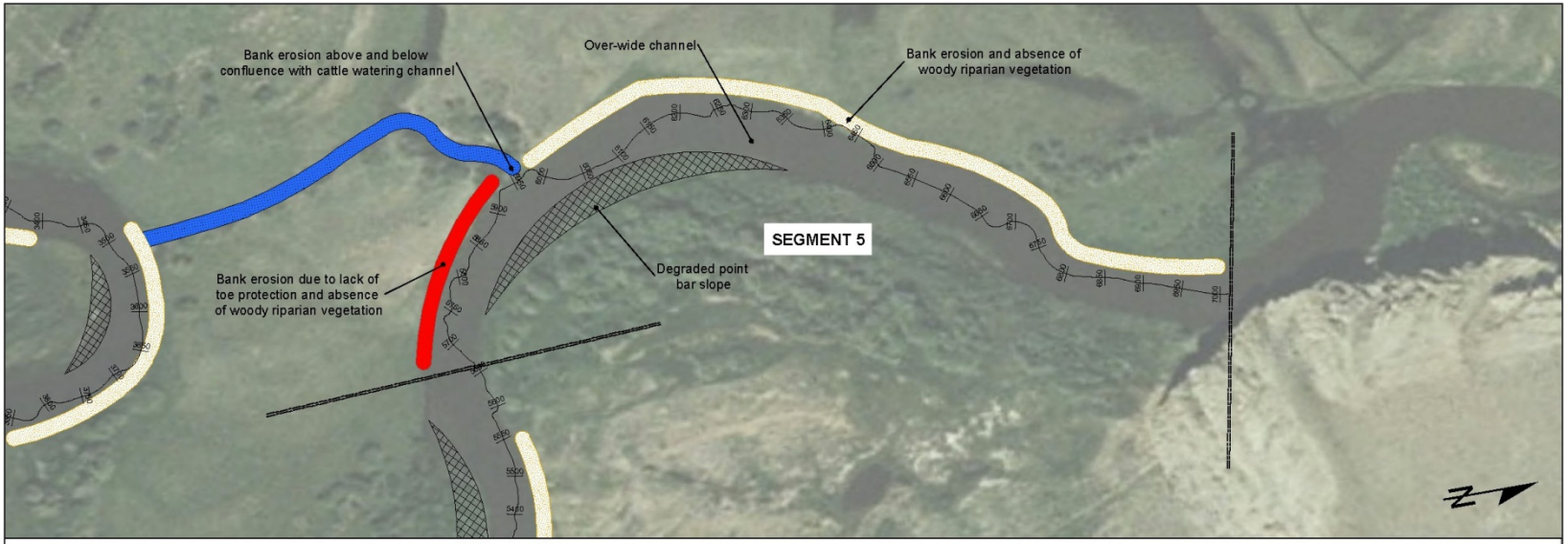
- Segment Breaks
- Thalweg
- Bank Erosion
- Bank Erosion (Bluff)
- Bank Erosion (Recovering)
- Bank Erosion (Severe)
- Degraded Point Bar
- Watering Channel
- Beaver Dam

0 25 50 100 150 200 Feet

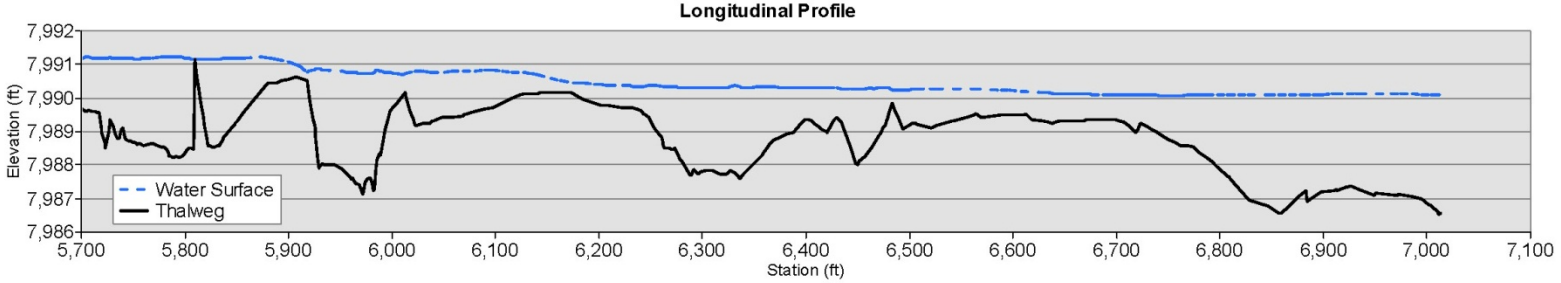
SEGMENT 4	
DRAWN: ERICHER	6/3/2013
CHECKED:	
APPROVED:	
SHEET: 5 OF 6	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

NORTH PLATTE RIVER
VERNER SWA
SITE ASSESSMENT



Longitudinal Profile



Legend

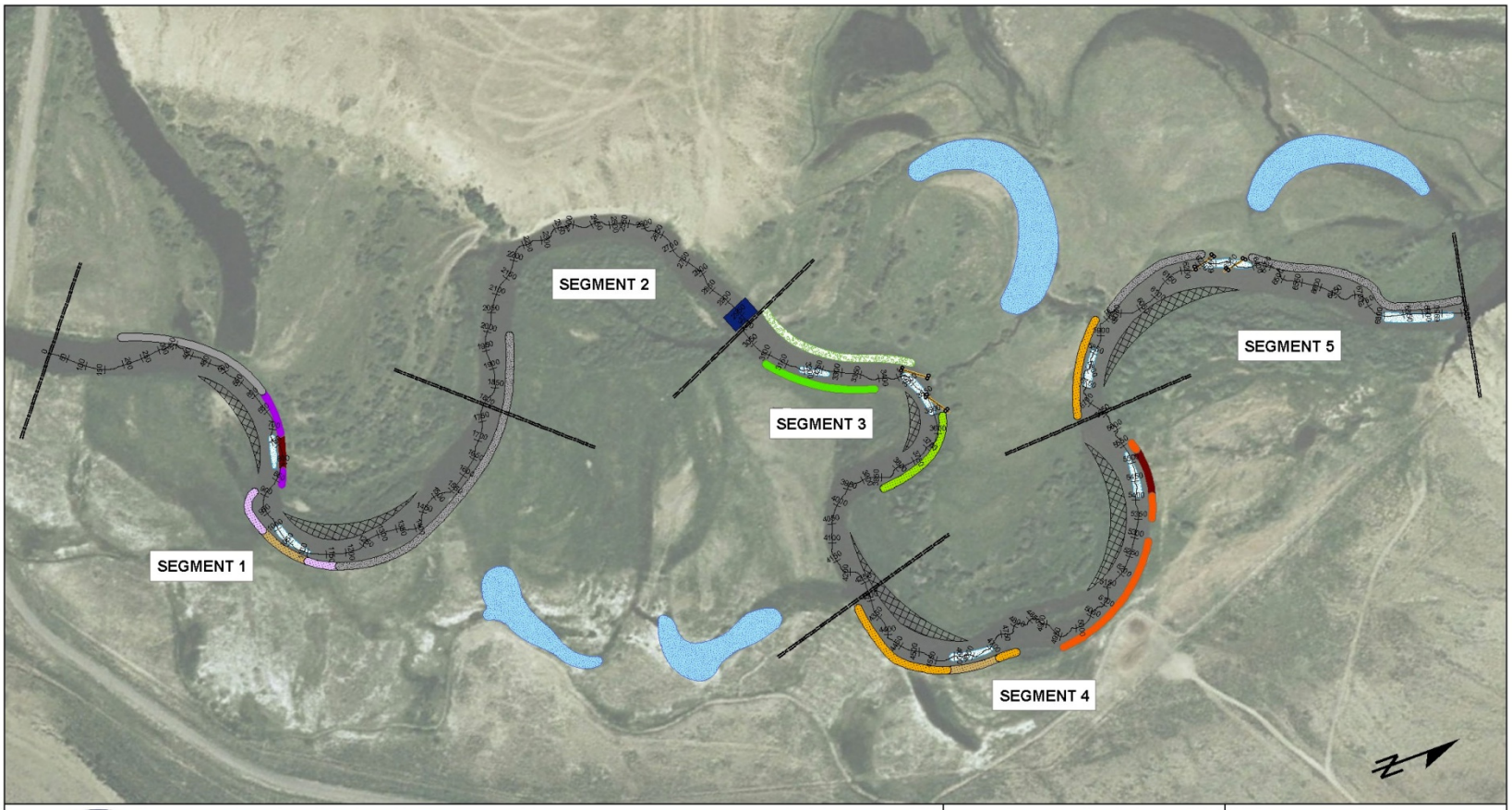
- Segment Breaks
- Thalweg
- Bank Erosion
- Bank Erosion (Bluff)
- Bank Erosion (Recovering)
- Bank Erosion (Severe)
- Degraded Point Bar
- Watering Channel
- Beaver Dam

0 25 50 100 150 200 Feet

SEGMENT 5	
DRAWN: ERICHER	6/3/2013
CHECKED:	
APPROVED:	
SHEET: 6 OF 6	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

NORTH PLATTE RIVER
VERNER SWA
SITE ASSESSMENT



Legend

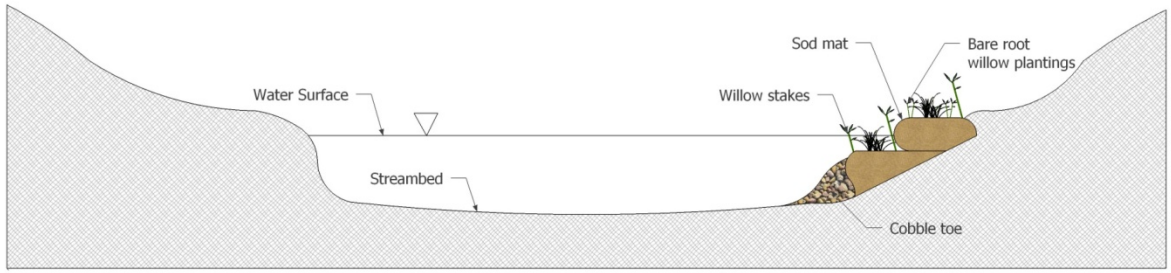
- Segment Breaks
- Cobble Toe with Soil Lift
- Cobble Toe with Sod Mat
- Horizontal Log with Sod Mat
- Horizontal Log with Soil Lift
- Brush Fascine with Sod Mat
- Brush Fascine with Soil Lift
- Coir Log with Sod Mat
- Coir Log with Soil Lift
- Root Wad with Sod Mat
- Root Wad with Soil Lift
- Establish Willows
- Enhance Pool
- Grade Point Bar
- Log Vane
- Hardened Cattle Crossing
- Oxbow Development

0 50100 200 300 400 Feet

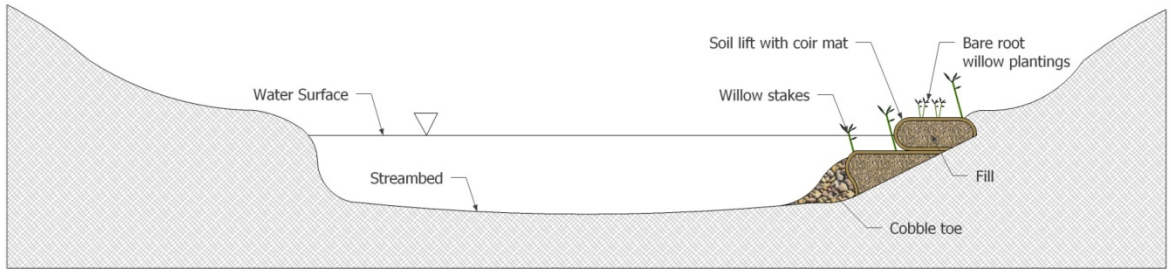
RESTORATION PLAN	
DRAWN: ERICHER	6/3/2013
CHECKED:	
APPROVED:	
SHEET: 1 OF 9	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

NORTH PLATTE RIVER VERNER SWA CONCEPTUAL DESIGN



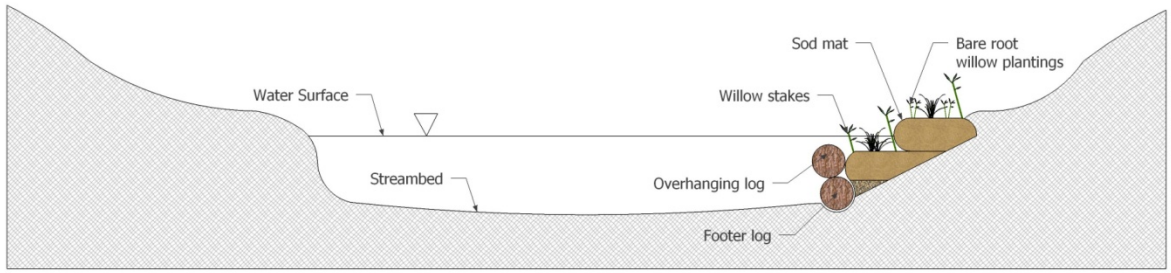
COBBLE-TOE WITH SOD MAT A1



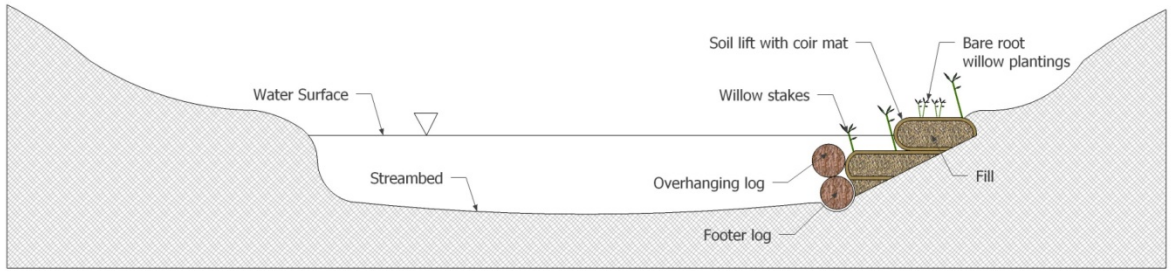
COBBLE-TOE WITH SOIL LIFT A2

NOT TO SCALE

COBBLE-TOE BANK TREATMENTS		STATE OF COLORADO DEPARTMENT OF NATURAL RESOURCES COLORADO PARKS AND WILDLIFE FORT COLLINS, COLORADO
DRAWN: ERICHER	6/3/2013	
CHECKED:		NORTH PLATTE RIVER VERNER SWA CONCEPTUAL DESIGN
APPROVED:		
SHEET: 2 OF 9		



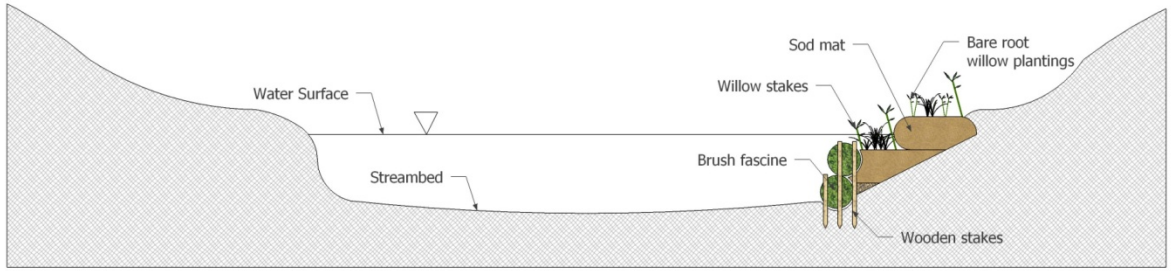
HORIZONTAL LOG WITH SOD MAT B1



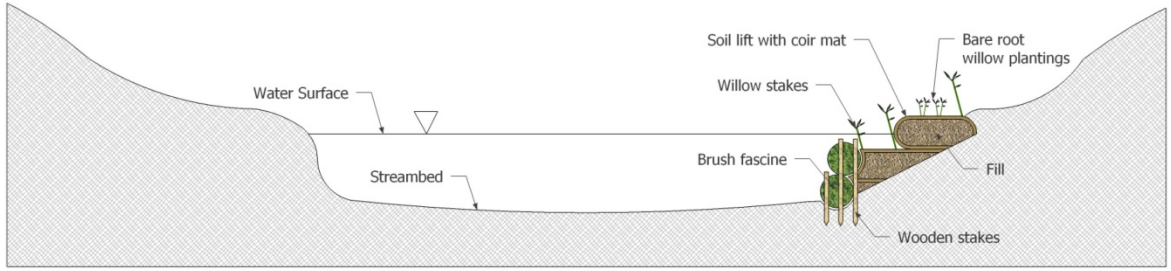
HORIZONTAL LOG WITH SOIL LIFT B2

NOT TO SCALE

HORIZONTAL LOG BANK TREATMENTS		STATE OF COLORADO DEPARTMENT OF NATURAL RESOURCES COLORADO PARKS AND WILDLIFE FORT COLLINS, COLORADO
DRAWN: ERICHER	6/3/2013	
CHECKED:		NORTH PLATTE RIVER VERNER SWA CONCEPTUAL DESIGN
APPROVED:		
SHEET: 3 OF 9		



BRUSH FASCINE WITH SOD MAT C1



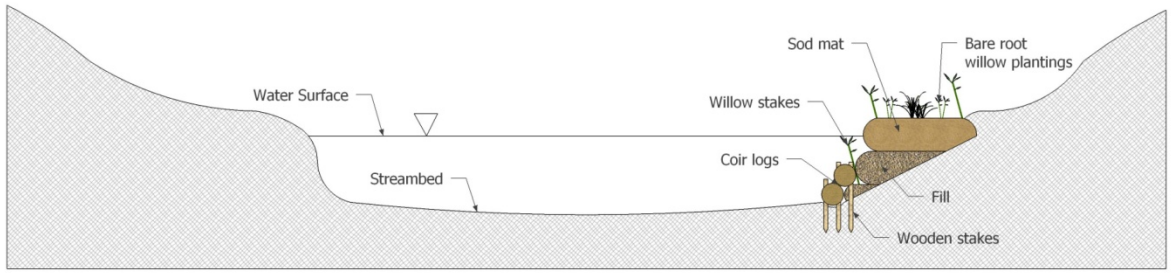
BRUSH FASCINE WITH SOIL LIFT C2

NOT TO SCALE

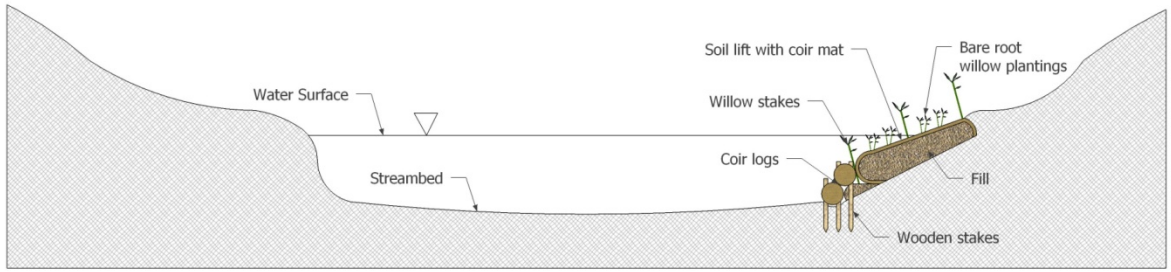
BRUSH FASCINE BANK TREATMENTS	
DRAWN: ERICHER	6/3//2013
CHECKED:	
APPROVED:	
SHEET: 4 OF 9	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

NORTH PLATTE RIVER
VERNER SWA
CONCEPTUAL DESIGN



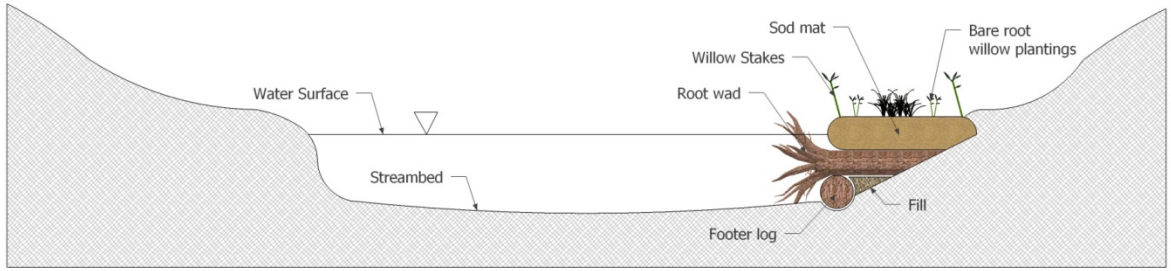
COIR LOG WITH SOD MAT D1



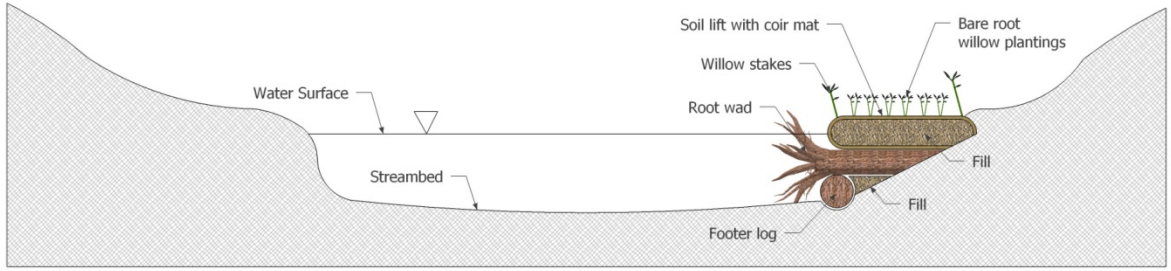
COIR LOG WITH SOIL LIFT D2

NOT TO SCALE

COIR LOG BANK TREATMENTS		STATE OF COLORADO DEPARTMENT OF NATURAL RESOURCES COLORADO PARKS AND WILDLIFE FORT COLLINS, COLORADO
DRAWN: ERICHER	6/3/2013	
CHECKED:		NORTH PLATTE RIVER VERNER SWA CONCEPTUAL DESIGN
APPROVED:		
SHEET: 5 OF 9		



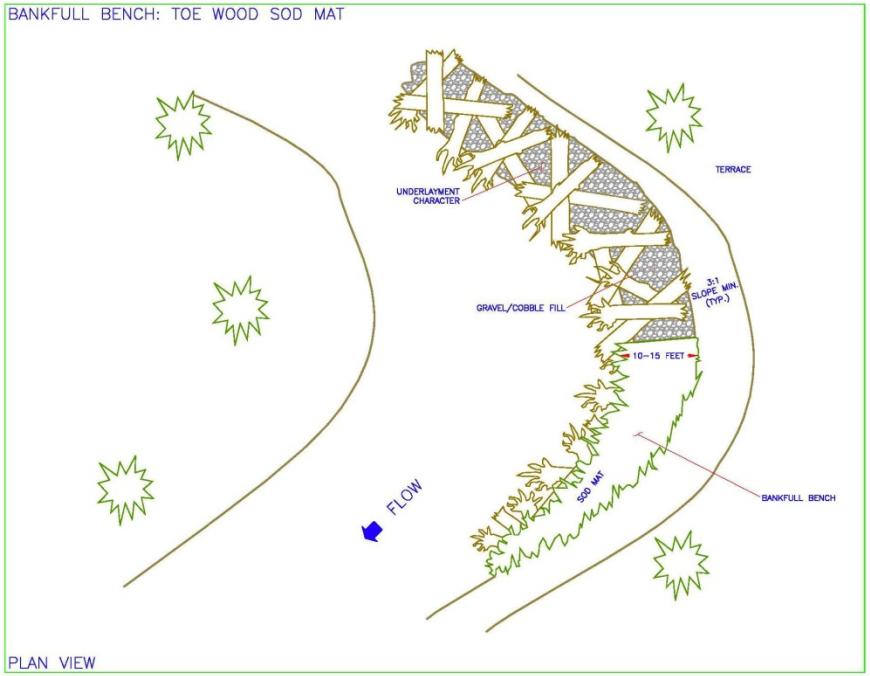
ROOT-WAD WITH SOD MAT E1

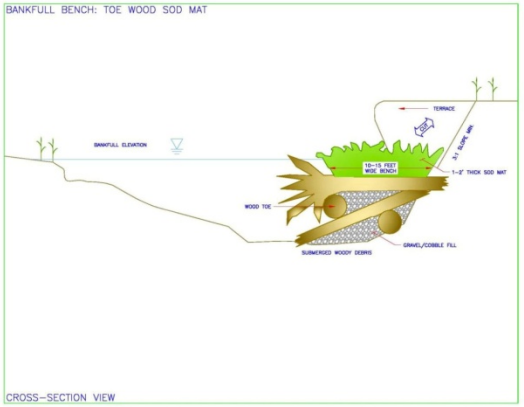


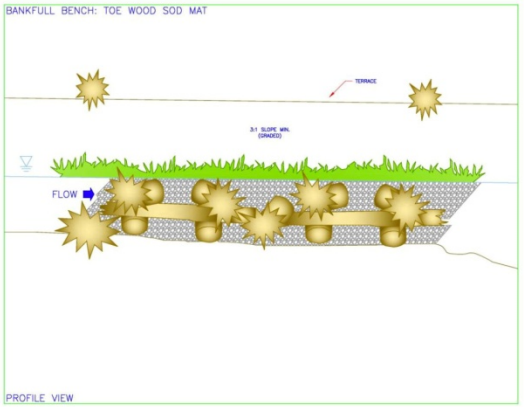
ROOT-WAD WITH SOIL LIFT E2

NOT TO SCALE

ROOT-WAD BANK TREATMENTS		STATE OF COLORADO DEPARTMENT OF NATURAL RESOURCES COLORADO PARKS AND WILDLIFE FORT COLLINS, COLORADO
DRAWN: ERICHER	6/3/2013	
CHECKED:		NORTH PLATTE RIVER VERNER SWA CONCEPTUAL DESIGN
APPROVED:		
SHEET: 6 OF 9		





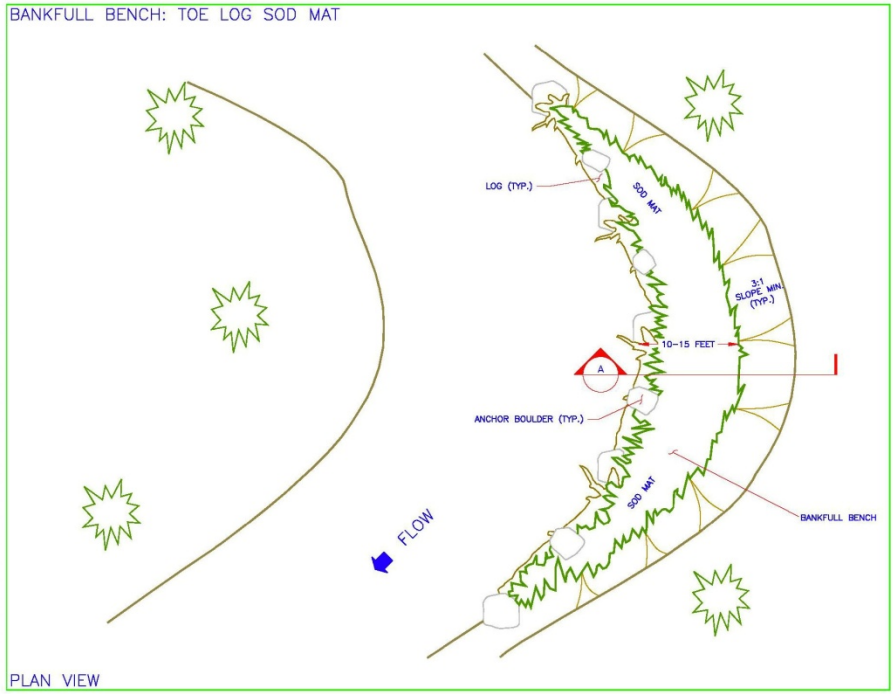


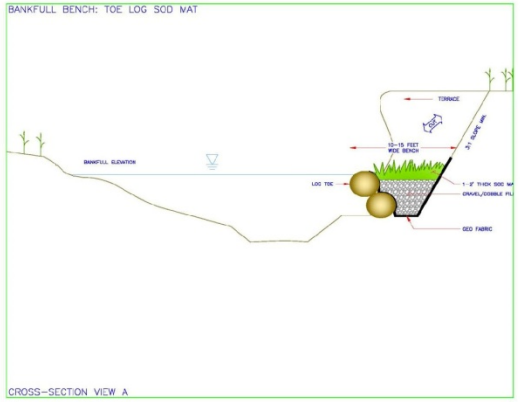
NOT TO SCALE

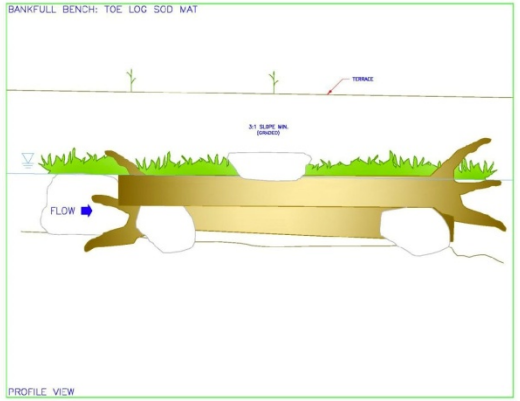
ROOT-WAD / SOD MAT DETAIL	
DRAWN: ERICHER	5/27/2013
CHECKED:	
APPROVED:	
SHEET: 7 OF 9	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

NORTH PLATTE RIVER
VERNER SWA
CONCEPTUAL DESIGN





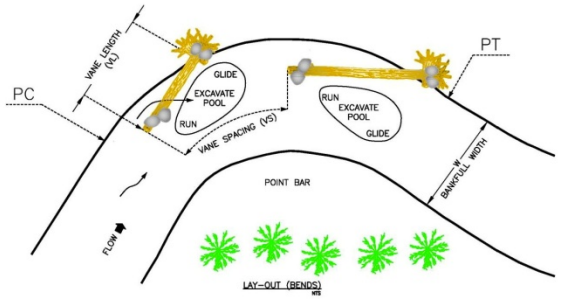


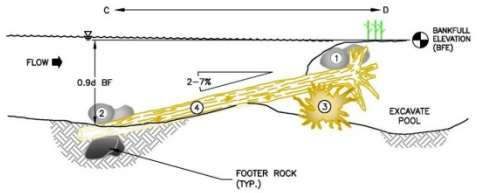
NOT TO SCALE

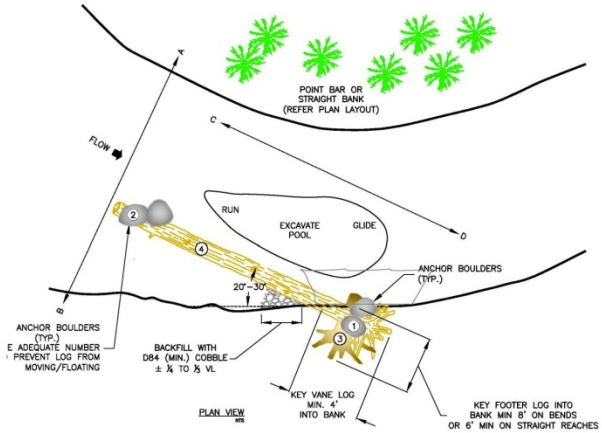
HORIZONTAL LOG / SOD MAT DETAIL	
DRAWN: ERICHER	5/27/2013
CHECKED:	
APPROVED:	
SHEET: 8 OF 9	

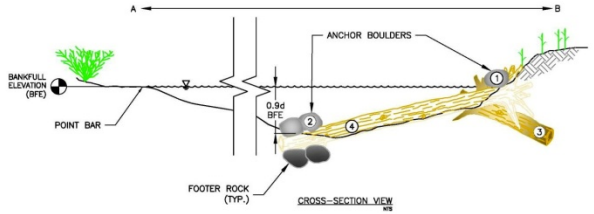
STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

NORTH PLATTE RIVER
VERNER SWA
CONCEPTUAL DESIGN







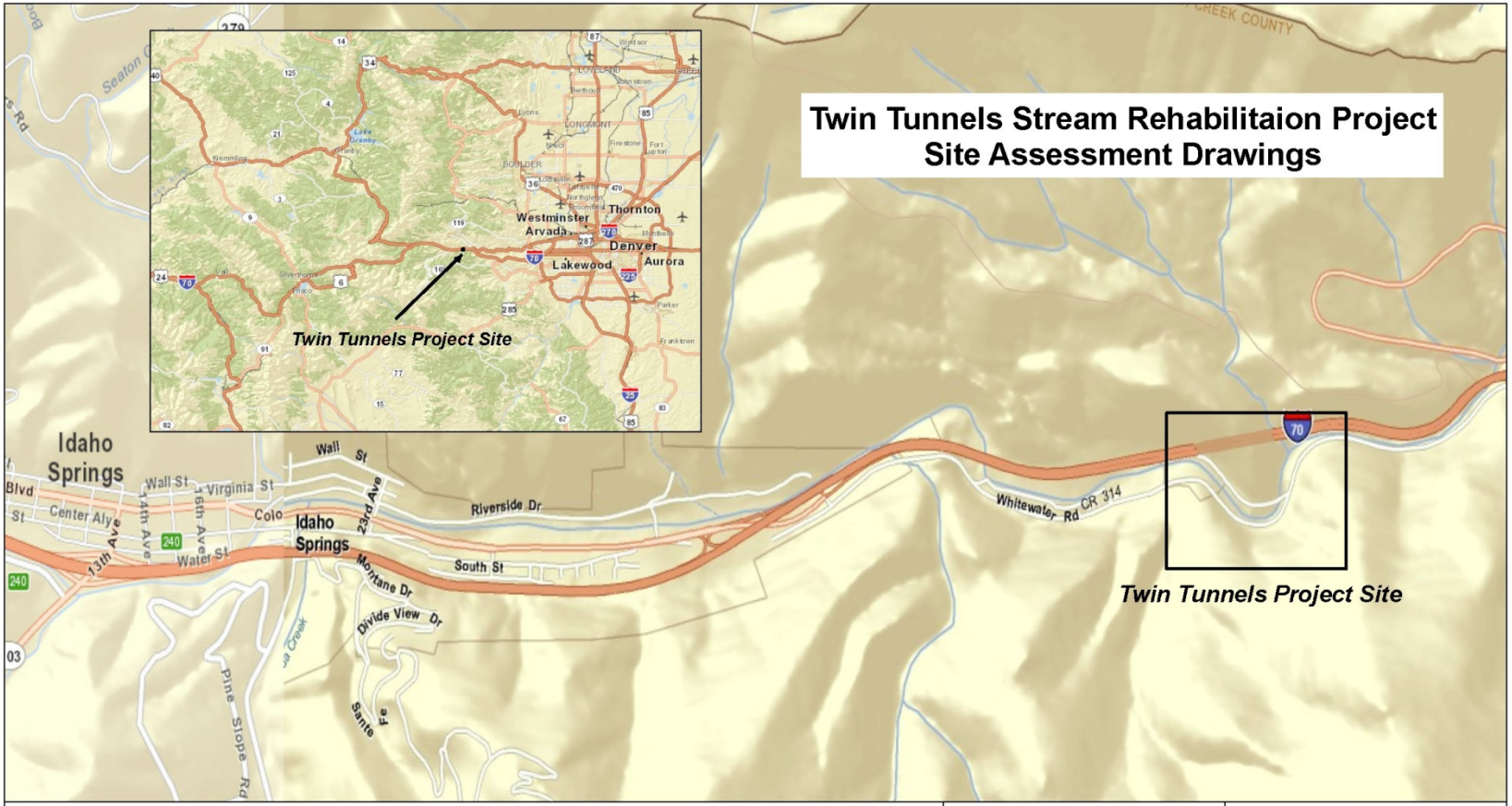


NOT TO SCALE

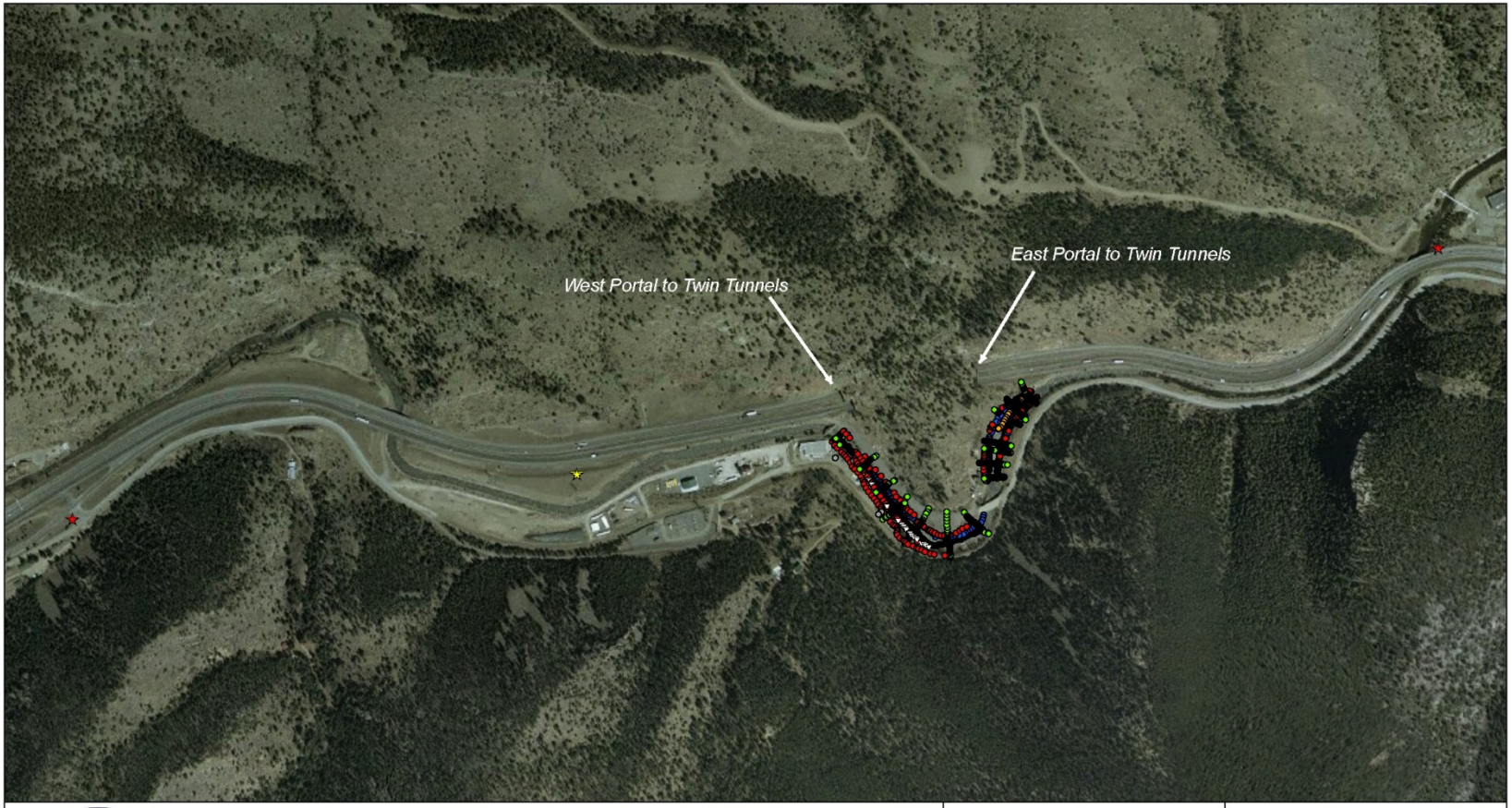
LOG VANE DETAIL	
DRAWN: ERICHER	6/3/2013
CHECKED:	
APPROVED:	
SHEET: 9 OF 9	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

NORTH PLATTE RIVER
VERNER SWA
CONCEPTUAL DESIGN



LOCATION MAP		STATE OF COLORADO DEPARTMENT OF NATURAL RESOURCES COLORADO PARKS AND WILDLIFE FORT COLLINS, COLORADO
DRAWN: ERICHER	4/4/2013	TWIN TUNNELS PROJECT CLEAR CREEK SITE ASSESSMENT
CHECKED:		
APPROVED:		
SHEET: 1 OF 10		



Survey Data

BASE WS XS EFFLUENT
CP THL GRND
BANK BKF ISLAND

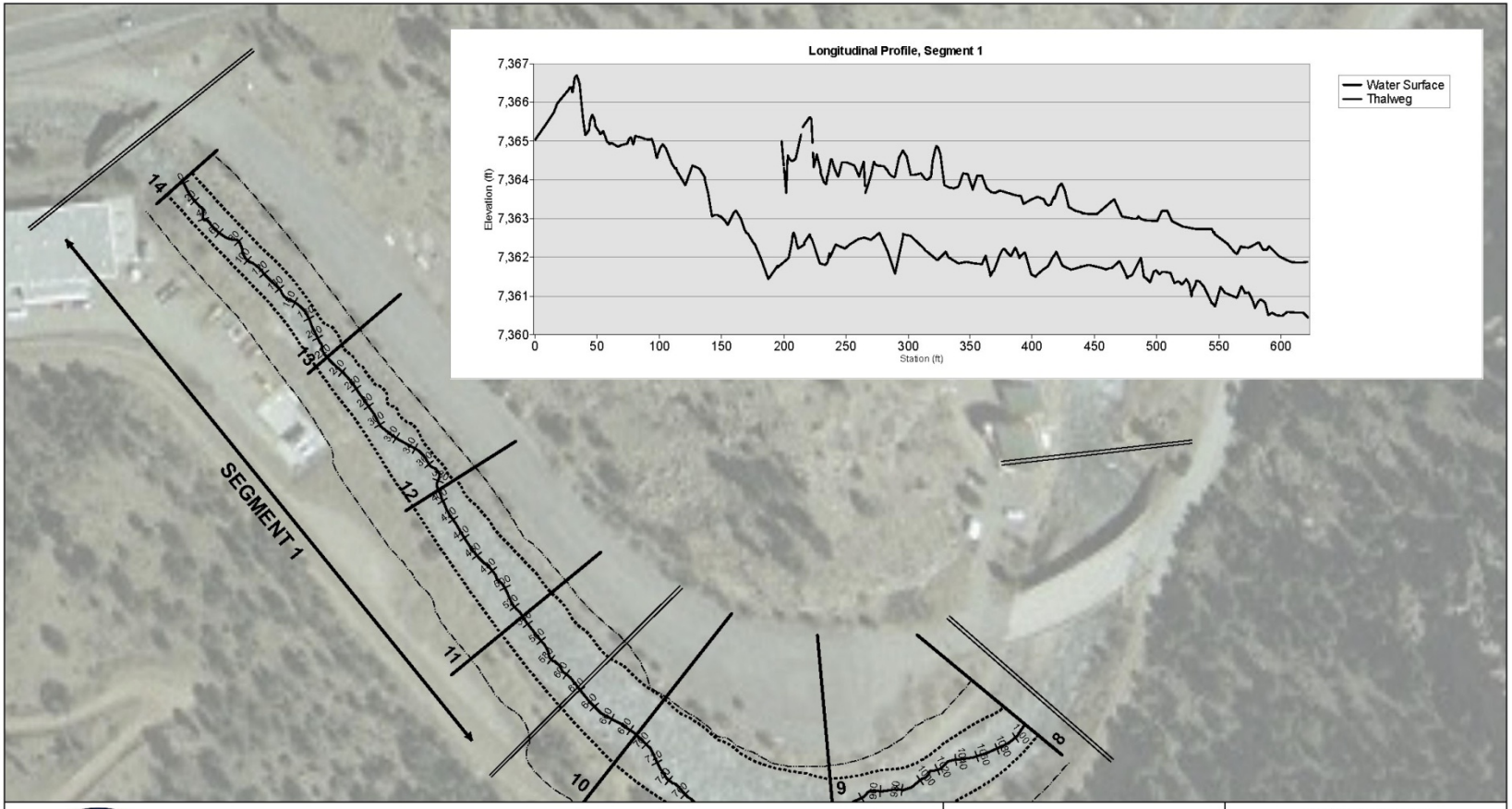
0 190 380 760 1,140 1,520 Feet

N

SURVEY POINTS	
DRAWN: ERICHER	4/2/2013
CHECKED:	
APPROVED:	
SHEET: 2 OF 10	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

TWIN TUNNELS PROJECT
CLEAR CREEK
SITE ASSESSMENT



Longitudinal Profile

Thalweg
Water Surface
Top of Bank
Cross-Sections
Segments

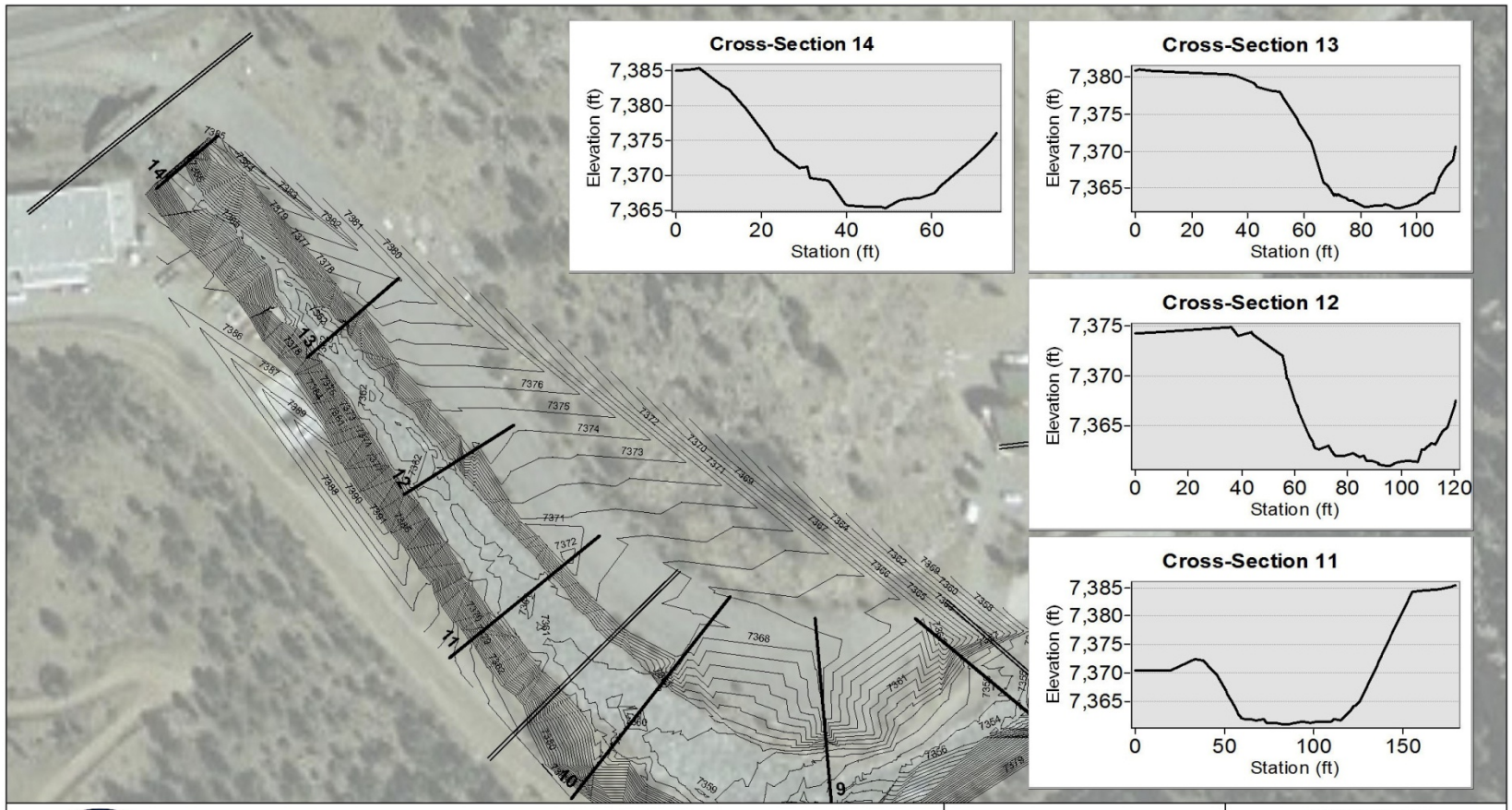
0 30 60 120 180 240 Feet

N

SEGMENT 1	
DRAWN: ERICHER	4/2/2013
CHECKED:	
APPROVED:	
SHEET: 4 OF 10	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

TWIN TUNNELS PROJECT
CLEAR CREEK
SITE ASSESSMENT



Cross-Sections

- Cross-Sections
- Segments
- Contours (1 ft interval)

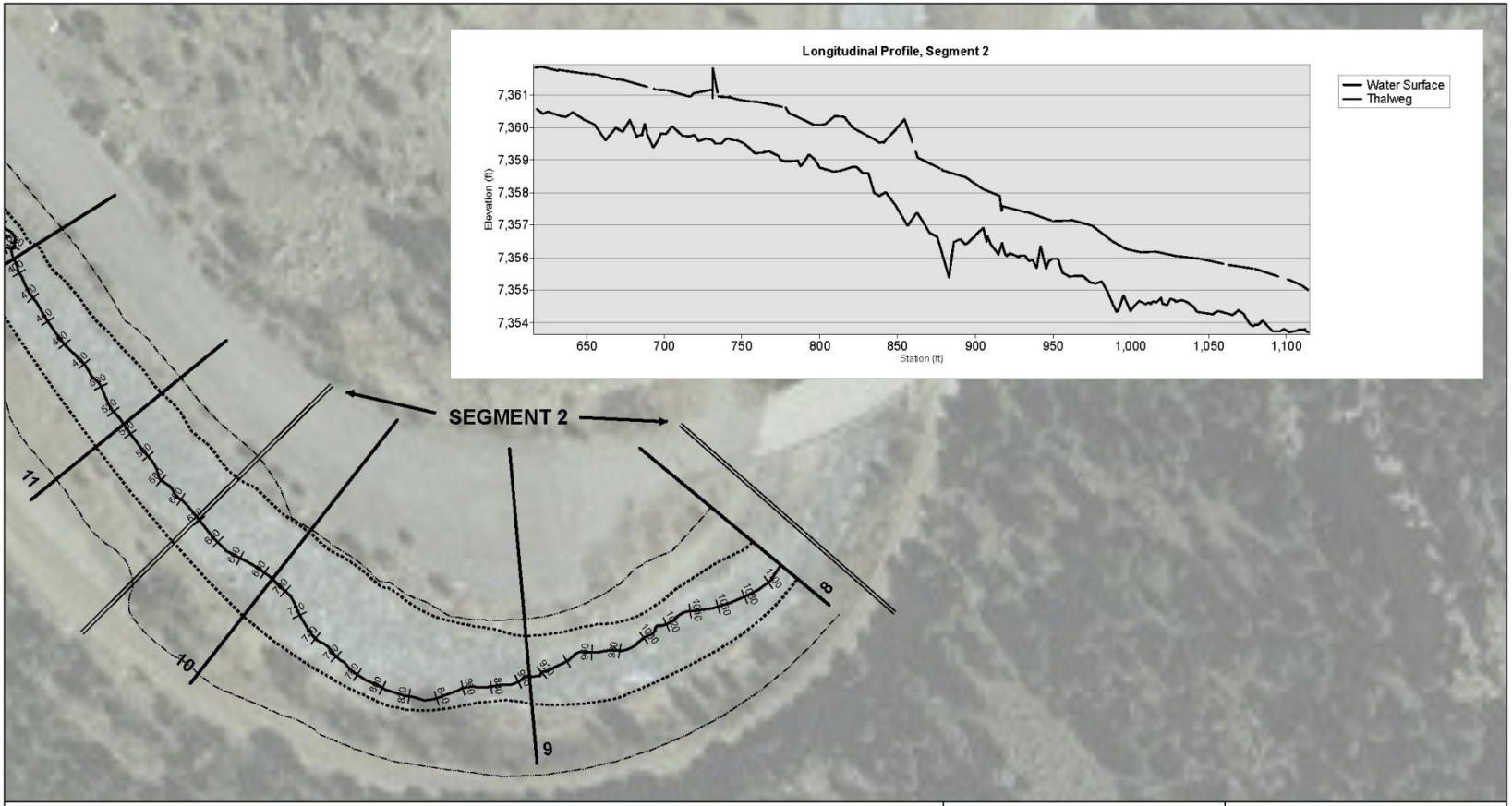
0 30 60 120 180 240 Feet

N

SEGMENT 1	
DRAWN: ERICHER	4/4/2013
CHECKED:	
APPROVED:	
SHEET: 5 OF 10	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

TWIN TUNNELS PROJECT
CLEAR CREEK
SITE ASSESSMENT



Longitudinal Profile

Thalweg — Cross-Sections
Water Surface — Segments
Top of Bank

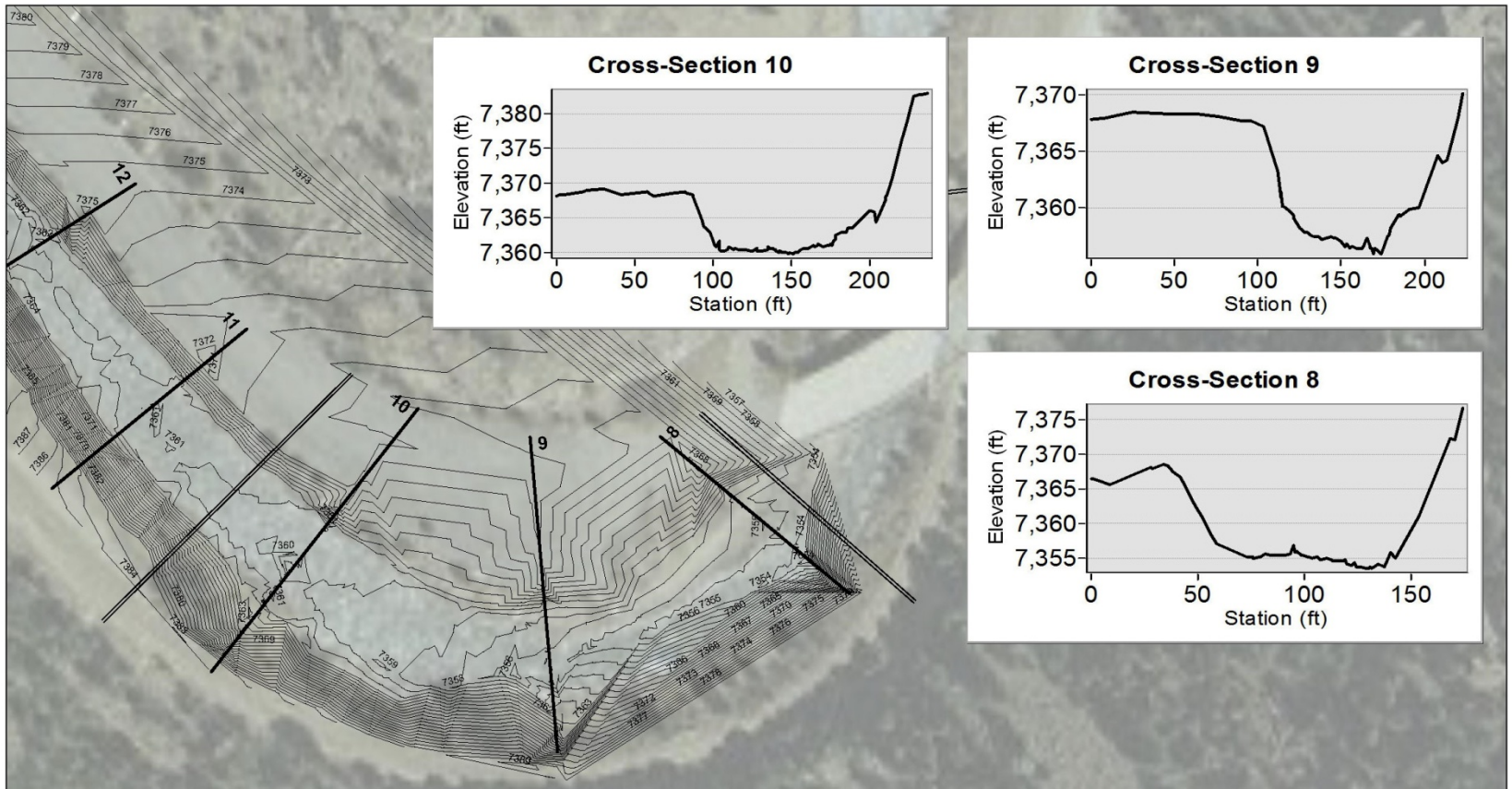
0 20 40 80 120 160 Feet

N

SEGMENT 2	
DRAWN: ERICHER	4/2/2013
CHECKED:	
APPROVED:	
SHEET: 6 OF 10	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

TWIN TUNNELS PROJECT
CLEAR CREEK
SITE ASSESSMENT



Cross-Sections

- Cross-Sections
- Segments
- Contours (1 ft interval)

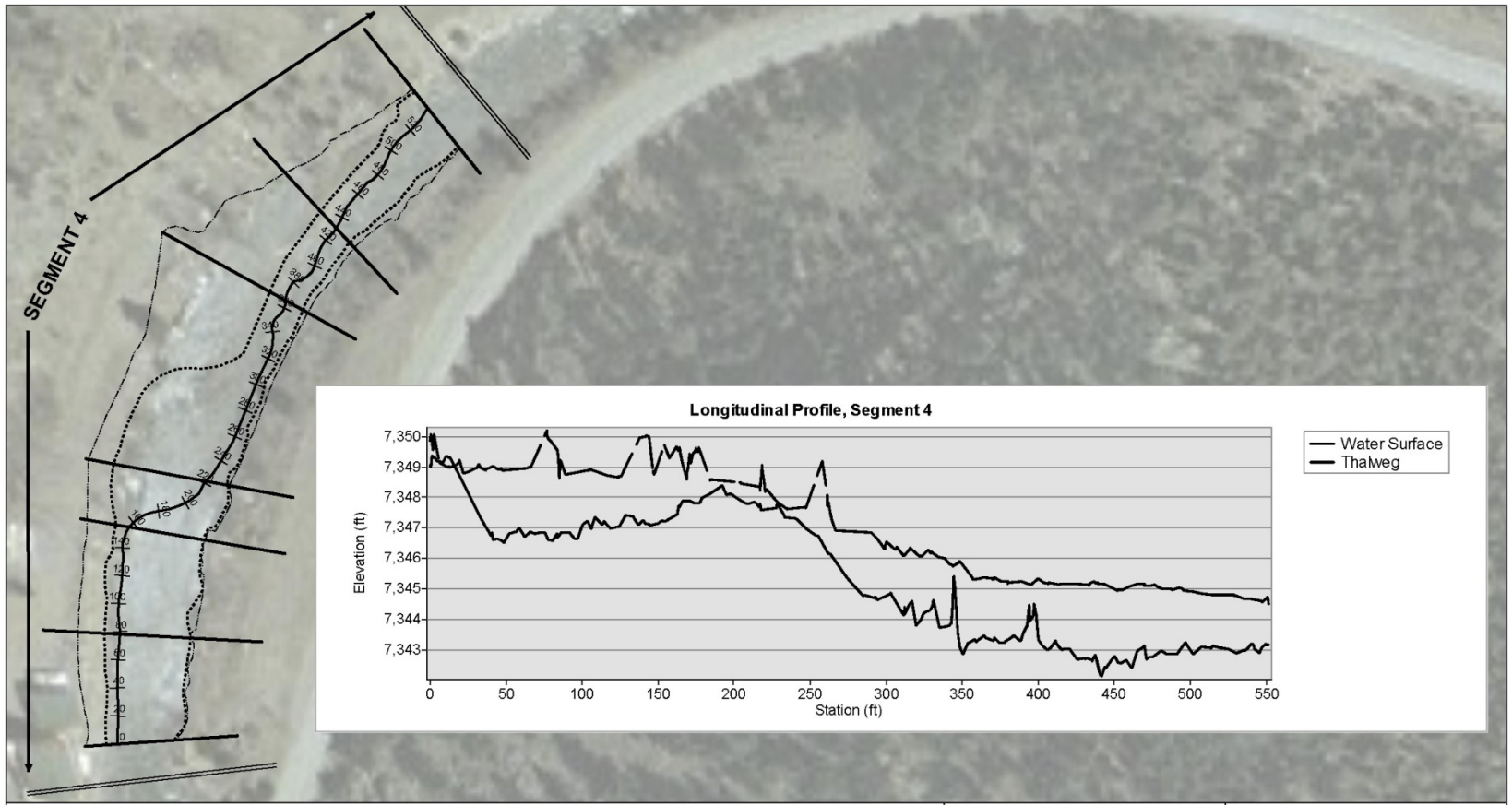
0 20 40 80 120 160 Feet

N

SEGMENT 2	
DRAWN: ERICHER	4/2/2013
CHECKED:	
APPROVED:	
SHEET: 7 OF 10	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

TWIN TUNNELS PROJECT
CLEAR CREEK
SITE ASSESSMENT



Longitudinal Profile

Thalweg
Water Surface
Top of Bank
Cross-Sections
Segments

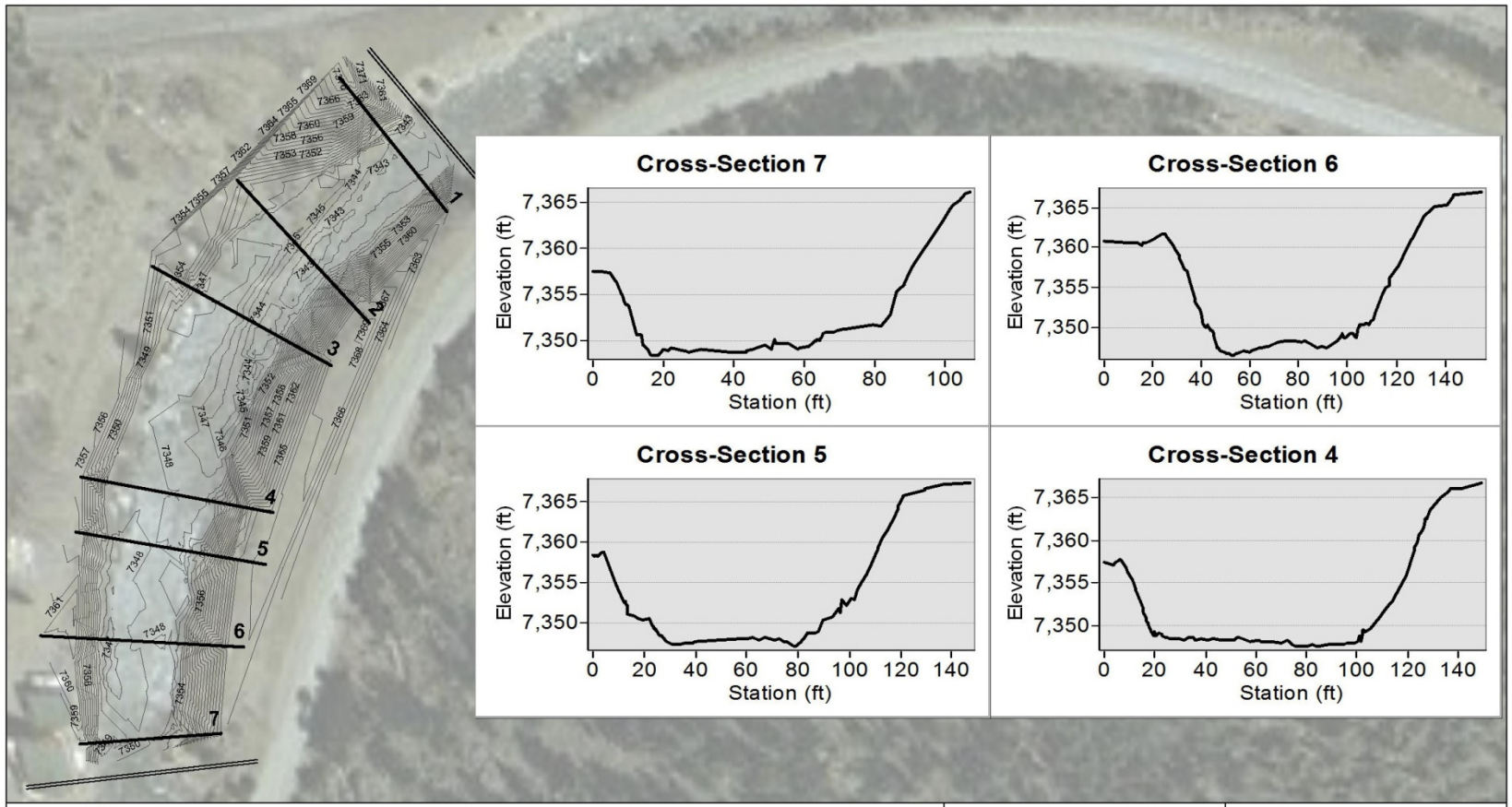
0 20 40 80 120 160 Feet

N

SEGMENT 4	
DRAWN: ERICHER	4/2/2013
CHECKED:	
APPROVED:	
SHEET: 8 OF 10	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

TWIN TUNNELS PROJECT
CLEAR CREEK
SITE ASSESSMENT



Cross-Sections

- Cross-Sections
- Segments
- Contour lines (1 ft interval)

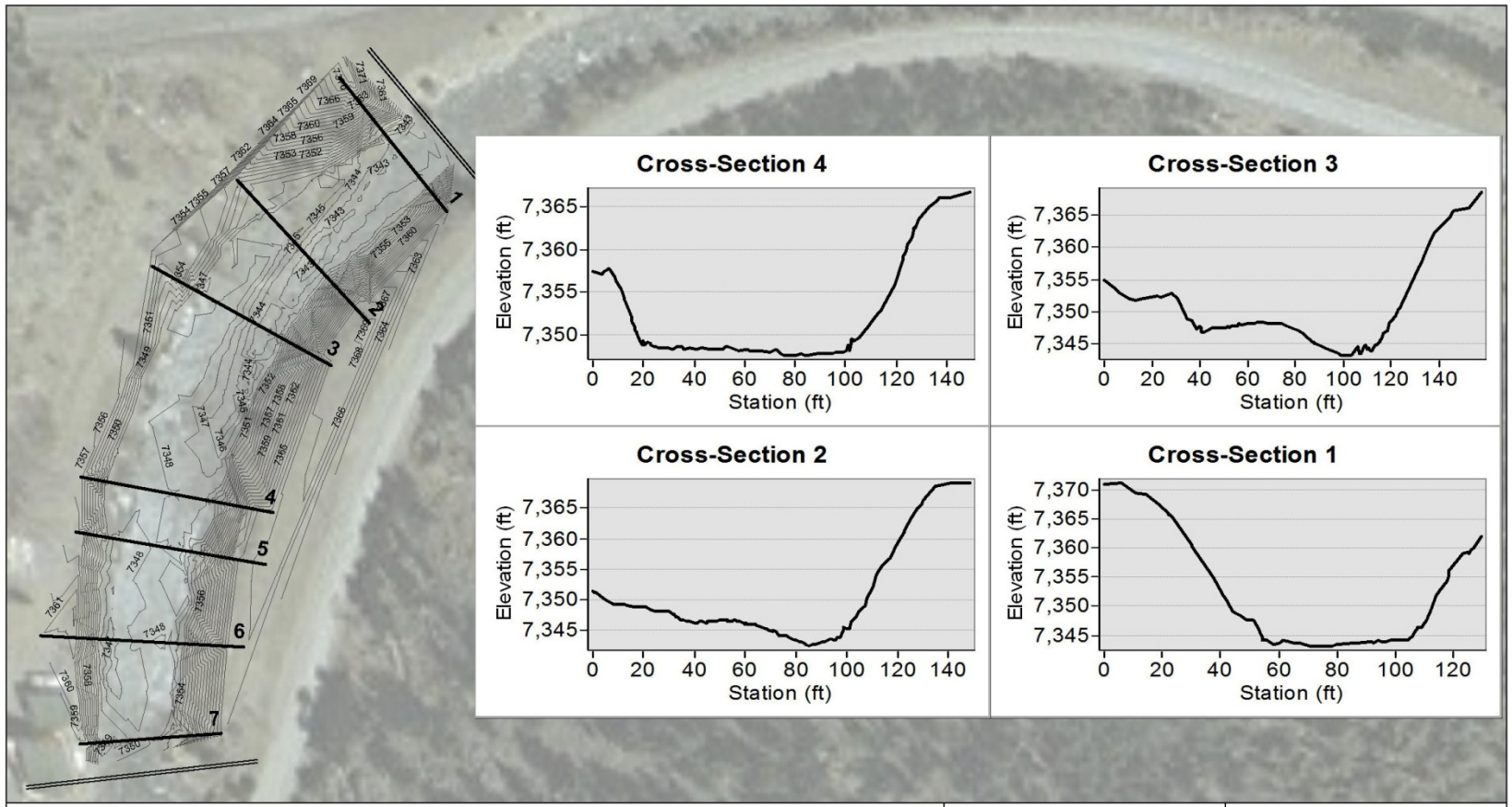
0 25 50 100 150 200 Feet

N

SEGMENT 4	
DRAWN: ERICHER	4/2/2013
CHECKED:	
APPROVED:	
SHEET: 9 OF 10	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

TWIN TUNNELS PROJECT
CLEAR CREEK
SITE ASSESSMENT



Cross-Sections

- Cross-Sections
- Segments
- Contour lines (1 ft interval)

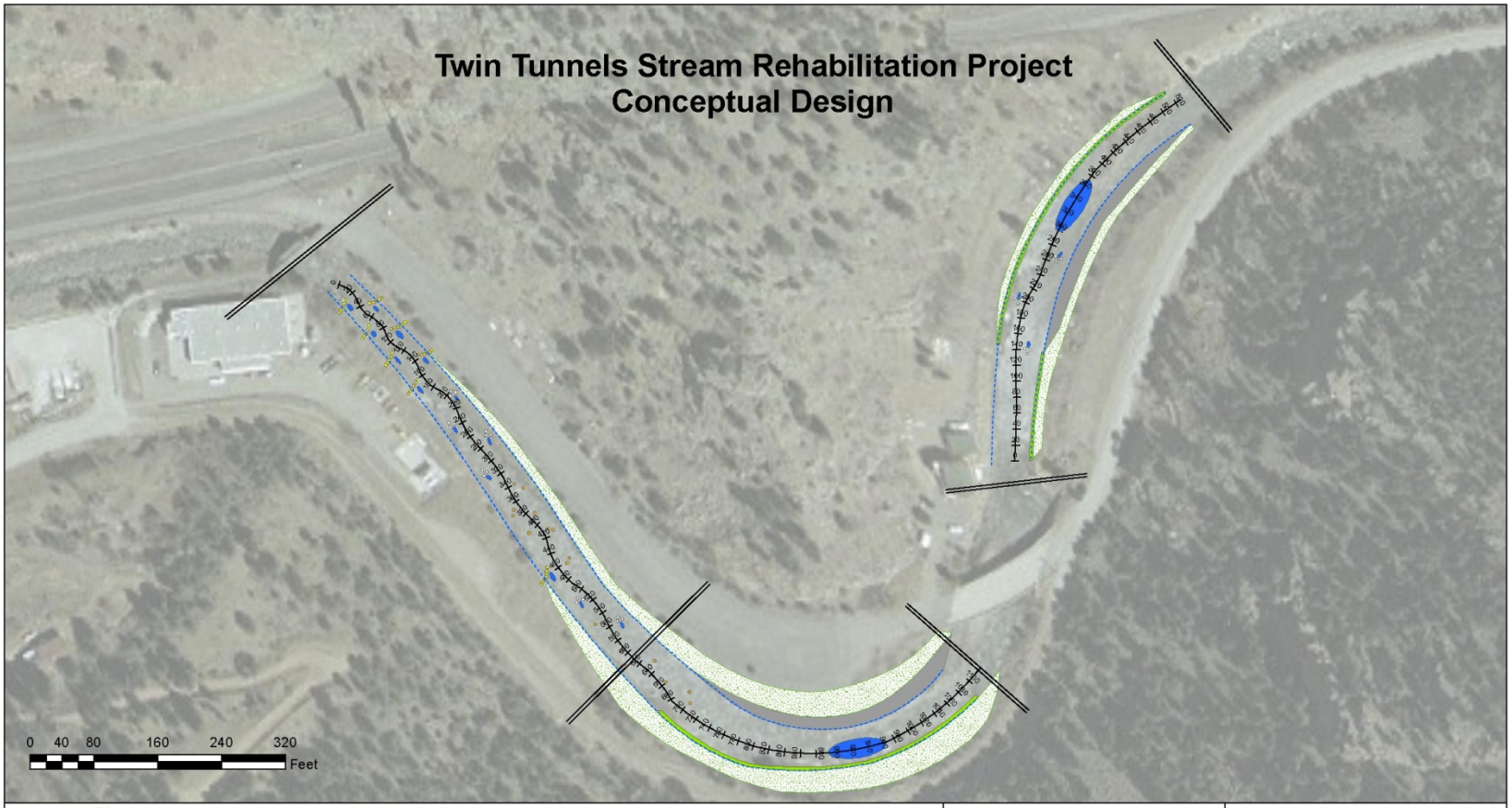
0 25 50 100 150 200 Feet

N

SEGMENT 4	
DRAWN: ERICHER	4/2/2013
CHECKED:	
APPROVED:	
SHEET: 10 OF 10	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

TWIN TUNNELS PROJECT
CLEAR CREEK
SITE ASSESSMENT

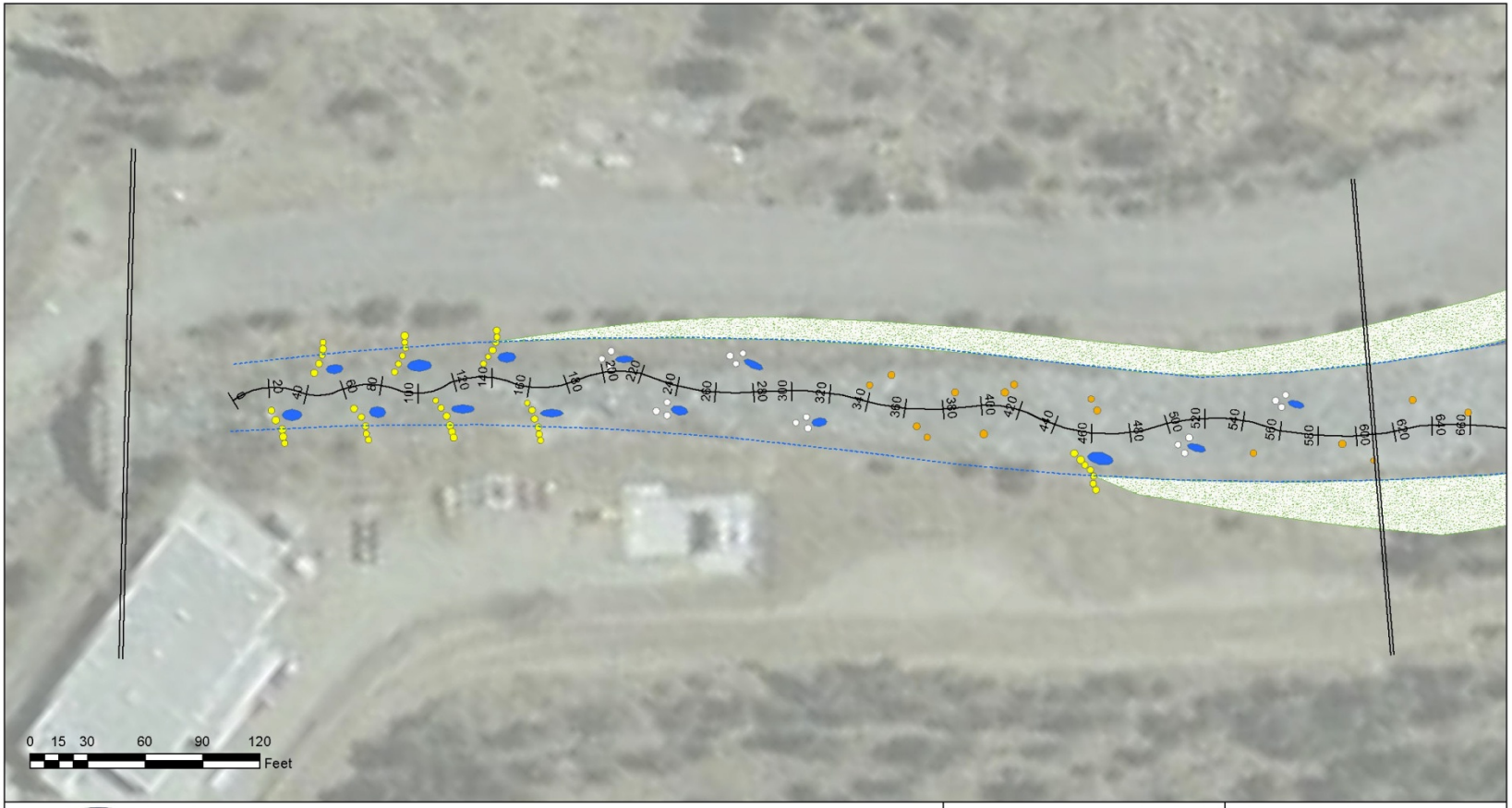


Bank-toe Protection
Establish/Enhance Riparian Bench
Grade Point Bar
Excavate/Enhance Pool
Boulder Rib Deflector
Boulder Cluster
Random Boulder
Segments
Thalweg
Bankfull Channel Boundary
N

DESIGN OVERVIEW	
DRAWN: ERICHER	4/5/2013
CHECKED:	
APPROVED:	
SHEET: 1 OF 4	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

TWIN TUNNELS PROJECT
CLEAR CREEK
CONCEPTUAL DESIGN

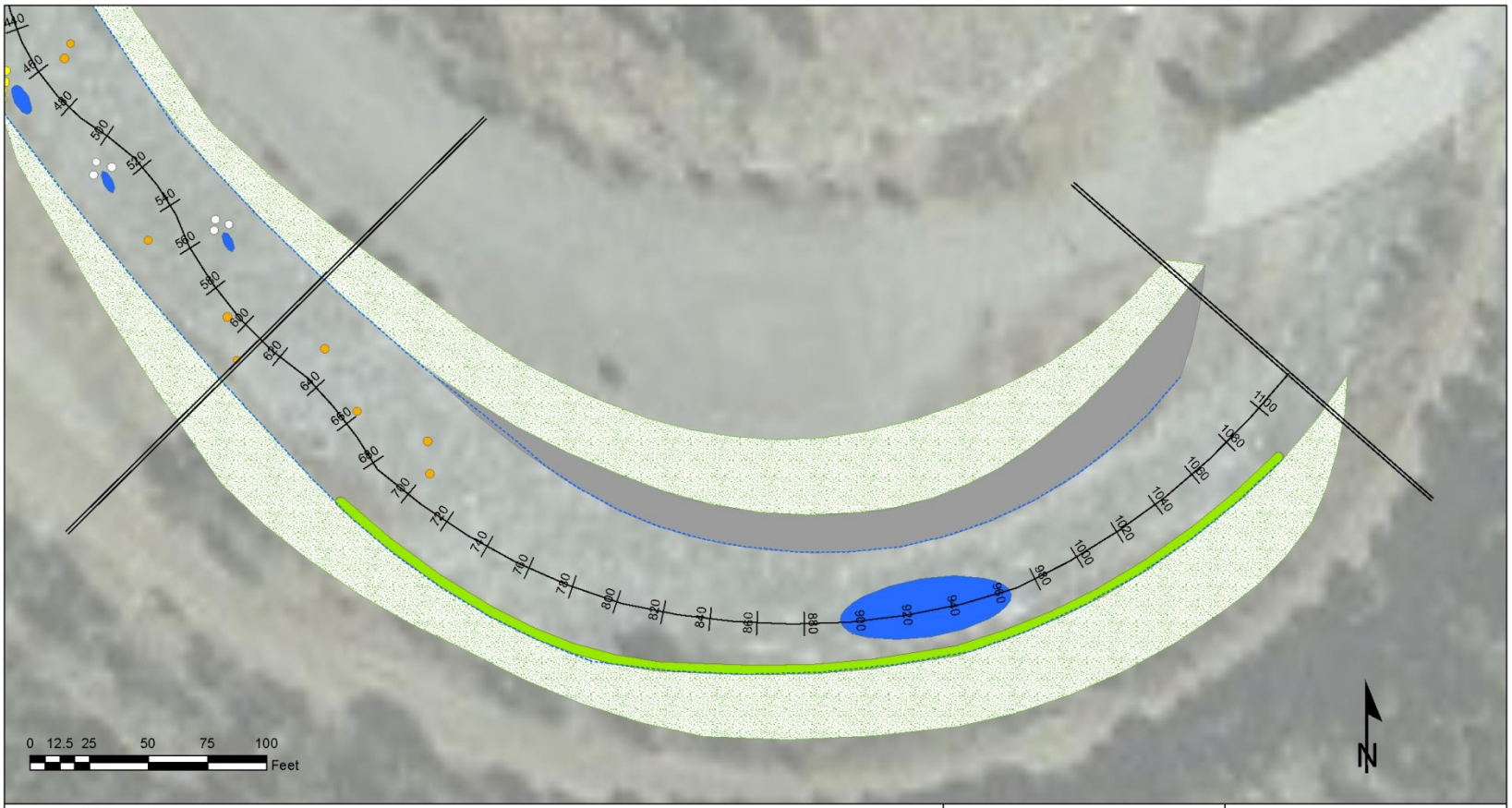


Bank-toe Protection
Establish/Enhance Riparian Bench
Grade Point Bar
Excavate/Enhance Pool
Boulder Rib Deflector
Boulder Cluster
Random Boulder
Segments
Thalweg
Bankfull Channel Boundary

SEGMENT 1	
DRAWN: ERICHER	4/5/2013
CHECKED:	
APPROVED:	
SHEET: 2 OF 4	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

TWIN TUNNELS PROJECT
CLEAR CREEK
CONCEPTUAL DESIGN

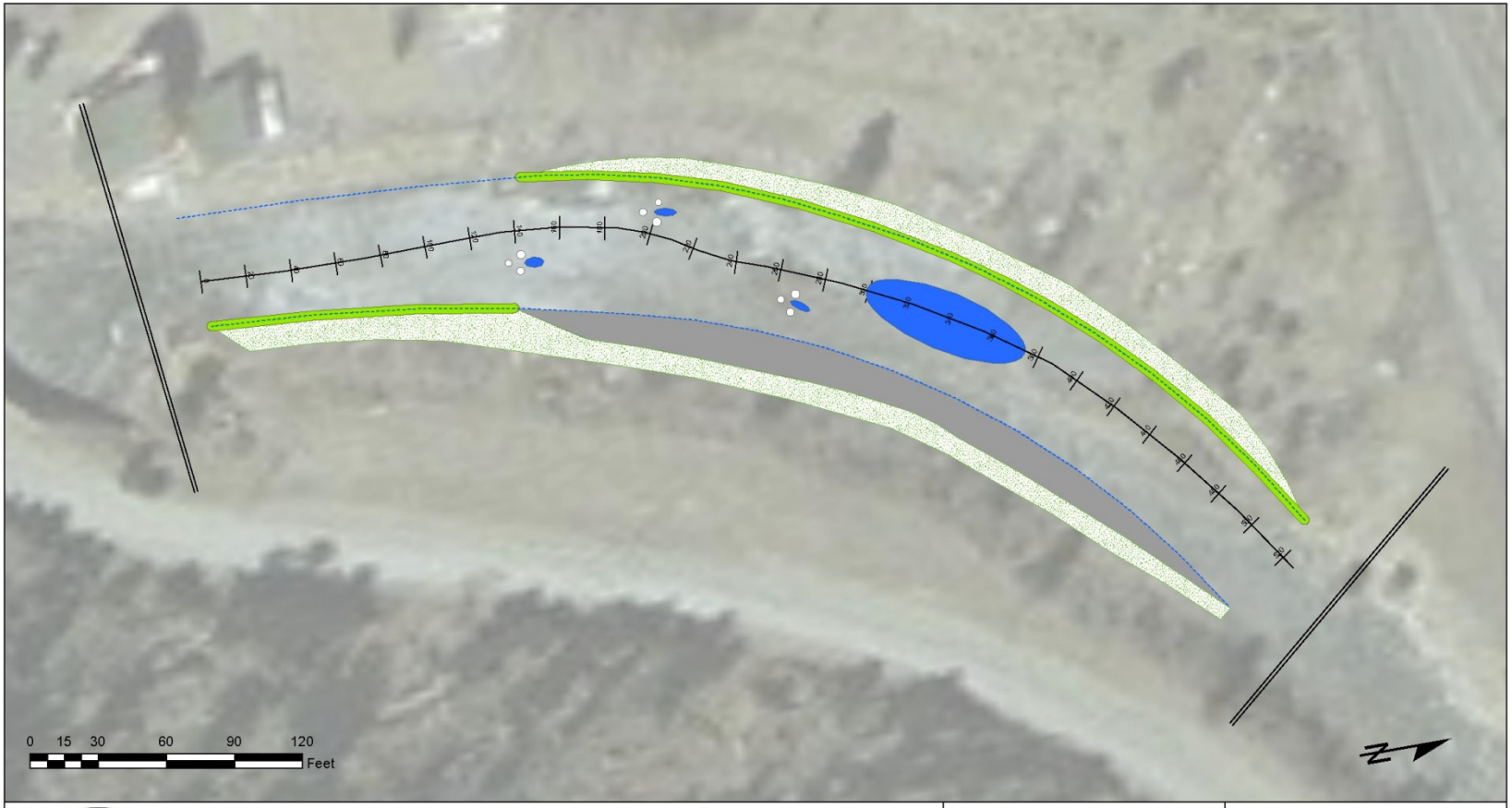


Bank-toe Protection
Establish/Enhance Riparian Bench
Grade Point Bar
Excavate/Enhance Pool
Boulder Rib Deflector
Boulder Cluster
Random Boulder
Segments
Thalweg
Bankfull Channel Boundary

SEGMENT 2	
DRAWN: ERICHER	4/5/2013
CHECKED:	
APPROVED:	
SHEET: 3 OF 4	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

TWIN TUNNELS PROJECT
CLEAR CREEK
CONCEPTUAL DESIGN

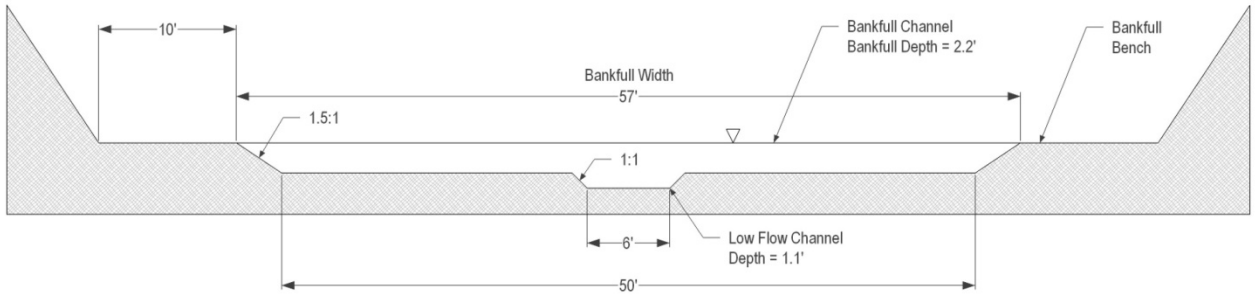


Bank-toe Protection
Establish/Enhance Riparian Bench
Grade Point Bar
Excavate/Enhance Pool
Boulder Rib Deflector
Boulder Cluster
Random Boulder
Segments
Thalweg
Bankfull Channel Boundary

SEGMENT 4	
DRAWN: ERICHER	4/5/2013
CHECKED:	
APPROVED:	
SHEET: 4 OF 4	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

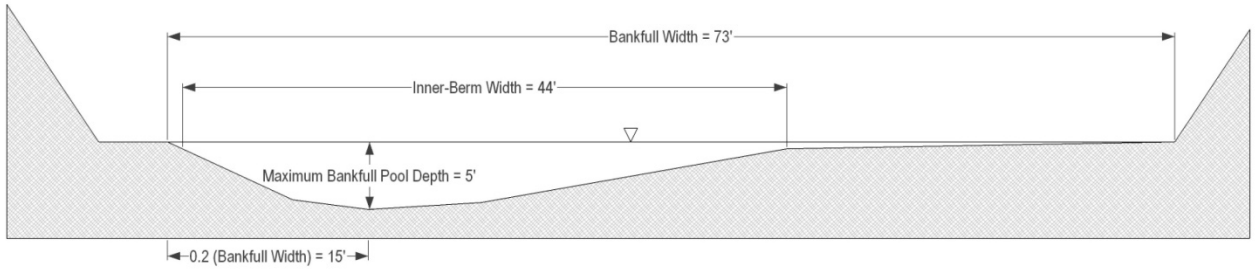
TWIN TUNNELS PROJECT
CLEAR CREEK
CONCEPTUAL DESIGN



Typical Riffle Cross-Section

NTS

Riffle dimensions vary as the riffle transitions to and from pools. Dimensions given are for the maximum width and depth (center of riffle)

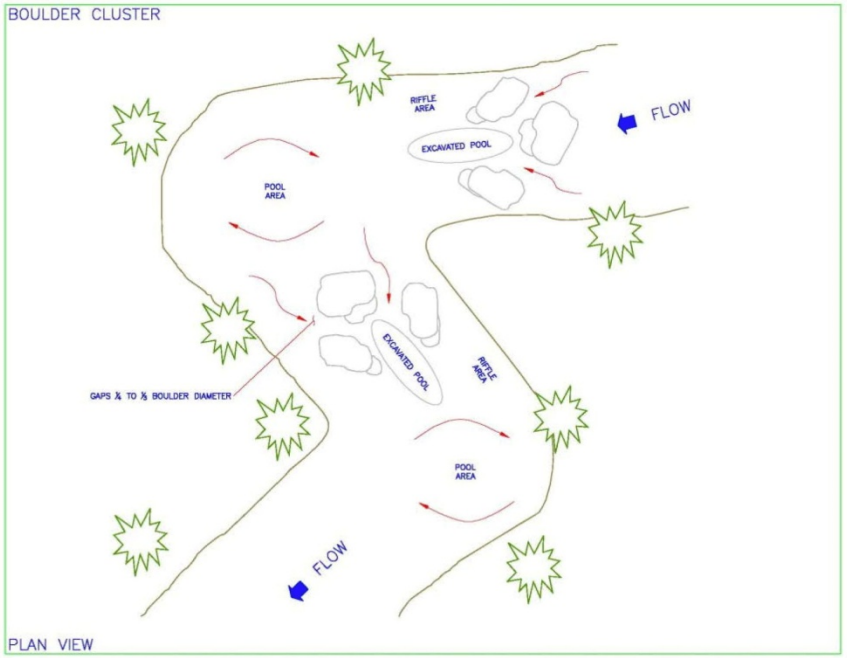


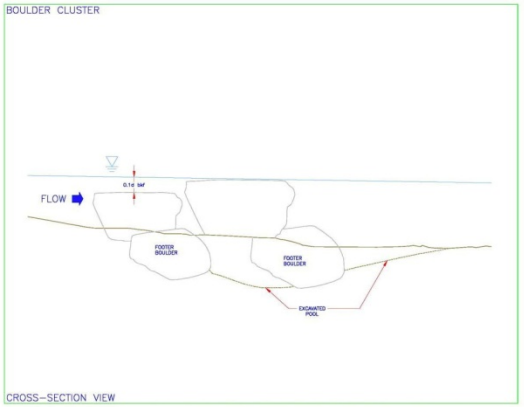
Typical Pool Cross-Section

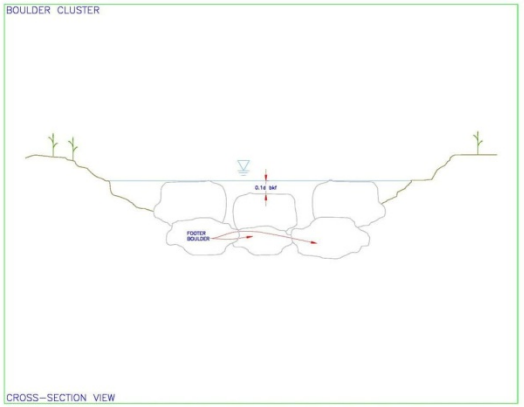
NTS

Pool dimensions vary as the upstream riffle transitions to the upper end of the pool (run) and from the lower end of the pool (glide) to the downstream riffle. Dimension are given for the pool at maximum width and depth.

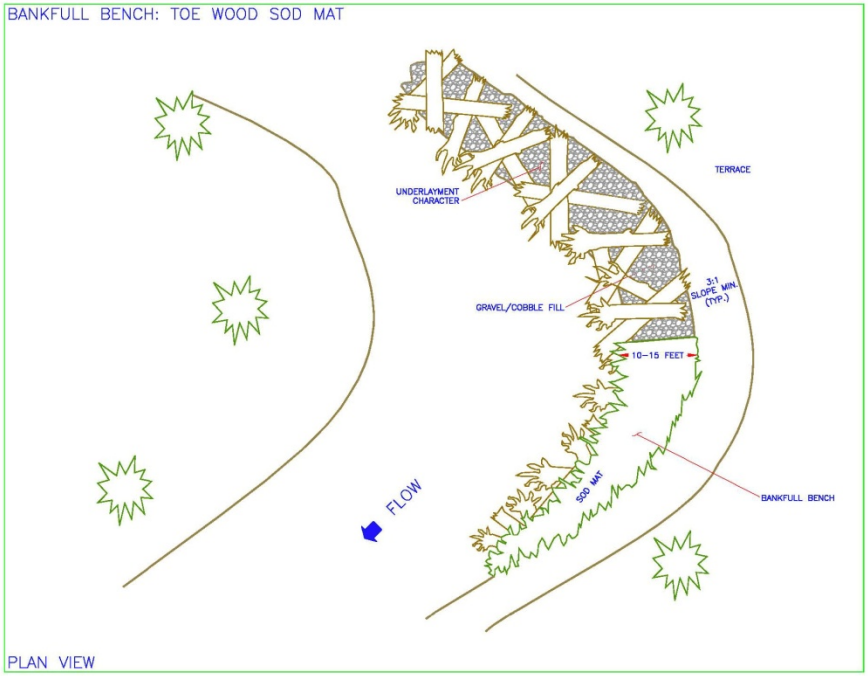
	TYPICAL CROSS-SECTIONS	STATE OF COLORADO DEPARTMENT OF NATURAL RESOURCES COLORADO PARKS AND WILDLIFE FORT COLLINS, COLORADO
	DRAWN: 4/5/2013	
	CHECKED:	TWIN TUNNELS PROJECT CLEAR CREEK CONCEPTUAL DESIGN
	APPROVED:	
	SHEET:	

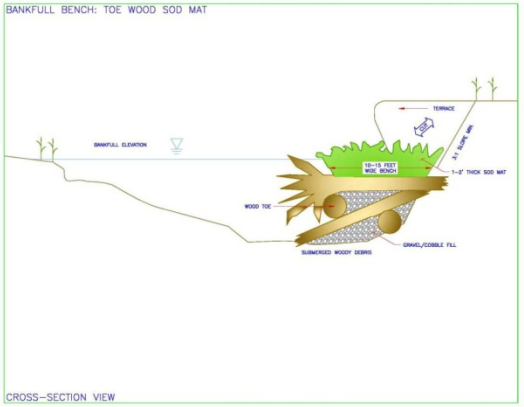


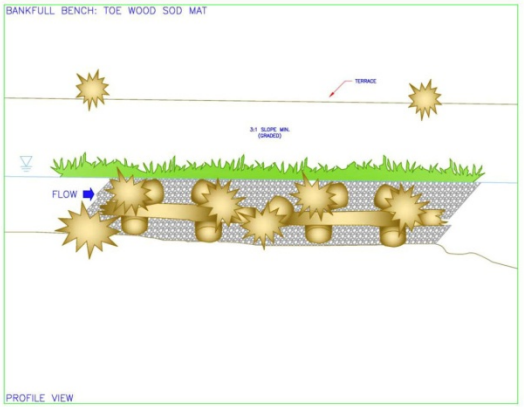




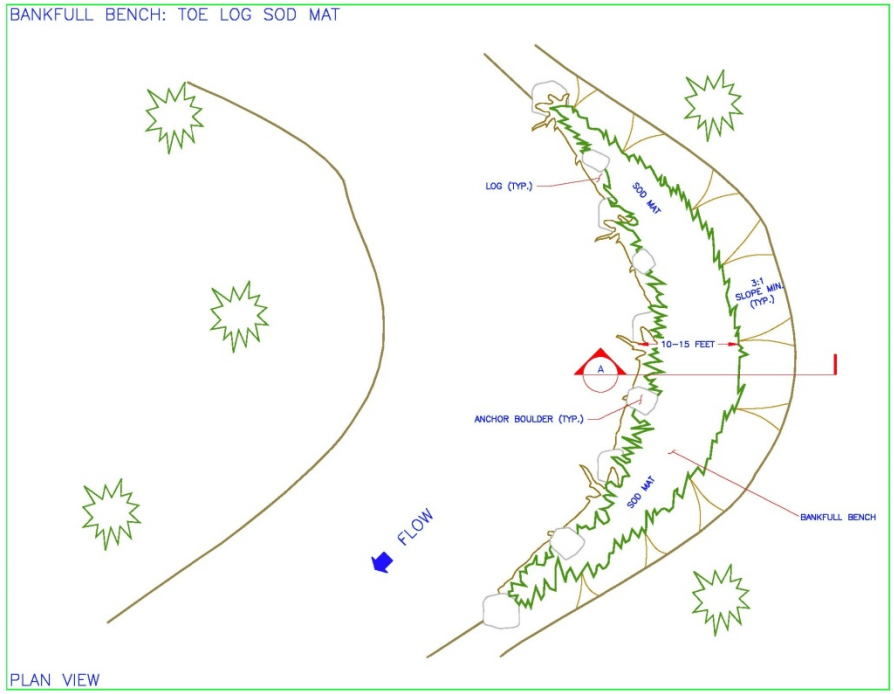
BOULDER CLUSTER DETAIL		STATE OF COLORADO DEPARTMENT OF NATURAL RESOURCES COLORADO PARKS AND WILDLIFE FORT COLLINS, COLORADO
DRAWN:	4/4/2013	
CHECKED:		TWIN TUNNELS PROJECT CLEAR CREEK CONCEPTUAL DESIGN
APPROVED:		
SHEET:		

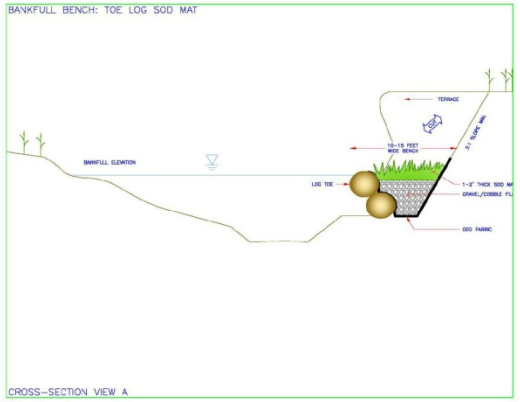


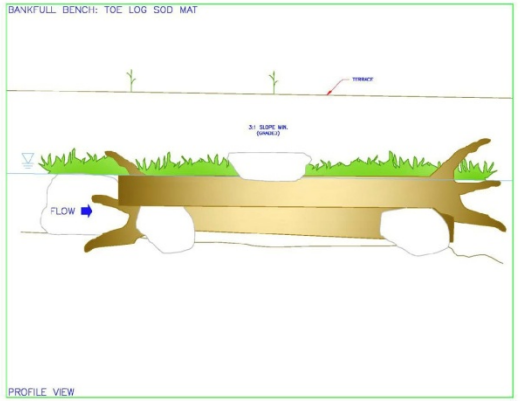




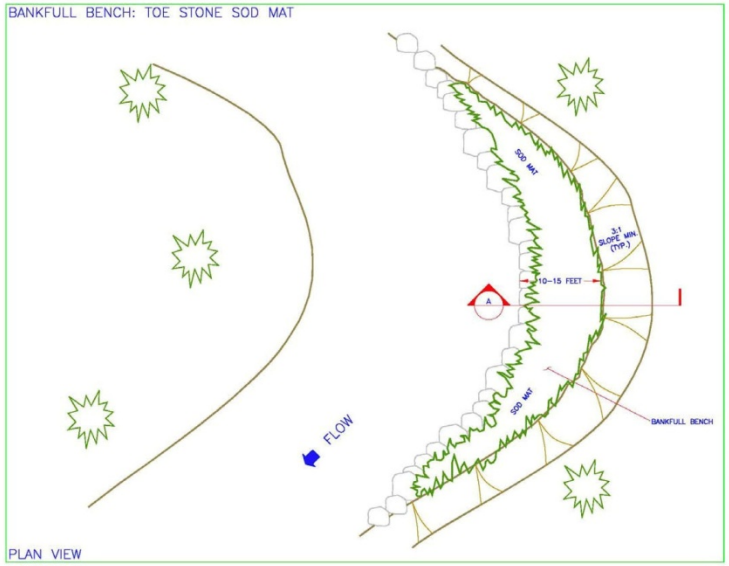
	WOOD TOE / SOD MAT DETAIL	STATE OF COLORADO DEPARTMENT OF NATURAL RESOURCES COLORADO PARKS AND WILDLIFE FORT COLLINS, COLORADO
	DRAWN: 4/4/2013	
	CHECKED:	TWIN TUNNELS PROJECT CLEAR CREEK CONCEPTUAL DESIGN
	APPROVED:	
	SHEET:	

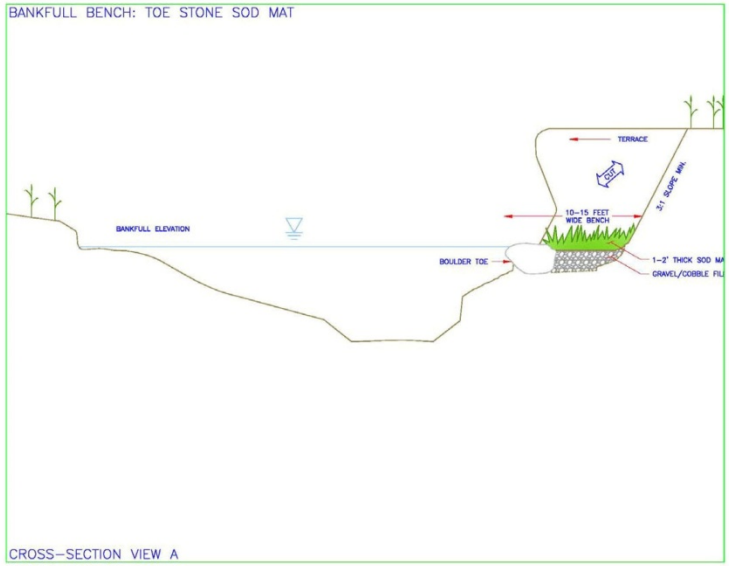




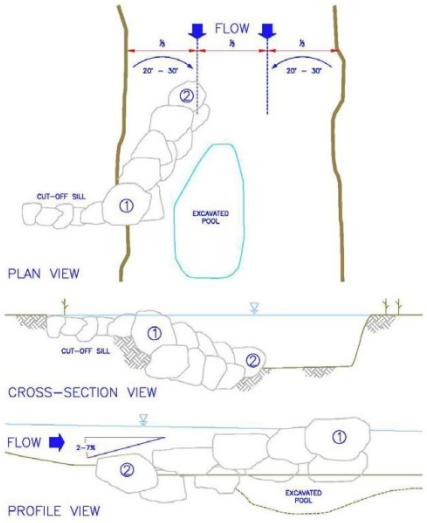


	LOG TOE / SOD MAT DETAIL	STATE OF COLORADO DEPARTMENT OF NATURAL RESOURCES COLORADO PARKS AND WILDLIFE FORT COLLINS, COLORADO
	DRAWN: 4/4/2013	
	CHECKED:	TWIN TUNNELS PROJECT CLEAR CREEK CONCEPTUAL DESIGN
	APPROVED:	
	SHEET:	





	BOULDER TOE DETAIL	STATE OF COLORADO DEPARTMENT OF NATURAL RESOURCES COLORADO PARKS AND WILDLIFE FORT COLLINS, COLORADO
	DRAWN: 4/4/2013	
	CHECKED:	TWIN TUNNELS PROJECT CLEAR CREEK CONCEPTUAL DESIGN
	APPROVED:	
	SHEET:	

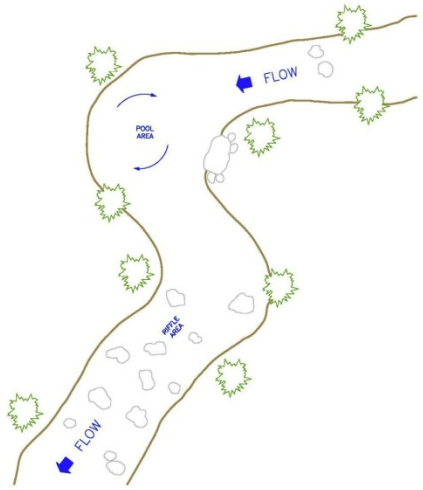


BOULDER HALF–VANE – PLAN, SECTION AND PROFILE VIEW

The Half-Vane Detail is similar to the Boulder Rib Deflectors proposed in the Twin Tunnels Conceptual Design. However, the Boulder Rib Deflector structures differ in design from the Half-Vane structure, as outlined below:

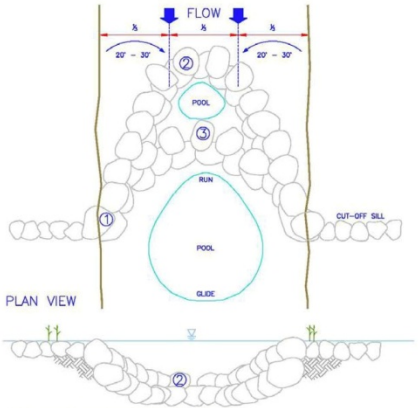
- Ribs should be angled from the bank at 45-90°
- Boulders at the bank should be set at 1/2 to 2/3 of the bankfull depth
- Boulders should still be keyed into the bank
- Each boulder placed into the active channel moving out from the bank should be set at a lower elevation using a slope of 10%
- Gaps between boulders should be 1/2 to 2/3 of the boulder diameter
- Ribs should alternate from one side of the channel to the other at a spacing of 0.5 bankfull widths resulting in increased sinuousity

HALF-VANE DETAIL		STATE OF COLORADO DEPARTMENT OF NATURAL RESOURCES COLORADO PARKS AND WILDLIFE FORT COLLINS, COLORADO
DRAWN:	4/4/2013	
CHECKED:		TWIN TUNNELS PROJECT CLEAR CREEK CONCEPTUAL DESIGN
APPROVED:		
SHEET:		



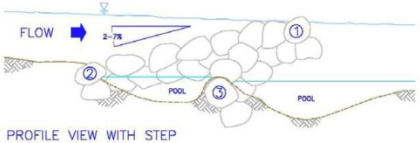
RANDOM BOULDER PLACEMENT

	ENHANCED RIFFLE DETAIL	STATE OF COLORADO DEPARTMENT OF NATURAL RESOURCES COLORADO PARKS AND WILDLIFE FORT COLLINS, COLORADO
	DRAWN: 4/4/2013	
	CHECKED:	TWIN TUNNELS PROJECT CLEAR CREEK CONCEPTUAL DESIGN
	APPROVED:	
	SHEET:	



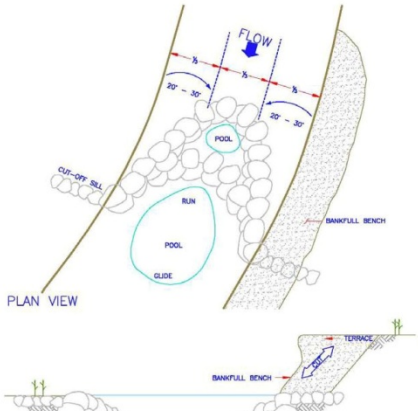
PLAN VIEW

CROSS–SECTION VIEW WITHOUT STEP



PROFILE VIEW WITH STEP

CROSS–VANE – PLAN, SECTION AND PROFILE VIEW



PLAN VIEW

CROSS–SECTION VIEW CROSS–VANE W/ BANKFULL BENCH

CROSS–VANE W/ BANKFULL BENCH – PLAN AND SECTION VIEW

	CROSS-VANE DETAIL	STATE OF COLORADO DEPARTMENT OF NATURAL RESOURCES COLORADO PARKS AND WILDLIFE FORT COLLINS, COLORADO
	DRAWN: 4/4/2013	
	CHECKED:	TWIN TUNNELS PROJECT CLEAR CREEK CONCEPTUAL DESIGN
	APPROVED:	
	SHEET:	

COLORADO PARKS AND WILDLIFE

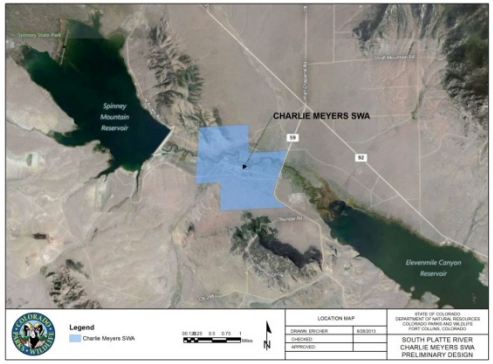
South Platte River Habitat Enhancement Project: Charlie Meyers State Wildlife Area

Preliminary Design Drawings

Prepared for:
U.S. Army , Corps of Engineers
Regional General Permit No. 12 Application

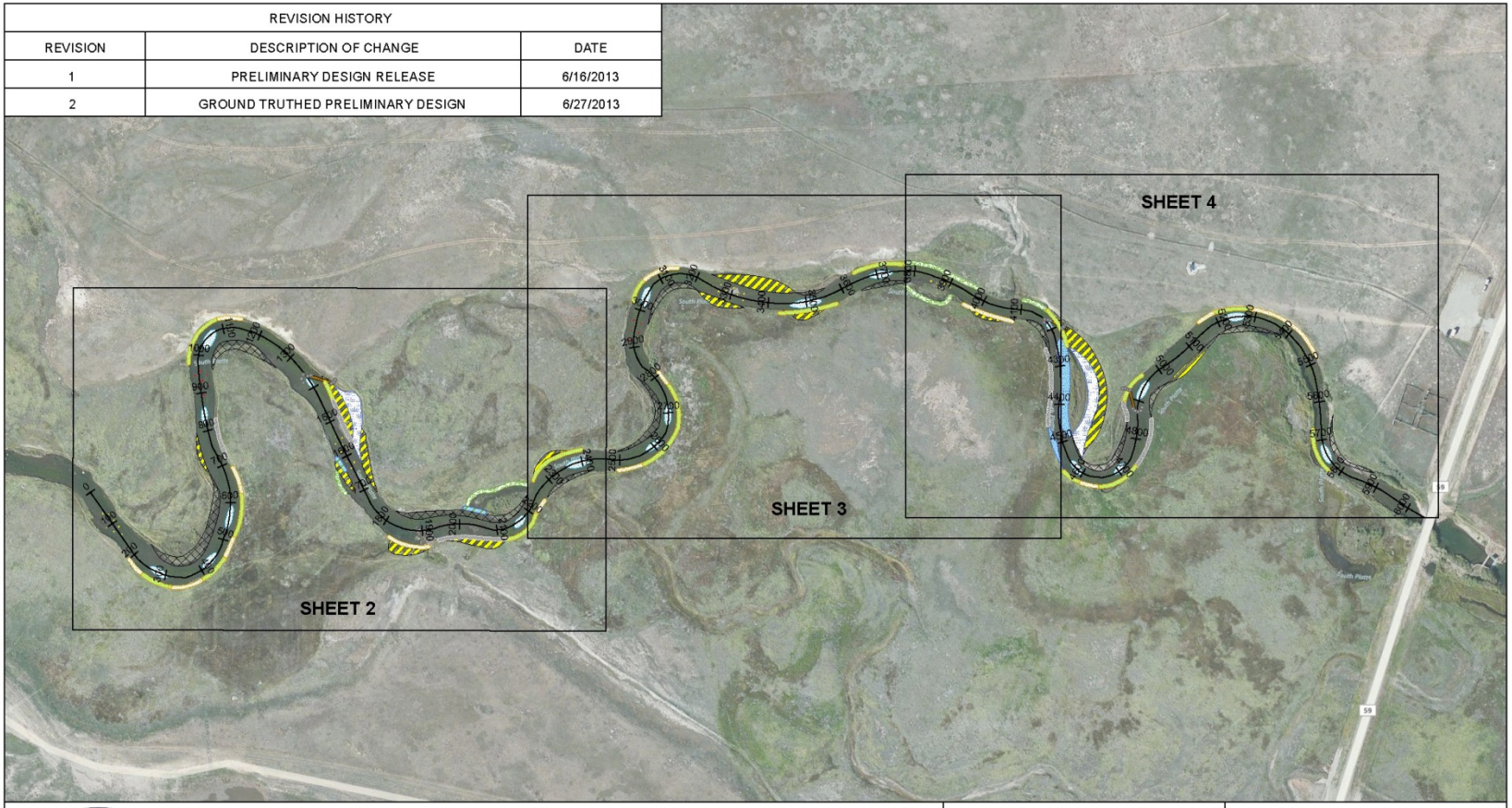
Prepared by:
Colorado Parks and Wildlife
Wildlife Research Center
317 W. Prospect Road
Fort Collins, CO 80526

June 28, 2013



STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

REVISION HISTORY		
REVISION	DESCRIPTION OF CHANGE	DATE
1	PRELIMINARY DESIGN RELEASE	6/16/2013
2	GROUND TRUTHED PRELIMINARY DESIGN	6/27/2013



Legend

- Wood Toe
- Brush Toe / Horizontal Log
- Cobble Toe
- Plant Willows
- Grade Control Sill
- Develop Pool
- Develop Rearing Habitat
- Grade Point Bar
- Narrow Channel
- Realign Channel
- Log-Vane J-Hook Combo
- Enhance Riffle
- Rock Garden

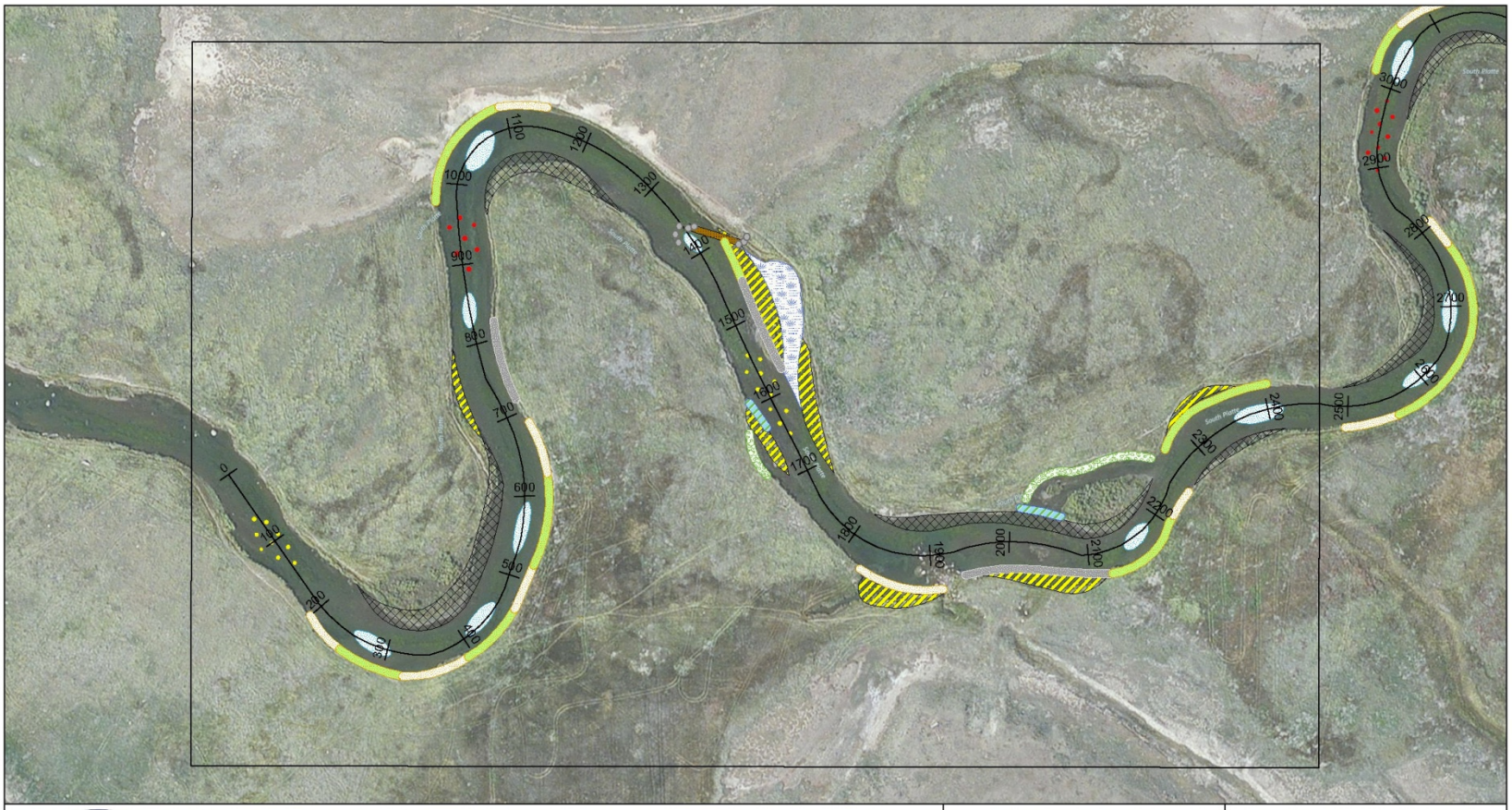
0 55 110 220 330 440 Feet

N

DESIGN LAYOUT	
DRAWN: ERICHER	8/5/2013
CHECKED: MKONDRATIEFF	--/--/----
APPROVED:	
SHEET: 1 OF 8	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

SOUTH PLATTE RIVER CHARLIE MEYERS SWA PRELIMINARY DESIGN



Legend

- Wood Toe
- Brush Toe / Horizontal Log
- Cobble Toe
- Plant Willows
- Grade Control Sill
- Develop Pool
- Develop Rearing Habitat
- Grade Point Bar
- Narrow Channel
- Realign Channel
- Log-Vane J-Hook Combo
- Enhance Riffle
- Rock Garden

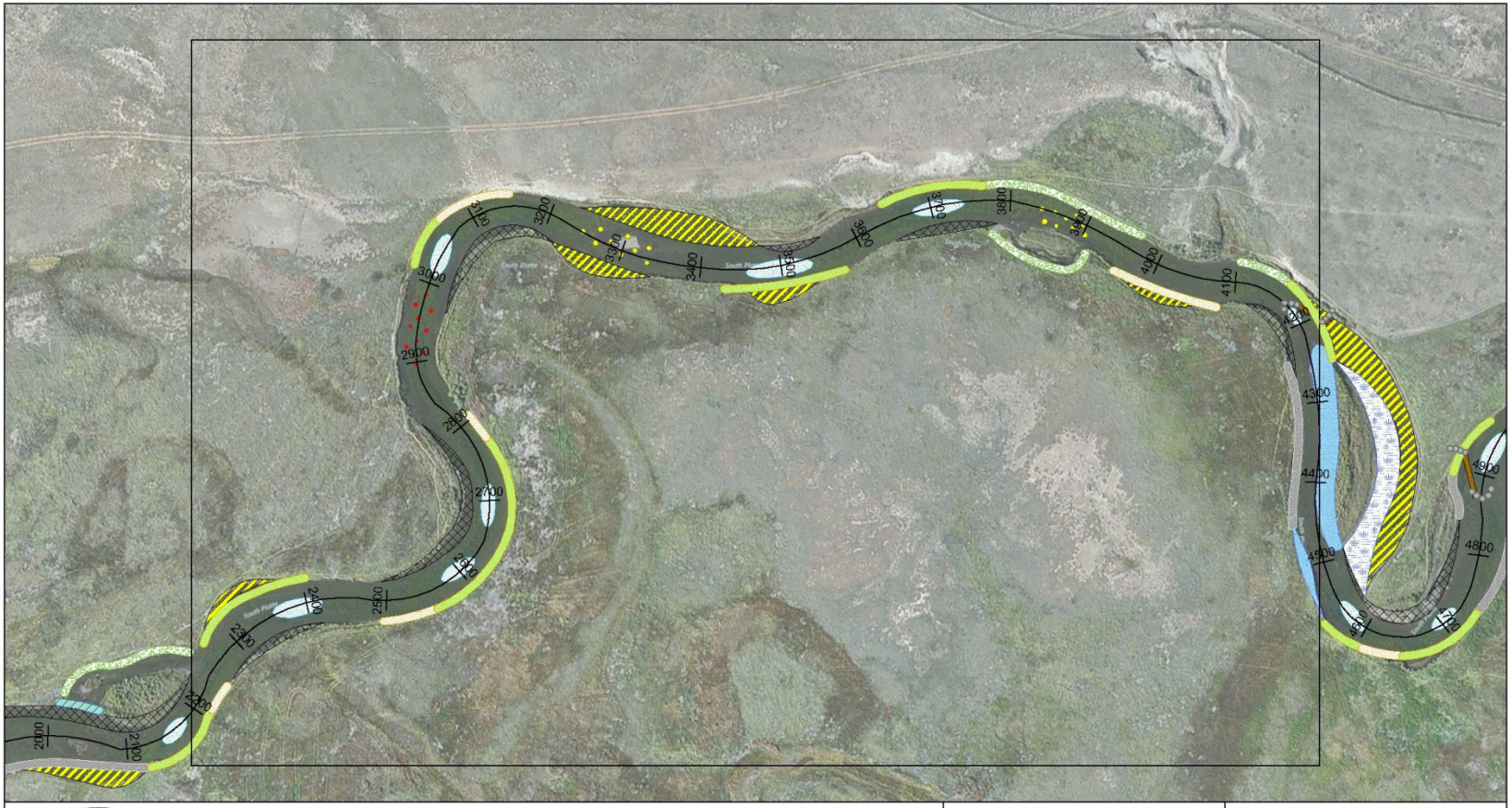
0 25 50 100 150 200 Feet

N

DESIGN LAYOUT	
DRAWN: ERICHER	8/5/2013
CHECKED: MKONDRATIEFF	--/--/----
APPROVED:	
SHEET: 2 OF 8	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

SOUTH PLATTE RIVER
CHARLIE MEYERS SWA
PRELIMINARY DESIGN



Legend

- Wood Toe
- Brush Toe / Horizontal Log
- Cobble Toe
- Plant Willows
- Grade Control Sill
- Develop Pool
- Develop Rearing Habitat
- Grade Point Bar
- Narrow Channel
- Realign Channel
- Log-Vane J-Hook Combo
- Enhance Riffle
- Rock Garden

0 25 50 100 150 200 Feet

N

DESIGN LAYOUT	
DRAWN: ERICHER	8/5/2013
CHECKED: MKONDRATIEFF	--/--/----
APPROVED:	
SHEET: 3 OF 8	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

SOUTH PLATTE RIVER
CHARLIE MEYERS SWA
PRELIMINARY DESIGN

Legend

- Wood Toe
- Brush Toe / Horizontal Log
- Cobble Toe
- Plant Willows
- Grade Control Sill
- Develop Pool
- Develop Rearing Habitat
- Grade Point Bar
- Narrow Channel
- Realign Channel
- Log-Vane J-Hook Combo
- Enhance Riffle
- Rock Garden

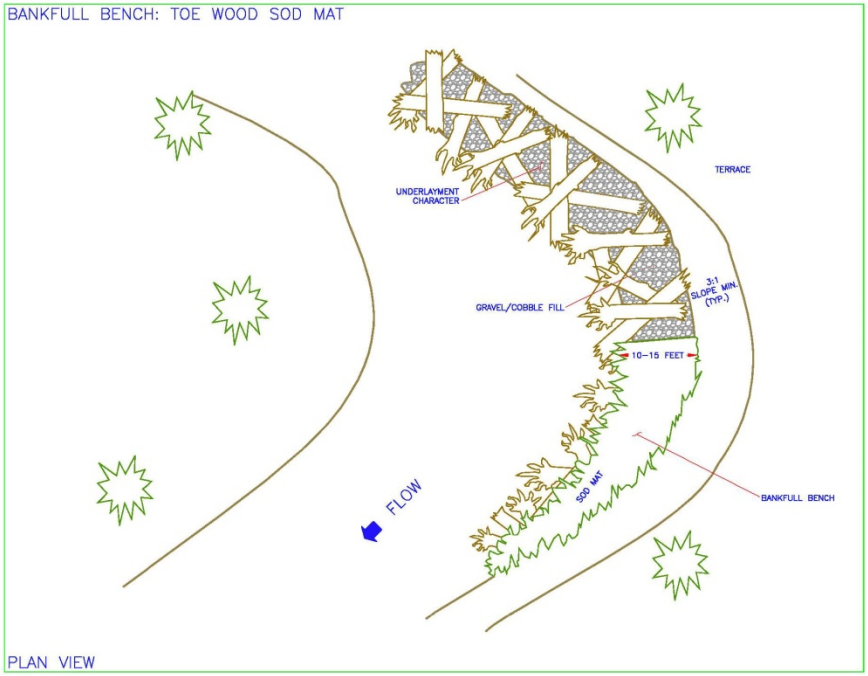
0 25 50 100 150 200 Feet

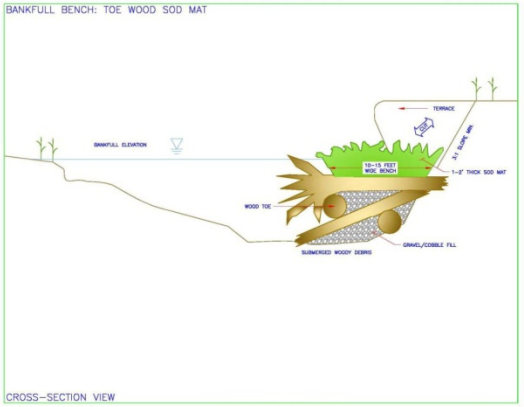
N

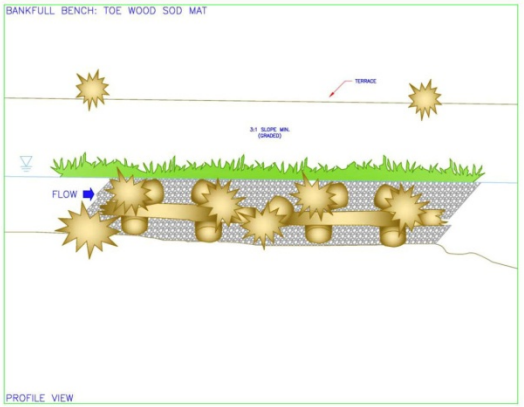
DESIGN LAYOUT	
DRAWN: ERICHER	8/5/2013
CHECKED: MKONDRATIEFF	--/--/----
APPROVED:	
SHEET: 4 OF 8	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

SOUTH PLATTE RIVER
CHARLIE MEYERS SWA
PRELIMINARY DESIGN





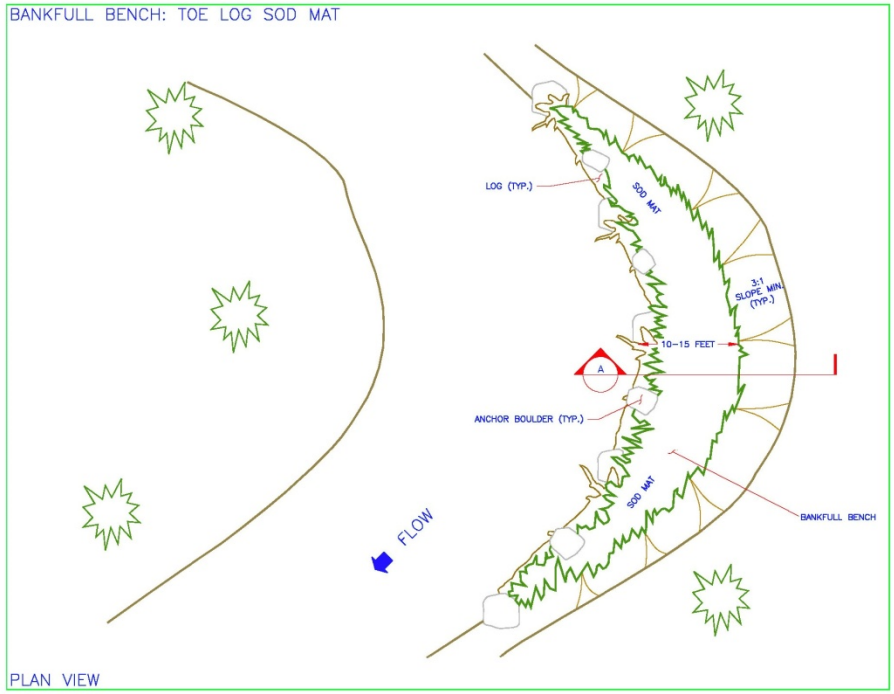


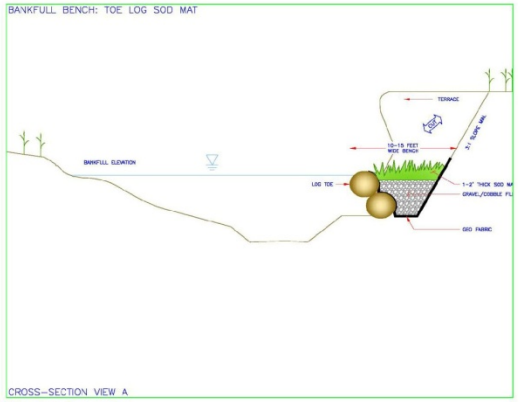
NOT TO SCALE

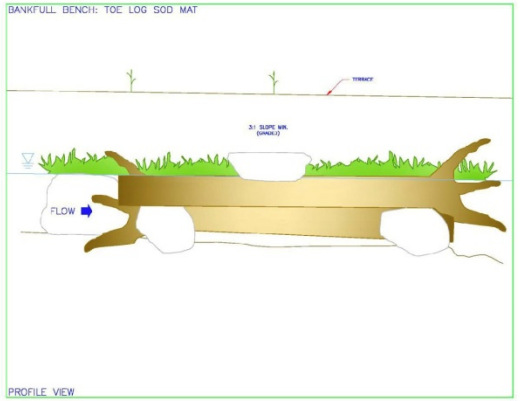
WOOD TOE DETAIL	
DRAWN: ERICHER	6/28/2013
CHECKED:	
APPROVED:	
SHEET: 5 OF 8	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

SOUTH PLATTE RIVER
CHARLIE MEYERS SWA
PRELIMINARY DESIGN

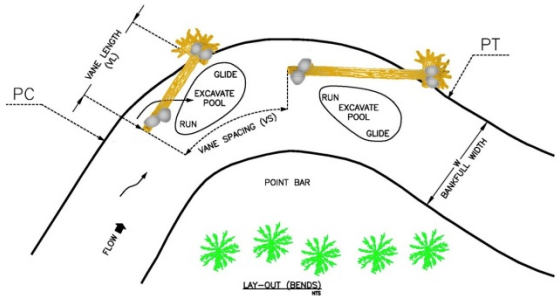




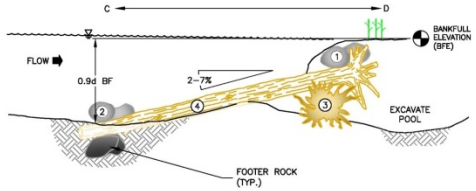


NOT TO SCALE

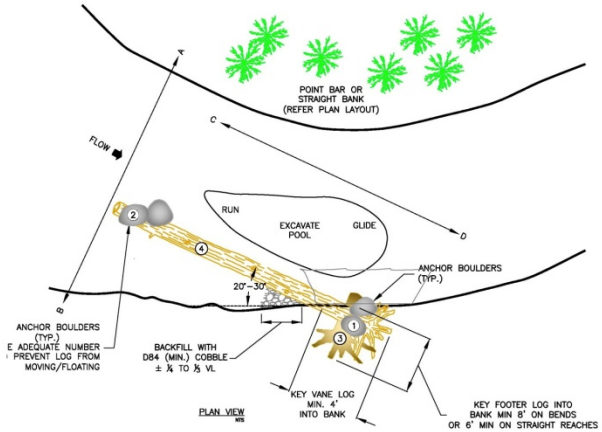
BRUSH TOE / HORIZONTAL LOG DETAIL		STATE OF COLORADO DEPARTMENT OF NATURAL RESOURCES COLORADO PARKS AND WILDLIFE FORT COLLINS, COLORADO
DRAWN: ERICHER	6/28/2013	
CHECKED:		SOUTH PLATTE RIVER CHARLIE MEYERS SWA PRELIMINARY DESIGN
APPROVED:		
SHEET: 6 OF 8		



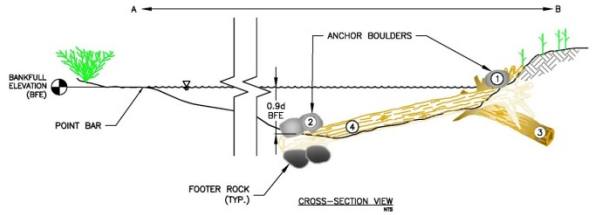
LAY-OUT (BENDS)
NTS



PROFILE VIEW
NTS



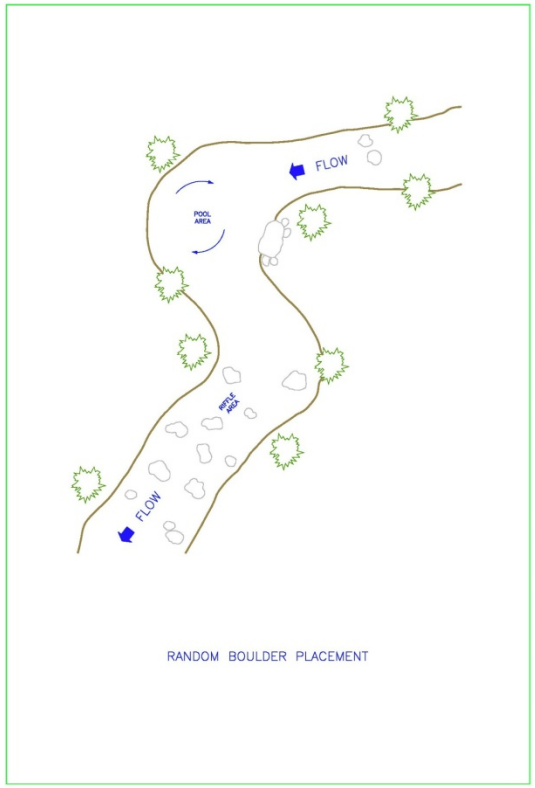
PLAN VIEW
NTS



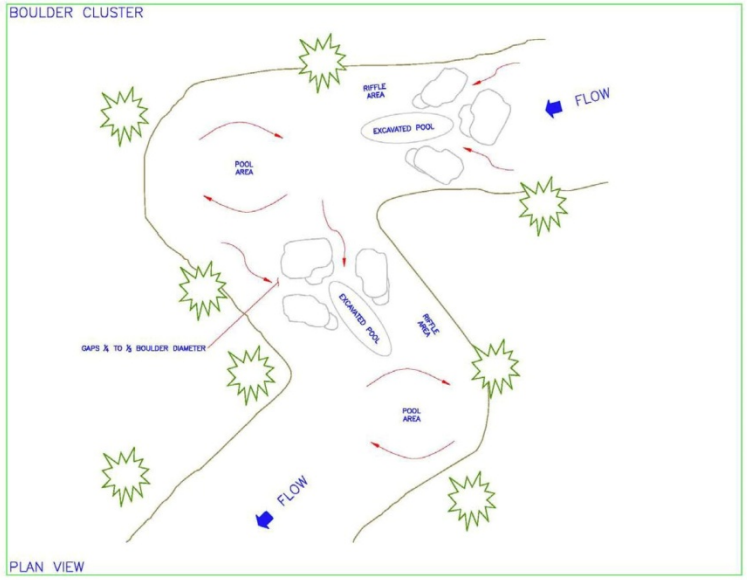
CROSS-SECTION VIEW
NTS

NOT TO SCALE

LOG VANE DETAIL		STATE OF COLORADO DEPARTMENT OF NATURAL RESOURCES COLORADO PARKS AND WILDLIFE FORT COLLINS, COLORADO
DRAWN: ERICHER	6/28/2013	
CHECKED:		SOUTH PLATTE RIVER CHARLIE MEYERS SWA PRELIMINARY DESIGN
APPROVED:		
SHEET: 7 OF 8		



RANDOM BOULDER PLACEMENT



NOT TO SCALE

ROCK GARDEN DETAIL		STATE OF COLORADO DEPARTMENT OF NATURAL RESOURCES COLORADO PARKS AND WILDLIFE FORT COLLINS, COLORADO
DRAWN: ERICHER	6/28/2013	
CHECKED:		SOUTH PLATTE RIVER CHARLIE MEYERS SWA PRELIMINARY DESIGN
APPROVED:		
SHEET: 8 OF 8		