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South Platte Park
South Platte River Enhancement Plan

ERC

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1.0 INTRODUCTION

1.1 Authorization

Ecological Resource Consultants, Inc. was retained by Urban Drainage and Flood Control District (UDFCD) to prepare the South Platte Park (SPP), South Platte River Enhancement Plan (the Plan) which provides preliminary level designs for stream and riparian habitat restoration improvements on the South Platte River and its riparian corridor through South Platte Park in Littleton, Colorado. This project reach commences immediately downstream of C-470 and continues north for approximately 2.4 miles to Reynolds Landing Park. The Plan is co-sponsored by UDFCD, City of Littleton, South Suburban Parks and Recreation, Denver and Cutthroat Chapters of Trout Unlimited, Colorado Parks and Wildlife, the Colorado Water Conservation Board and the US Army Corps of Engineers. The agreement to prepare the Plan (Agreement No. 10-12.07) was executed on December 22nd, 2010.

One previous project relating to the geomorphologic character of the South Platte River has been sponsored by UDFCD through the project reach. The previous study presented the results of 10 years of cross-section monitoring through a large segment of the South Platte River and included the current project reach though South Platt Park. The report was titled Geomorphic Assessment at Surveyed Cross-Sections, South Platte River, prepared by Michael Stevens dated June 1996.

The US Army Corps of Engineers, Omaha District also prepared a Feature Design Memorandum (No PC-45, February 1990) which presented a plan to compensate for fish and wildlife habitat losses due to channelization of the South Platte River below Chatfield Dam. Key items of this memorandum are discussed in **Section 2.4** of this report.

1.2 Purpose and Scope

This Plan develops an approach that can be used to rehabilitate the intended natural function of the stream and adjacent riparian areas while maintaining the flood control characteristics of the property.

The scope of work for the Plan was developed in conjunction with UDFCD and the project co-sponsors. The scope of work is as follows:

- Conduct assessments of existing conditions
- Review previous studies
- Conduct a geomorphic assessment
- Address bank erosion at key locations
- Coordinate project development with project shareholders
- Complete an enhancement plan for the river and adjacent areas

A natural based restoration approach was taken for proposed improvements whenever possible. The guiding principle of the natural restoration approach is that an enhanced stream system should mimic a natural channel in appearance and function. Recreating the natural form and function within the stream system will allow lost natural balance to be restored. Like a natural channel, the enhancement plan was approached with a design that will allow the stream to migrate within the confinements of the setting in response to flow and sediment loads but is intended to maintain its basic form without significant aggradation or degradation. This approach will allow the restored resources to function as naturally as possible given the modern day physical constraints of the site.

The Plan is intended to be a living document that helps guide the stream and riparian enhancements through SPP. The Plan was developed to identify key project components and design elements that will allow the project reach to be enhanced in a manner that improves the natural and ecological condition of the stream system, helping to offset past decades of impacts. Ideas and improvements identified in the Plan are intended to provide a "roadmap" that can be followed as interest and funding allow improvements to be implemented.

The purpose of this report is to present the Plan and the design methods and assumptions that were used to develop it. The Plan presents general concepts along with preliminary level design plans that can be used to guide future improvements to the South Platte River through SPP. As the plans contained herein are preliminary, detailed design of all improvements will be required prior to implementation.

1.4 Need for the Project

The project area has been significantly impacted by the construction of the Chatfield Dam, past land use practices and water usage. Water releases from Chatfield Dam are clear and free of sediment resulting in increased erosion potential. Channel downcutting and degradation of downstream banks have occurred subsequent to construction of the dam. Downcutting has been addressed previously by the construction of grade control structures through this section. Flows through the park are controlled almost entirely by release from Chatfield Reservoir. Releases from the reservoir are significantly less than the native flows that occurred prior to the dam's construction resulting in a channel that is oversized for the flow conditions. Past land practices in the park included extensive gravel mining operations and agricultural production. These activities and other land practices have encroached upon the stream resulting in unintended channelization and loss of riparian habitat. The combined impacts of these stressors have degraded the stream and adjacent riparian area to the point they no longer function as a natural system.

1.4.1 Chatfield Dam

The South Platte River at the upstream end of SPP has a total tributary area of approximately 3,020 square miles. Historically the channel meandered laterally through the valley with minimal downcutting. Land adjacent to the river was used primarily for agricultural purposes from the 1860s to the 1960s (Rogers 1975). Major floods in the South Platte through what is now SPP occurred in 1844, 1933, 1935, 1942, 1965 and 1973. The flood of 1965 resulted in the death of 28 people and caused approximately $540 million in damage (http://www.littletongov.org/history/othertopics/flood.asp). Chatfield Dam was constructed with the primary purpose of providing flood control for the Denver region. Chatfield Dam, constructed from 1967 to 1975, has a total storage capacity of approximately 355,000 acre-feet (http://www.nwo.usace.army.mil/html/Lake_Proj/TriLakes/TLCLDam.htm). The reservoir reduces outflows from the dam to a rate of 5,000 cfs or less, greatly reducing the 100-year storm inflow to the reservoir of 90,000 cfs (Rogers 1975). With reduced flows, the channel, which was created given the natural flow regime of the undammed river system, is too wide for current flow conditions. This results in a situation where the channel has an unnaturally high width to depth ratio. During low flow periods which persist below the dam, limited flow is spread out over the wide channel resulting in low flow conditions that are not conducive to aquatic habitat and reduced peak flows are not in balance with the channel size, resulting in a disturbed system.

In addition to peak flood events, operations of the reservoir as both a flood control facility and for water supply have altered the historic flow hydrograph and effectively cut off the natural sediment inflow to the project area. Changes in flow and sediment loads have impacted the natural function of the stream, its floodplain and the native riparian areas. As a result of the reduction in sediment loads, the sediment starved stream began downcutting. To arrest the active downcutting, grade control structures were constructed previously through the project area. These grade control structures altered the profile of the channel by converting the stream from a natural bend/pool morphology to a system where a majority of the elevation is lost at distinct vertical drops. This change resulted in the loss of natural habitat variety and the drop structures create migration barriers to aquatic life.

1.4.2 Channelization

While the park is intended to be a natural floodplain park, historical land use practices within what is now SPP have also had a significant impact on the stream. Historic aerial photos show the river to be a meandering stream that was free to migrate laterally across the valley. After formation of SPP in 1974, formal development was prohibited in the park. However past gravel operations had a significant effect on the stream and riparian corridor. From the 1930s to its current conditions, channel encroachment effectively reduced the stream sinuosity from approximately 1.4, which is considered a meandering channel, to 1.1, which is on the low end of what is considered a sinuous channel. The straightened channel has lost characteristics of a natural stream, impacting aquatic habitat and the adjacent riparian zone.

Figures 1 to **5** illustrate the channel alignment as it has changed through SPP from 1937 to 1955, 1993, 1999 and 2010.

Figure 1 – 1937 River Alignment

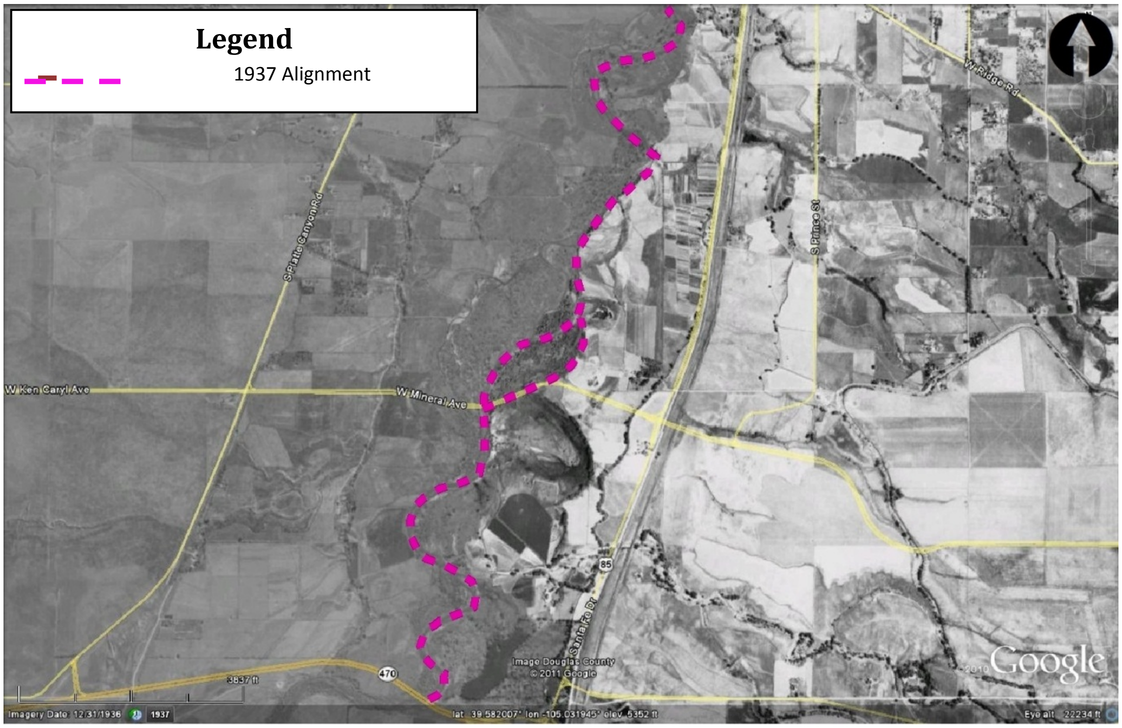


Figure 2 – 1937 and 1955 River Alignments

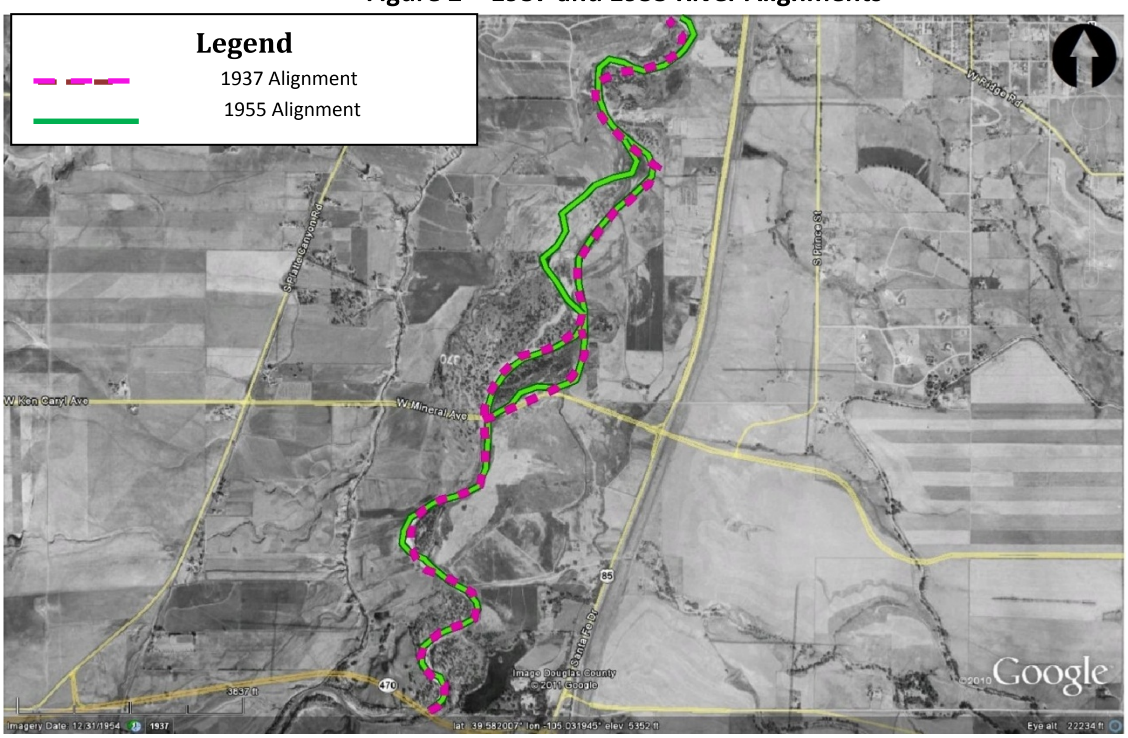


Figure 3 – 1937, 1955 and 1993 River Alignments

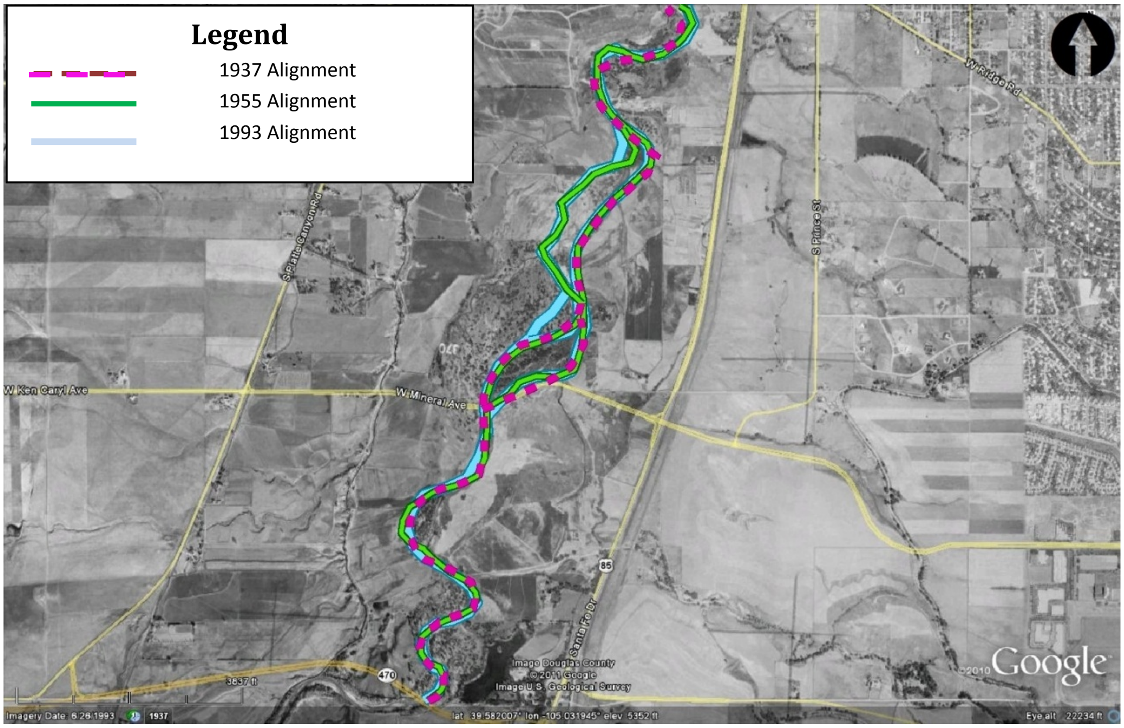


Figure 4 – 1937, 1955, 1993 and 1999 River Alignments

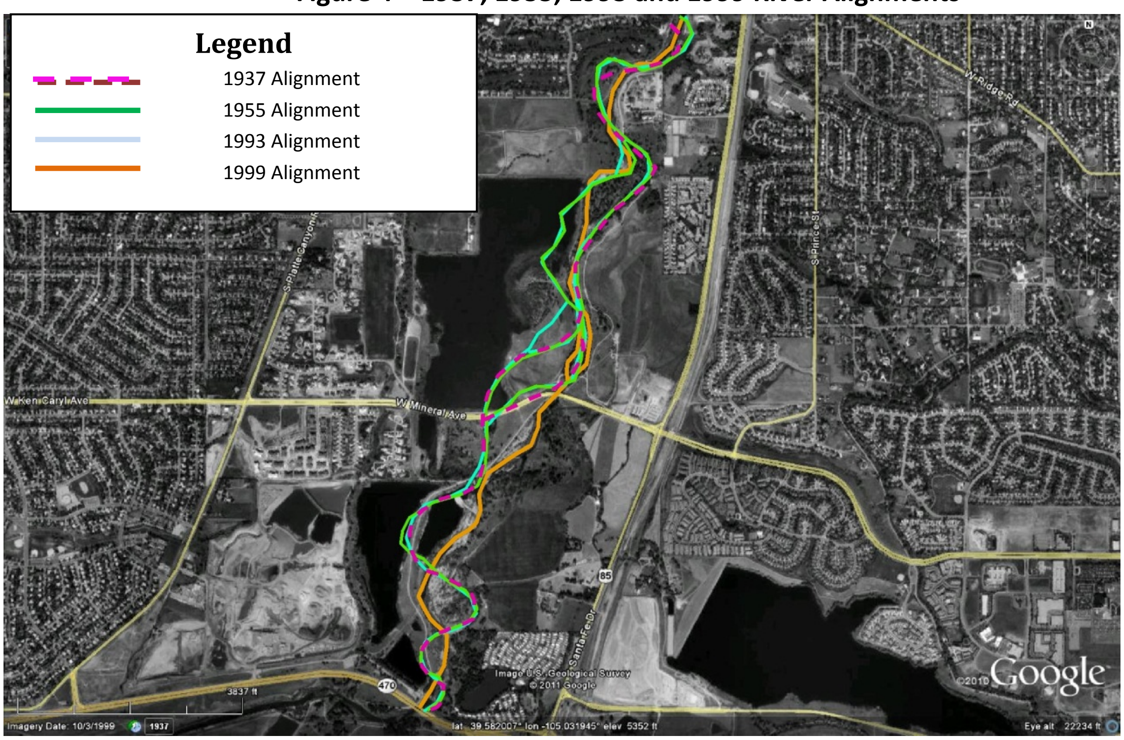
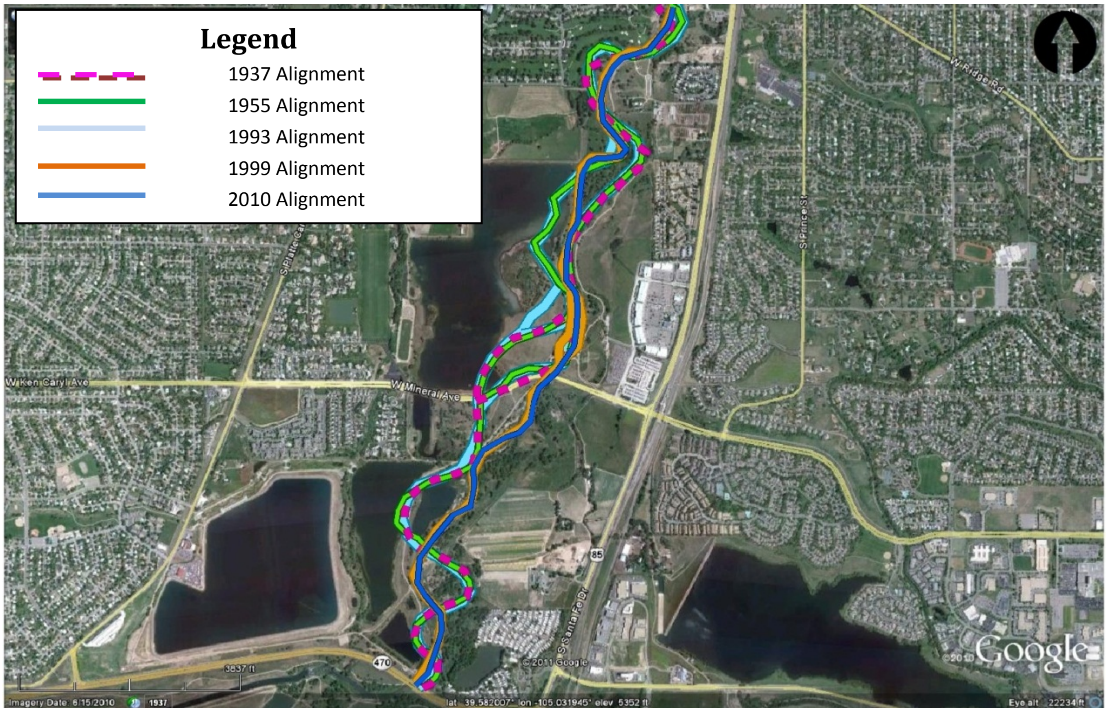


Figure 5 – 1937, 1955, 1993, 1999 and 2010 River Alignments



1.4.3 Resulting Conditions

The combined impacts of the altered flow and sediment regime along with past channel encroachment have resulted in a stream system that is no longer functioning naturally. The intent of the Plan is to improve the ecological health of the stream and riparian system. True restoration, which would entail returning the system to its pre-human impact state is not an option given the presences of Chatfield Reservoir, changes in flows and land practices that now constrain the project area. Rather the intent of this project is to develop a riverine system that mimics a more natural condition taking into account current flow conditions, land constraints and existing infrastructure.

1.5 Mapping and Surveys

Base mapping for the project was obtained from UDFCD. The topographic map provided was a 2008 United States Geological Survey (USGS) map with LIDAR 2 foot contours of the water surface and surrounding land. The UDFCD mapping data was supplemented with additional field survey data along the channel thalweg at existing drop structures and other critical points through the project reach. All data are referenced to the 1988 North American Vertical Datum (NAVD88) and the 1983 North American Datum (NAD83) Horizontal Datum.

In addition to the topographic contours (2008), aerial photography from the Denver Regional Council of Governments (DRCOG) with a pixel resolution of one foot was used to aid in channel design. GIS files showing property boundaries were provided by South Suburban Parks and Recreation and used in conjunction with the aerial photography. All mapping was completed in the Modified Colorado State Plane Coordinate System, Central Zone.

1.6 Acknowledgements

This report was prepared in close coordination with the staff at UDFCD, South Suburban Parks and Recreation, the City of Littleton and Denver Trout Unlimited. The primary project sponsors and stakeholders providing input to the project included:

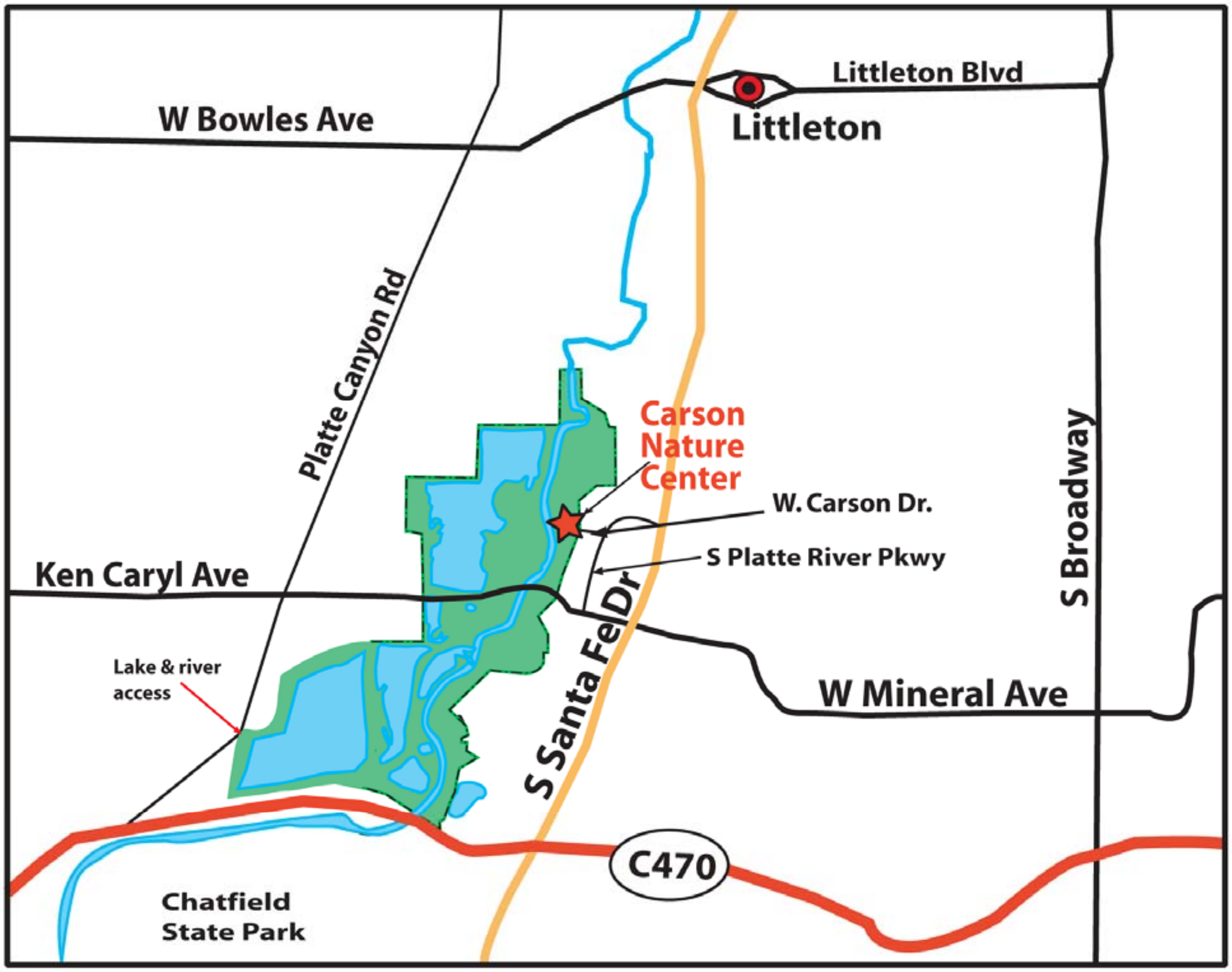
- Laura Kroeger, Urban Drainage and Flood Control District
- Dave Bennetts, Urban Drainage and Flood Control District
- Melissa Reese-Thacker, South Suburban Parks and Recreation
- David Lorenz, South Suburban Parks and Recreation
- Jim Priddy, South Suburban Parks and Recreation
- Skot Latona, South Suburban Parks and Recreation
- Charles Blosten, City of Littleton
- Todd Fehr, Denver Trout Unlimited

2.0 PROJECT AREA

2.1 Location

SPP is owned by the City of Littleton, Colorado and is managed by South Suburban Parks and Recreation. South Platte Park is an 878-acre parcel of land with approximately 2.4 miles of the South Platte River running through it. The project is focused on the portion of the South Platte River that runs through SPP. The project reach extends from the north side of C-470 to the boat chute at Reynolds Landing. The Mineral Avenue Bridge across the South Platte River is approximately halfway through the project reach. The general location of the project is shown on **Figure 6**. A site map is provided in **Figure 7**.

Figure 6 – Project Vicinity Map



South Suburban
PARKS AND RECREATION

Figure 7 – Project Site Map

2.2 Land Use

After a significant flood in 1965, the US Corps of Engineers decided to construct Chatfield Dam and channelize much of the South Platte River through the Denver metropolitan area for the purpose of flood control. In an effort to preserve the area now known as SPP, the City of Littleton began acquiring land to address flooding issues through non-structural methods. This led to the creation of a natural floodplain park along the South Platte River. In general the land adjacent to the river has not been developed, although significant gravel mining operations and reclamation have occurred generally west of the current stream alignment. These gravel pits are no longer operational and have been converted to open water lakes. Historic agricultural practices has also significant altered the landscape along the river, leveling the land and removing native vegetation communities that typically would have extended far beyond the edge of the river. The SPP is currently managed by South Suburban Parks and Recreation with 6.5 miles of trails and 2.4 miles of river. The SPP Management Plan (2009) states that per the Master Plan the intent of the Park is to "allow for visitor opportunity while providing an undisturbed area for wildlife retreat".

2.3 Recreational Aspects of the River and Park

Recreation is a major component of SPP's attraction with visitation counts of approximately 300,000 during the last formal census in 1998 (South Suburban Parks and Recreation, 2009) and current annual visitation estimated to exceed 500,000. Both active and passive recreation including hiking, fishing, canoeing, kayaking, rafting, tubing, horseback riding, bicycling, wildlife viewing cross-country skiing and showshoeing are enjoyed at the park. SPP is also used for educational purposes with formal and informal natural and cultural history based learning opportunities for park users.

2.4 Drainage and Inflows

2.4.1 Chatfield Release

Hydrology in the project area is dominated by the South Platte River which flows in a general south to north direction through SPP. Flows in the South Platte River through the project area are controlled primarily by release from Chatfield Reservoir. The reservoir was constructed as part of a U.S. Army Corps of Engineers (USACE) flood control program and limits flows out of the reservoir to a maximum of 5,000 cubic feet per second (cfs).

2.4.2 Inflows Downstream of Chatfield

Three less significant surface drainages, Jackass Gulch, a groundwater seep called The Southeast Feeder and Dad Clark Gulch, feed the South Platte through the project reach. The Jackass Gulch drainage basin is approximately 500 acres in size and encompasses the area around Mineral Avenue east of the river. Sustained flows from Jackass Gulch range from 0.5 to 2.0 cfs and are highly influenced by seasonal fluctuations and local precipitation events (Centennial Water and Sanitation, Hydrology and Vegetation Study, 1991). The Southeast Feeder is located south of Jackass Gulch on the east side of the river. It originates from groundwater seeps in higher ground east of the park and produces perennial flows up to 2 cfs (Centennial Water and Sanitation, Hydrology and Vegetation Study, 1991). Dad Clark Gulch is a small drainage located north of C-470 on the east side of the river. It carries runoff following precipitation events but is generally dry. Flows from Dad Clark Gulch typically seep into the alluvium prior to reaching the river (Centennial, 1991; Jack G. Raub Company, 1981).

2.4.3 Groundwater

Alluvial groundwater also has an effect on the park hydrology. The subsurface in the vicinity of the river consists of highly permeable sand and gravel overlying bedrock with a significantly lower permeability. This geologic configuration creates a “sink” that will hold groundwater. During times of the year when flows in the river are relatively low, the alluvial groundwater seeps from the surrounding area into the river, contributing to the surface flows. The alluvial groundwater originates primarily from groundwater flows from east of the park and seepage originating from the many area lakes. During high flows when the river is higher than the groundwater level, it contributes to the alluvial groundwater. Groundwater depths in the floodplain vary with the season and range from 3 to 15 feet below the surface (Centennial, 1991).

2.5 Water Rights

In the interest of maintaining aquatic life and recreation, the City of Littleton has filed water rights for minimum instream flows for the South Platte River below Chatfield. Instream flow water rights include 100 cfs for boat chute operations and fishery enhancement rights were filed for 70 cfs from April 1 – October 31 and 30 cfs from November 1 – March 31. Flows are measured at the upstream end of SPP at the boat chute nearest C-470 (Boat Chute 10). Water rights were declared absolute for the boat chute near Mineral Avenue (Boat Chutes 4), the boat chute at Reynold’s Landing (Boat Chute 9) and for Boat Chute 10 (South Suburban Parks and Recreation, 2009).

2.6 Aquatic Environment

The segment of the South Platte River that extends from Chatfield Dam to the Bowles Avenue Bridge was recently reclassified from a Cold Water Class 1 Fishery to a Warm Water Fishery. Colorado’s water quality criteria are set by the Department of Public Health and Environment – Water Quality Control Division. The Warm Water Class 1 designation is for waters that (1) currently are capable of sustaining a wide variety of warm water biota, including sensitive species, or (2) could sustain such biota but for correctable water quality conditions. Waters are considered capable of sustaining such biota where physical habitat, water flows or levels, and water quality conditions result in no substantial impairment of the abundance and diversity of species.

The section of river downstream of Chatfield Dam is a transition zone between cold water mountain streams and warm water systems on the plains (In Stream Issues Task Force, 1996). The South Platte Park Master Plan describes the fisheries habitat as fairly poor due to periodic scour from extended high flows, a lack of variation in the flow conditions and a subsequent lack of lower food chain organisms (South Suburban Parks and Recreation, 2009).

The US Army Corps of Engineers prepared a Feature Design Memorandum (No. PC-45) for the South Platter River, Chatfield Lake, Colorado (February 1990). The memorandum presents a plan to compensate for fish and wildlife habitat losses due to channelization of the South Platte River below Chatfield Dam. The memorandum identifies three segments within their study area; Segment 1 includes the SPP section that is the subject of this Plan. Many of the limiting factors seen today were also addressed by the Corps in the 1990 study. A summary of findings addressed in the 1990 study follow:

- Channel degradation is occurring due to the sediment-free water discharged from the Chatfield Dam resulting in a more confined and armored channel than in the past. Woody vegetation along the banks is lacking along most of the segment, perhaps due to agricultural and gravel mining prior to public ownership.

- This segment of the South Platte River has the greatest potential for an increase in fish population through restoration.

- Pool-holding habitat and cover are relatively scarce and may be limiting the fish population. There are some good riffle areas in association with the shale outcrops and some very limited areas of overhanging willow cover. Pool/holding habitat may become especially important to adult fish during periods of low flow (winter) and high summer temperatures. It also serves as velocity shelters for fry and juvenile life stages during periods of high flow (spring).

- 1972, 1982 and 1987 studies indicate that water quality and physical habitat are sufficient to maintain limited populations of rainbow and brown trout. Other game species present in past surveys included walleye, bluegill, yellow perch and green sunfish.

- Pool habitat and bank cover area are also necessary in providing cover from sunlight and avian predators.

A benthic macroinvertebrate sampling was conducted in the vicinity of the SPP by the Colorado Riverwatch group in December, 2008. The data is provided in **Table 1**. The quality or reliability of this data is unknown by ERC, however can provide some insight as to water quality and aquatic health. Approximately 86% of the sample consisted of the Order Ephemeroptera (mayflies) and Trichoptera (caddisflies). The presence and dominance of these Orders in a stream system can typically indicate “good” water quality and relatively “good” general aquatic health. Data from the insect count conducted on December 20, 2008 is presented in **Table 1**, below. **Table 2**, below presents the fish species found in the project section of the South Platte River and their relative abundance based on previous studies.

Table 1 – South Platte River Insect Count

Taxon	300-Count
TURBELLARIA	
Dugesia sp.	16
OLIGOCHAETA	
Tubificidae w/o hair chaetae	1
DECAPODA	
Orconectes sp.	1
ACARI	
Sperchon sp.	3
EPHEMEROPTERA	
Acentrella sp.	25
Baetis tricaudatus	40
Tricorythodes minutus	188
TRICHOPTERA	
Cheumatopsyche sp.	22
Hydropsyche sp.	11
Oecetis sp.	1
DIPTERA	
Cricotopus/Orthocladius sp.	12
Diamesa sp.	4
Microtendipes sp.	2
Parakiefferiella sp.	2
Pseudochironomus sp.	2
Simulium sp.	2
TOTAL ORGANISMS	**332**

Table 2 – South Platte Park Fish Species and Relative Abundance

Common Name	Relative Abundance
Western White Sucker	Common
Long Nose Sucker	Common
Fathead Minnow	Common
Creek Chub	Common
Sand Shiner	Common
Brown Trout	Occasional
Rainbow Trout	Occasional
Black Bullhead	Occasional
Longnose Dace	Occasional
Green Sunfish	Occasional
Largemouth Bass	Infrequent
Channel Catfish	Infrequent
Smallmouth Bass	Rare

Common Name	Relative Abundance
Yellow Perch	Rare
Common Shiner	Rare
Common Carp	Rare

*Sources: Hagen Fisheries Consultants, 1975; Division of Wildlife Surveys 1987, 1990

Fishing activity on the project stretch of the South Platte is managed by the Colorado Division of Wildlife (CDOW) Metro Fisheries Program. The CDOW uses a put and take approach to managing the fishery and stocks it annually. The South Platte below Chatfield Dam adheres to standard CDOW fishing regulations. In general, aquatic habitat through the project reach of South Platte is limited by low variability in the type of flow, an overly wide channel, and a lack of deep pools.

2.7 Natural Resource Communities

South Suburban Parks and Recreation have conducted extensive studies to map and document vegetation communities and specific species within the Park (South Platte Park Management Plan, Updated 2009). Four major ecological communities have been identified within the entire Park area in and along the river corridor which include Upland Woodland (13.9%), Upland Grassland (26.6%), Aquatic (45.1%) and Wetland and Riparian (14.4%). Ecological communities most associated with the river corridor are the Upland Woodland and Wetland and Riparian. The upland woodland community along the river primarily consists of scattered groves of mature plains cottonwoods (*Populus deltoids*) with a sparse understory. These groves are commonly disconnected from the original floodplain, remnants of more historic conditions of fewer disturbances from channelization and water use.

The wetland and riparian communities are typically located immediately adjacent to the river just above the ordinary high water mark of the river on the steep bank slopes. These communities along the stream corridor are the transition areas between the aquatic environment and uplands. This community type is the most influential community to the river system providing bank stability, instream habitat, shading and aquatic biomass. This community type within the Park is characterized primarily by a mid story dominated by dense stands of sandbar willow (*Salix exigua*) with other less common species including peachleaf willow (*Salix amygdaloides*) and wild plum (*Prunus Americana*) scattered throughout. All of these species are considered native to the Park as well as the Front Range of Colorado. Herbaceous wetland species along the river are typically located immediately along the ordinary high water mark, on mid-channel islands and intermixed throughout stands of willow. Common species include cattail (*Typha latifolia*) and reed canarygrass (*Phalaris aurdinacea*). These species are typically not considered native or invasive. To a lesser extent more native herbaceous wetland species include rushes (*Juncus spp.*) sedges (*Carex spp*.), switch grass (*Panicum virgatum*) and wheatgrass (*Pascopyron smithii*).

Upland grasslands include meadows, fields or grasslands dominated by grasses and forbs. Some of the areas are infested with non-native species which are of great concern and control is mandated by the State of Colorado.

Weed species are prevalent along the throughout the Park and river corridor. Weed species such as thistle (*Cirsium spp.*), knapweed (*Centaurea spp*.), kochia (*Kochia scoparia*), leafy spurge (*Euphorbia esula*), Russian olive (*Elaeagnus angustifolia*) and tamarisk (*Tamarix ramosissima*) exist and are currently being managed by SPP through mechanical, biological and chemical means.

2.8 General Wildlife

The project reach of the South Platte River also provides important bird habitat. SPP is comprised of five designated wildlife areas including East Trail, Cooley Lake, Nevada Ditch, Lake 5 and the Northern. These designated areas are considered to contain important and highly productive wildlife habitat. They are preserved and protected at all times. Wildlife Areas are defined as those areas documented through studies and observations of primary importance in providing habitat (food, water, shelter and space) for a diversity of plants and animals. They are important for resting, reproduction, forage and refuge from human activity, especially for species sensitive to disturbance (South Suburban Parks and Recreation, 2009). The National Audubon Society has designated SPP as one of their Nationally Important Bird Areas for winter waterfowl and summer breeding habitat for migratory birds.

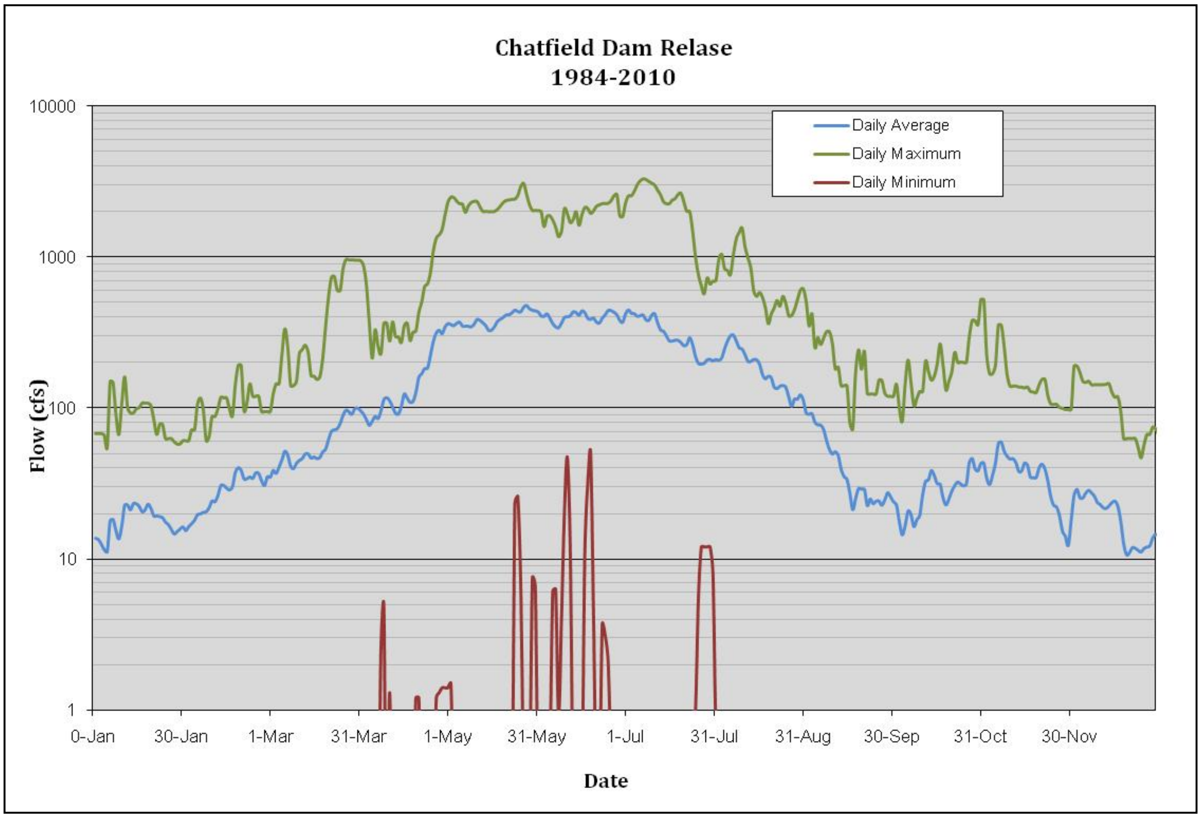
At least 17 species of fish-eating birds are found in the riparian corridors along the river. In the winter months, waterfowl tend to feed in the shallow riffle areas and around the mid-channel and point bars. The riparian corridor also provides valuable habitat for a large population of songbirds and smaller mammals. The CDOW has identified beaver sites throughout the urban corridor of the South Platte and deer have been known to use the corridor to move in and around the metro area (In Stream Issues Task Force, 1996).

3.0 HYDROLOGY AND HYDRAULICS

3.1 Flow Assumption

Flow data through the project reach was obtained from the South Platte River below Chatfield Reservoir (PLACHACO) station, operated by the Colorado Division of Water Resources. The station is located approximately 2,000 feet downstream from the Chatfield outlet structure. Complete daily data is available from this site from August 1986 to October 2011. **Figure 8** provides a graph of average, maximum and minimum daily Chatfield Reservoir release from 1987 to 2010.

Figure 8 – Daily Flows, South Platte River below Chatfield Reservoir



In an average year, flows in this portion of the river typically peak at approximately 500 cfs throughout late spring and early summer and drop to between 10 and 50 cfs throughout the fall and winter months. It is common for the release from Chatfield Reservoir to periodically drop near 0 cfs from September through March. From 1987 to 2010 release from Chatfield Reservoir dropped below 18 cfs an average of 123 days a year. Days with release of less than 5 cfs ranged from 71 days in 1998 to 185 days in 1991. Due to severe drought and its tendency to skew results, data from 2002 was not included in the low flow statistics presented above.

The channel design for the Plan needs to function at a wide range of flows, be stable at peak flow rates and maintain flood conveyance for the jurisdictional flood event. From an aquatic standpoint, low flow events are critical as improving habitat during low flow conditions was one of the objectives of the project. Bankfull flow, the flow that is generally responsible for the morphology of a channel, is another critical parameter for restoration design that was estimated as part of the flow analysis. Other design considerations including channel stability and conveyance are dependent on peak design flows while maintenance of the channel profile is dependent on sediment transport, which is a function of the full flow hydrograph. Design flows used in the analysis and their derivations are presented below.

3.1.1 Minimum Flows

The channel design was based on a selected low flow value of 20 cfs. This value was used to ensure sufficient water depth for fish to migrate through the constructed riffles the majority of time. The value of 20 cfs was chosen because it is the average daily median flow value from September through March, the typical low flow season. While current releases from Chatfield commonly fall to near zero, it is not practical to design a natural channel to provide good habitat at such low flows and accommodate the high flows that are observed in the spring.

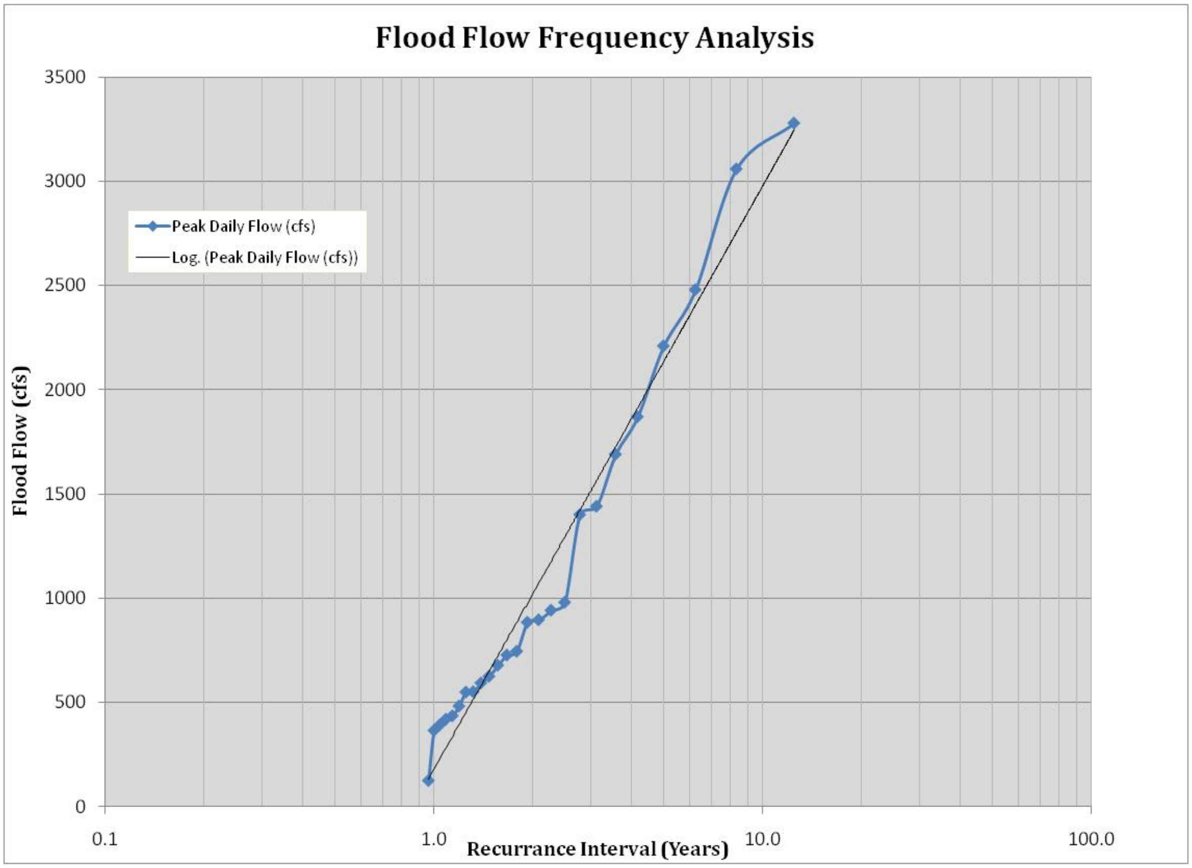
3.1.2 Bankfull Flows

A flood flow frequency analysis was performed to estimate the flood flow with a 1.5 year recurrence interval. This flow was assumed to be representative of what a natural bankfull flow through the project reach should be and was then used to determine the desired bankfull channel width.

Peak daily flow releases from the reservoir were determined based on the State Engineer’s Office gage records for 1987 through 2011. Peak daily flows were then sorted and plotted using the Weibull plotting position method, see **Figure 9**. The 1.5 year flood event was estimated to be 650 cfs for the project area based on the resulting plot.

The bankfull flow of 650 cfs was used as a critical flow parameter in the planned channel design. It is used for determining desired channel widths and elevations for riparian terraces and bank stabilization. Using the bankfull flow to set design elevations will allow water to occasionally flow on top of riparian terraces and bank stabilization features; this will mimic the flow processes of a natural stream.

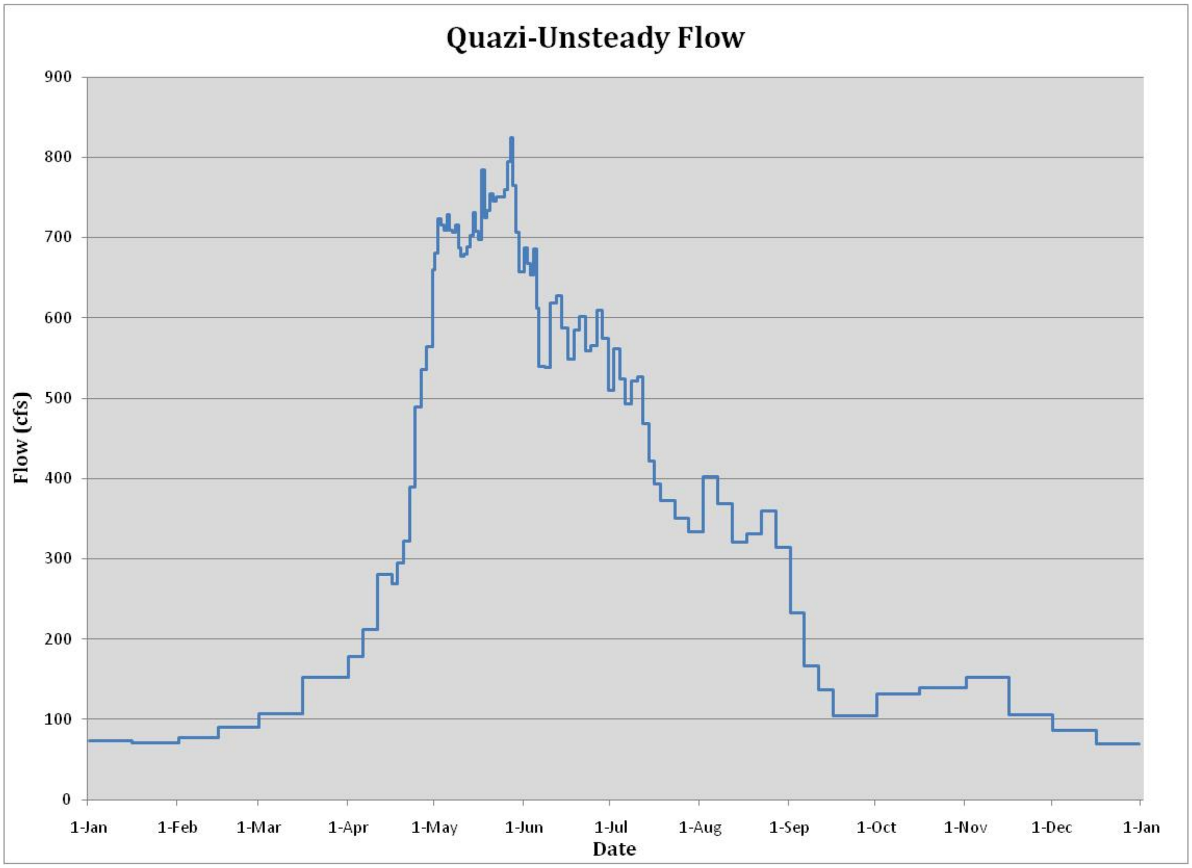
Figure 9 – Flood Flow Frequency



3.1.3 Quazi-Unsteady

Quazi-Unsteady flow data was used in the sediment transport modeling. The Quazi-Unsteady flow method approximates a hydrograph by a series of steady flow profiles associated with corresponding flow durations. This method is used because the majority of sediment transport typically occurs during a relatively brief period of peak flows and deposition typically occurs during low flows. The flows used were based on average daily flows at the USGS Littleton Gage (Station 6711565) and the flow durations were chosen based on the magnitude and rate of change in the flows. The USGS Littleton Gage was used rather than release from Chatfield because flows are generally higher at the Littleton Station and it accounts for flows entering the South Platte between Chatfield and the end of the project reach. The USGS Littleton Gage is located downstream of the confluence with Bear Creek and overestimates flow through the project reach. From a sediment transport standpoint, this is a conservative approach as it predicts higher mobility resulting in a design that will remain stable for greater than anticipated flows. The flow data used in the Quazi-Unsteady model is presented in **Figure 10** below.

Figure 10 – Quazi-Unsteady Flow Data



3.3 Flood Flows

The regulatory flood flows for the project reach were obtained from the Flood Insurance Study (FIS) titled "Flood Insurance Study, Arapahoe County, Colorado and Incorporated Areas", dated December 17, 2010. A flow value of 2,700 cfs was used for the 100-year flow model through the project reach. It is worth noting that the 100-year flow reported in the FIS was exceeded in both 1995 (peak flow 3,820 cfs) and 1987 (peak flow 3,060 cfs). Flows presented in the Arapahoe County FIS are shown in **Table 3**. The peak 100-year flow of 2,700 cfs was used to evaluate riffle stability during flooding events. Riffle stability during flooding was evaluated by replacing the peak day average daily flow with the peak 100-year flood flow in the quazi-unsteady flow data.

Table 3 – FIS Flood Flows

Recurrence Interval (years)	Flood Flow (cfs)
10-year	1,300
50-Year	2,200
100-Year	2,700
500-Year	4,000

3.4 Hydraulic Modeling

3.4.1 HEC-RAS

ERC used the hydraulic modeling software HEC-RAS, version 4.1, a one dimensional computer model developed by the Army Corps of Engineers, to calculate water surface elevations, energy grade elevations and other hydraulic parameters produced by the design flows. HEC-RAS steady flow analysis was applied to a geometry file containing the proposed channel modifications. The supplemented UDFCD two foot contour data mentioned in Section 1.4 was used to determine cross section geometry outside of the proposed channel. Because no modifications will be made in the vicinity of the Mineral Avenue Bridge or the adjacent pedestrian bridge and survey data was not obtained to evaluate the bridge hydraulics, those elements were left out of the HEC-RAS model. The project was modeled in an upstream and downstream segment with a gap around Mineral Avenue between the segments. The final design model should include an evaluation of Mineral Bridge.

Normal depth boundary conditions were used at the upstream and downstream ends of all channels for all steady flow analyses; the average channel slope of 0.21 percent was used to determine normal depth. To model bankfull flow, a Manning's n value of 0.035 was used for channel sections and a value of 0.05 was used for the overbanks. To model the low flow scenario a Manning's n value of 0.035 was used for channel sections between riffles. To determine a Manning's n value for riffles during low flow an equation developed by Jarret (1984) was used, see **Equation 1**. This equation was used to simulate the increase in channel roughness associated with a decrease in flow depth. The Manning's n value was calculated at each riffle through a series of iterations at a flow of 20 cfs. A list of Manning's n values used at each riffle is presented in **Appendix B**.

Equation 1

$$n = AS_bR_c$$

n = Manning's n value
S= Slope
R= Hydraulic Radius
A= 0.393
b= 0.38
c= -0.16

4.0 PROPOSED DESIGN

The main elements of the enhancement design include adjusting the channel profile, narrowing the stream to an appropriate width, stabilizing eroding banks, increasing riparian habitat and improving Red Tail Lake. Methods used to achieve these improvements are discussed in this section of the report.

4.1 Channel Profile

Design **Plan Sheets 1 through 5** show the plan and profile of the proposed concepts. A key element of the proposed design is regrading the channel to create a stream width that is in balance with the current flow regime and grade the profile to create 11 distinct riffle, pool, glide habitat sequences. Each different type of stream segment has a typical geometry. All riffles were designed to maintain a minimum flow depth of 6 inches during low flow periods, defined as a flow rate of 20 cfs. This flow depth will allow fish to migrate through the riffles during the fall and winter months and mitigate the current condition where migration is not possible past existing grade control structures. Pools will be located downstream of riffles. The higher flow velocity of the riffle sections will provide energy required to continually scour the pools maintaining quality pool habitat. Glides are located between pools and riffles and generally have a mild adverse slope leading up to the next riffle. Glides have a well-defined thalweg that will contain flow to a defined channel during low flow periods. Because the top of the downstream riffle acts as grade control, the flow in the upstream glide remains slower and deeper. A table presenting key preliminary channel invert elevations is presented on the design plans and in **Appendix A**.

4.2 Typical Channel Width and Cross-Section Geometry

The South Platte River through the project reach is a relatively wide channel that was formed based on historic flow patterns that existed prior to construction of Chatfield Dam. One of the main improvements planned as part of the Plan is to narrow the channel so the stream width is in balance with the current post-dam flow regime. Narrowing the active channel during low and average flows will increase flow depth, improve aquatic habitat and restore some of the natural balance that typically exists between flows and channel geometry.

Approximate channel widths and depths were estimated based on the standard geomorphologic principles. The desired channel width was estimated based on typical geomorphologic principles that relate bankfull flows with appropriate bankfull channel widths (Andrews 1984). Based on available flow data, the bankfull flow through the project area was estimated to be approximately 650 cfs. Standard regional geomorphologic curves suggest that the bankfull channel width for a natural channel with this flow should be on the order of 40 - 60 feet wide. This general parameter provided the criteria that was used to define the approximately channel width at a bankfull event.

Given that the principle purpose of the stream channel through the project reach is to act as a flood conveyance element, the channel was not designed with traditional vegetated riparian terraces that would start to flood for events greater than the bankfull event. The Plan design instead allows for these larger peak events to extend beyond the main channel and flow within the confines of the existing, larger active channel. In this manner, peak flood flows are still conveyed through the project reach without negative impacts on the floodplain. During detailed design of the channel it may be determined that some of the channel bars could be vegetated to create riparian terraces without negative impacts on flood conveyance. If this is determined to be the case, vegetating bars should be encouraged as this will promote additional riparian improvements.

Different cross-sections were defined for riffle, pool and glide sections that will contain the lower flow events yet allow peak flows to continue to be conveyed through the project area. Each cross-section is defined by a standard bottom width and standard side slopes. Depths will vary through each section depending on the existing geometry and flow depth. In general, the cross-sections were designed to maintain reduced channel widths during periods of low flow. Areas outside of the proposed cross-section where the existing channel is excessively wide will be converted to cobble bars.

Riffles are designed as a trapezoidal section and are intended to narrow from upstream to downstream. At the upstream end riffles are intended to have a base width of 25 feet; this will contract to a downstream base width of 20 feet. Riffles are intended to have a symmetrical geometry with 3:1 side slopes. A typical channel cross-section at a riffle is presented in **Plan Sheet 6.**

Pools will typically be located at a bend in the channel and are planned to be trapezoidal in shape with side slopes that are steeper on the outside of the bend than they are on the inside to mimic natural pool geometry. The outside of the bend will have a steep slope to simulate a cut bank and the inside of the bend will have a mild slope to simulate a point bar. Pools will be generally excavated to a depth of four feet below the bottom of the upstream riffle. Increased flow velocity from the upstream riffle and locating the pool on the outside of a bend will help to minimize deposition in the pool. Pools are designed with a 5 foot bottom width and cross-sectional slopes of 8H:1V on the point bar side (inside of bend), and a 2H:1V slope on the cut bank side (outside of bend). A typical channel cross-section at a pool is presented in **Plan Sheet 7.**

The majority of modified channel will be comprised of glide segments. Glides will have a well-defined thalweg and are designed with a skewed cross section similar to pools. The water depth in each glide will be maintained by the downstream riffle elevation, which is typically 1 to 2 feet above the glide invert. Glides will be constructed with a 15 foot bottom width and side slopes of 2:1 on the outside of the bend and 8:1 on the inside of the bend. A typical channel cross-section at a glide is presented in **Plan Sheet 8**. At the downstream ends, the cross section of the glide is intended to transition to match the upstream end of the next riffle.

4.3 Constructed Point Bars

In many sections the existing channel is significantly wider than what is required for the designed bankfull width. The design calls for areas outside of the modified bankfull channel to be converted to point bars. Point bars are typically located on the inside of bends and will act to increase channel sinuosity and reduce the channel width. The design calls for significant point bar construction as needed to obtain a channel width that is appropriate for the current flow regime.

Point bars in different locations will require different construction techniques depending on the anticipated shear stresses. In critical sections where the bars are necessary to maintain the desired channel width the bar design includes soil riprap. The point bar should be tied several feet into the existing bank and will act as armor to protect the point bar from erosion. In other areas point bars can be constructed from native material derived from excavation of the low flow channel. Point bars should be constructed with an 8H:1V slope on the channel side and a 3H:1V slope on the bank side and should be keyed into the channel bottom a minimum of 1 foot. The point bar area will then be filled with a soil riprap mix and topped with native material. It is expected that a limited amount of vegetation may develop on some upper portions of the point bar through natural recruitment. However, point bars are intended to be inundated during high flow periods and exposed during low flow periods. A typical detail of a constructed point bar formed with the soil riprap is presented in **Plan Sheet 7**. **Figure 11** depicts the concept of alternating point bars.

Figure 11 – Alternating Point Bars

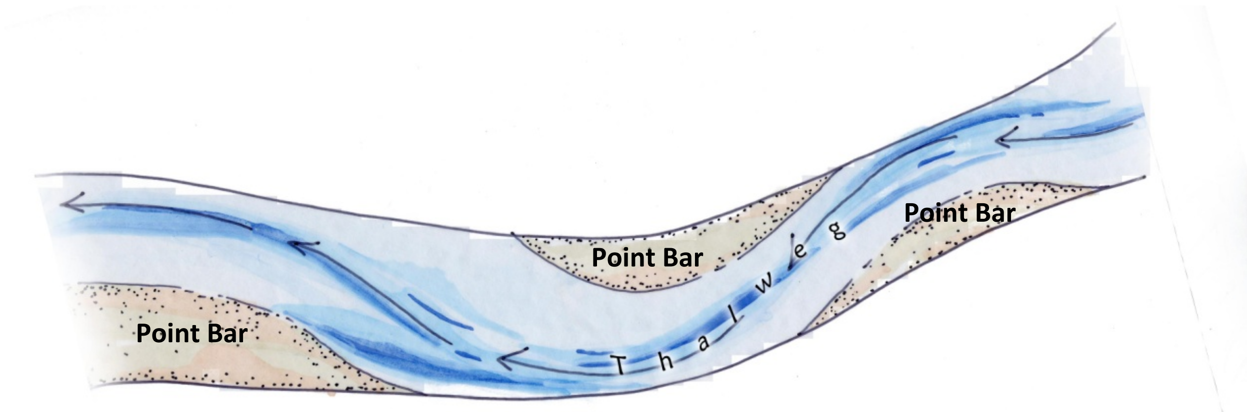
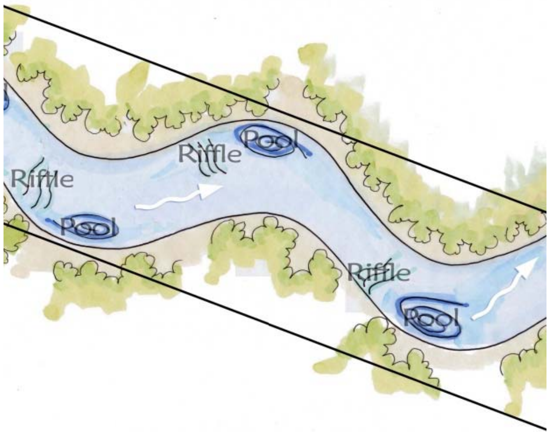


Photo example (left) shows an example below Dillon Dam where the existing Blue River channel* was too wide for the flows released from the dam resulting in shallow flow depths and minimal habitat. *Photo example (right) shows the enhancement implementation concept in 2003 of alternating point bars that re-establish the appropriate width depth ratio for current flow conditions.

A total of approximately 8 acres of constructed point bars are anticipated to reshape the channel to its desired width. From a cost estimating standpoint is was assumed that approximately 4.5 acres of point bars will be constructed utilizing the two foot thick soil riprap and the remaining 3.5 acres of point bars can be constructed utilizing native material.

4.4 Riffle Construction

Riffles are designed as a layer of soil filled riprap. The preliminary riprap layer construction detail with key upstream and downstream elevations are shown in **Appendix A** and on the design plans. Riffles are designed with 3H:1V side slopes with areas outside of those slopes filled with native material and armored with soil filled riprap. The riprap should be placed at a minimum thickness of 2 feet and should consist of Type M riprap. An anticipated scour depth of 3 feet was calculated using the method outlined in *Mason and Arumugam, 1985*. This method is generally considered appropriate for in-stream grade control structures and the scour depth is calculated from the bottom of the structure; in our design we considered this point to be the bottom of the riffle. The calculated scour depth is less than the design pool depth by approximately one foot, therefore the depth of the riffle turn down was based on pool geometry rather than calculated scour. The upstream and downstream ends of the riffle should have turndowns to a depth of 5 feet to prevent undercutting. The turndowns are designed with a slope of 5H:1V the upstream turndown should be buried. A typical detail of the proposed riffles is shown in **Plan Sheet 6.** The depth of the turn downs at the end of each riffle should be evaluated as part of final design.



Graphic example (left) shows an example of riffle-pool sequences typical found in functional stream systems. Photo example (right) shows the enhancement implementation concept of a constructed Riffle-pool sequence and point bar (Blue River, Summit County 2005).

From cost estimating, the riprap required for all riffles was assumed to be 70 feet wide along the entire length of each riffle as well as the upstream and downstream cutoff structures. Costs include mixing the riprap with soil and assume that the native soils excavated as part of this work will be utilized in the soil mixture. No soil import was assumed.

4.5 Existing Drop Modification

There are five existing drops located in the project reach. Most of these drops consist of grouted in place boulders constructed with longitudinal slopes of approximately 5H:1V. While the current configuration of the drops provides grade control and some pool habitat downstream of the drop, the steep slope creates a barrier to fish migration during low flows. The Plan calls for the existing drops to be converted into lower gradient riffles. The riffles will be constructed in the same manner as other riffles, however, the upstream end will be built over the existing drop and an upstream turndown will not be required. Minor adjustments in the invert elevation of each drop may be required and will need to be evaluated for each specific drop structure as part of final design.

From cost estimating, the riprap required for all riffles was assumed to be 70 feet wide along the entire length of each riffle as well as the upstream and downstream cutoff structures. Costs include mixing the riprap with soil and assume that the native soils excavated as part of this work will be utilized in the soil mixture. No soil import was assumed.

4.6 Bank Stabilization

There are two types of proposed bank stabilization. Type A bank stabilization includes a reinforced toe and maintains the upper portion of the eroding bank in place to provide continued cut bank habitat for such wildlife as kingfisher. Type B involves laying back an eroding bank at a flatter, more stable slope which will provide suitable characteristics for development of native riparian habitat. Details of the two proposed stabilization techniques are provided below.

4.6.1 Type A

The Plan calls for 2,135 linear feet of Type A bank stabilization. Type A bank stabilization is used in locations where there are large cottonwood trees or where cut bank habitat is to be maintained, preventing the eroding slope from being laid back to a stable slope and revegetated. Type A bank stabilization consists of a toe stabilized using soil filled riprap with planting pocket located at the top of the toe at the bankfull elevation. The riprap portion of the toe should be constructed with a 3H:1V slopes and a top width of 5 feet. The toe should be built to an elevation equal to the estimated bankfull water surface elevation. Planting pockets will be created behind the front slope of the toe. Planting pockets will consisted of a 2' diameter and 2' deep hole formed within the soil-filled riprap and spaced at approximately 6' intervals along the entire length of the bank stabilization. A 5-gallon rooted native riparian shrub will be installed and backfilled with topsoil. A list of appropriate shrub species is provided in **Table 4**.

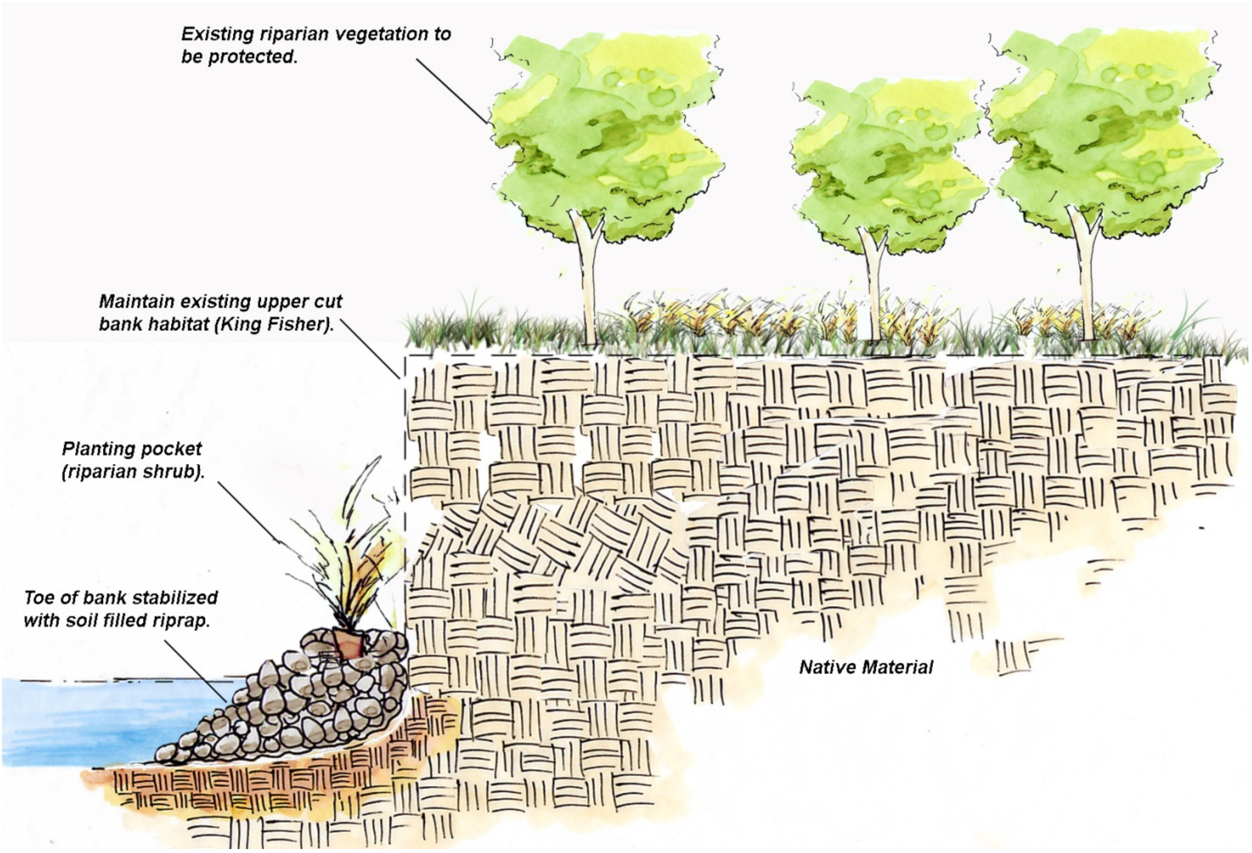
This will create a stable lower bank edge while maintaining the upper vertical cut bank habitat in addition to creating riparian shrub habitat. A typical detail of the Type A bank stabilization is shown in **Plan Sheet 9**. A schematic depiction of this bank stabilization technique is provided in **Figure 12**.

For a cost estimating standpoint it was assumed that 1.55 cubic yards of soil riprap was required for each linear foot of Type A bank stabilization. It is assumed that planting pockets include topsoil backfill, soil amendments, wood chip mulch and one 5 gallon shrub planted every six feet along the terrace. Costs include mixing the riprap with soil and assume that the native soils excavated as part of this work will be utilized in the soil mixture. No soil import was assumed.

Table 4 – Appropriate Native Shrub Species

Scientific Name	Common Name
Amelanchier arborea	Common serviceberry
Amorpha canescens	Leadplant
Padus virginiana melanocarpa	Chokecherry
Prunus americana	Wild plum
Rhus trilobata	Skunkbush sumac
Ribes aureum	Golden currant
Ribes cereum	Wax currant
Rosa woodsii	Woods rose
Rubus deliciosus	Boulder raspberry
Salix exigua	Sandbar willow
Sambucus racemosa	Red elderberry
Symphoricarpos albus	Common snowberry

Figure 12 – Type A Bank Stabilization

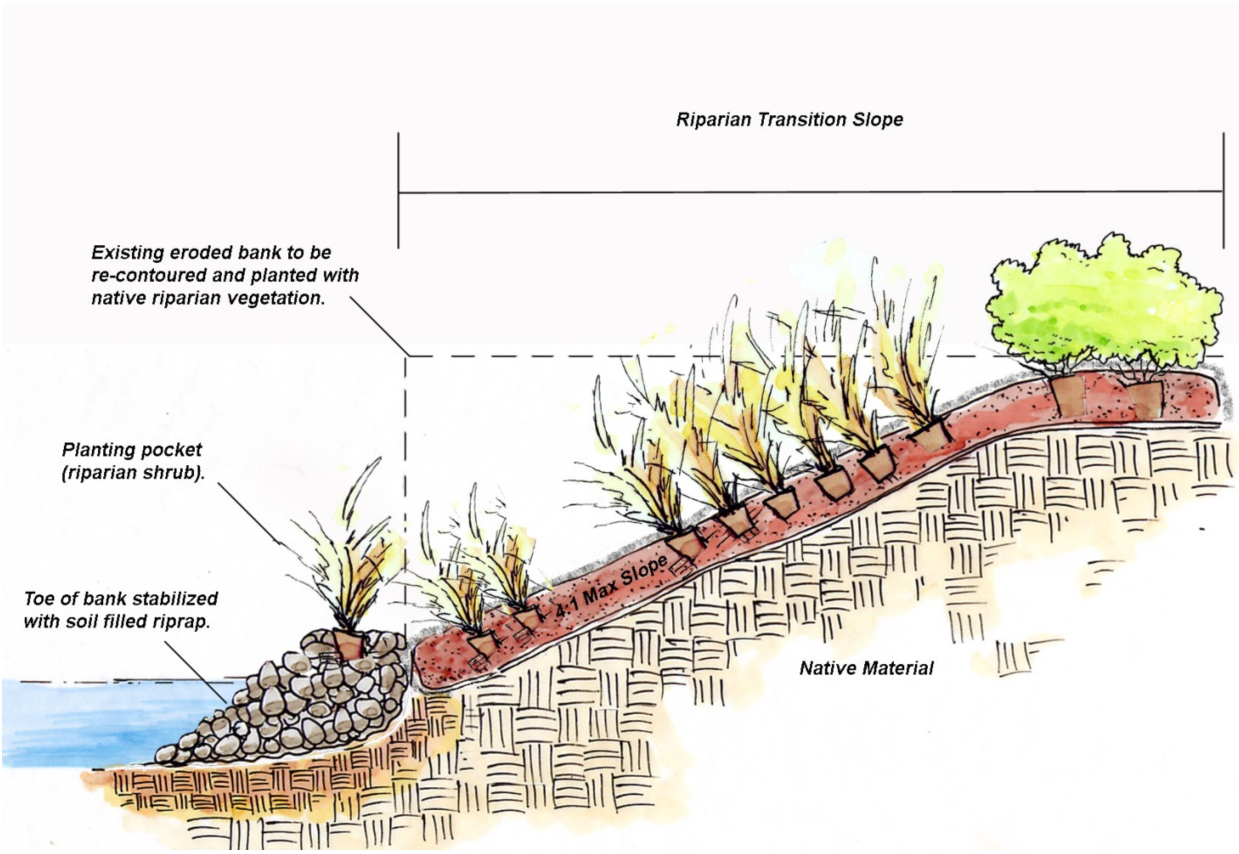


4.6.2 Type B

The Plan calls for 1,820 linear feet of Type B bank stabilization. Type B bank stabilization is used in locations where there is space to lay the bank back to a stable slope and create a riparian transition slope at the top of the slope. Type B bank stabilization is similar to the Type A in that it constructs a reinforced toe and planting pockets, in additional cuts the upper bank back to a 4H: 1V slope. The cut will be laid back to tie in to the existing top of bank elevation. This will create riparian transition slope, stabilize the eroding bank and providing an opportunity to create riparian habitat. A typical detail of the Type B bank stabilization is shown in **Plan Sheet 10**. A schematic depiction of this bank stabilization technique is provided in **Figure 13**.

For a cost estimating standpoint it was assumed that 1.55 cubic yards of soil riprap was required for each linear foot of Type B bank stabilization. It is assumed that planting pockets include topsoil backfill, soil amendments, wood chip mulch and one 5 gallon shrub planted every six feet along the terrace. The slope above the riprap that will be graded at 4H:1V was assumed to be an average of 20 feet long. Slopes are assumed to be seeded with a native mix, soils amended, covered with erosion control fabric and native 5 gallon shrubs planed at six foot on center spacing along the slope. A list of appropriate shrub species is provided in the previous **Table 4**. Costs include mixing the riprap with soil and assume that the native soils excavated as part of this work will be utilized in the soil mixture. No soil import was assumed.

Figure 13 – Type B Bank Stabilization



4.7 Riparian Planting Zones

Riparian corridors refer to the entire ecosystem connected to the river consisting of the physical channel, banks, wetland vegetation and associated upland area and vegetation. Typically riparian corridors in the region are characterized by having a mature overstory of plains cottonwood trees, clusters of shrubs in the midstory and an understory of mixed grasses. These corridors are some of the most biologically diverse habitats within the park having a consistent source of water and providing structural habitat diversity utilized by a wide variety of wildlife. These corridors, although relatively highly disturbed, provide the only natural environment and movement corridors in a highly urbanized setting. Urban development, agriculture and mining have resulted in channelization, floodplain reduction, fragmentation as well as a loss of associated vegetation communities throughout the river corridor. Specifically within the park historic gravel mining and agricultural practices have significantly altered and disturbed the riparian vegetation community. Gravel mining has replaced riparian vegetation communities with created relatively large open water bodies with steep slope banks surrounded by large expanses of non-native grasslands. The historic agricultural practices across much of the park has resulted in limited development of natural vegetation communities, depleted soil nutrients and has created an opportunity for weed establishment.

The primary habitat type or vegetation community recommended as part of the Plan which is locally native and appropriate for the environmental setting within the SPP is the cottonwood gallery riparian planting zone. This vegetation community is intended to replicate the naturally occurring habitat commonly and historically found along the South Platte River in the local region. Replicating the natural characteristic of typical riparian corridors including the re-establishment of a plains cottonwood (*Populus deltoides*) overstory, shrub midstory and a mixed grassland understory is the primary objective of the riparian planting zones.

Photo example (left) of existing riparian corridor lacking native vegetation communities and structural diversity. Photo example (right) of well vegetated, structurally diverse riparian corridor of the area and goal of riparian planting zones.

The plains cottonwood is the primary species of native tree on the eastern plains as well as the largest tree species reaching heights of up to 60' with trunk diameters of 3'. Cottonwoods are now primarily found along drainages and streams of the eastern plains. Cottonwood stands provide habitat for 82% of all bird species breeding in northeastern Colorado (USDA, FEIS). This species establishes quickly under ideal conditions and is relatively drought tolerant. The establishment of tree stands will provide significant increased wildlife habitat. Many of the large mature cottonwoods present within the SPP are approaching the mid to end of life span. The planting of second generation stands of plains cottonwood will ensure the continued existence of this valuable habitat type.

Vegetation structure within cottonwood galleries typically consists of patches of plains cottonwood within the canopy layer, with sandbar willow along the stream edge and mixed-grass prairie understory. Only few shrubs such as yucca (*Yucca glauca*), four-winged saltbush (*Atriplex canescens*), common snowberry (*Symphoricarpos albus*), skunkbush sumac (*Rhus trilobata*), woods rose (*Rosa woodsii*) and rabbitbrush (*Chrysothamnus nauseosus*) are typically associated with this community. The mixed-grass prairie community is characterized by graminoids and forbs able to survive poor soil conditions and extended periods of drought. An established grassland understory community provides numerous environmental benefits including soil stabilization, overland runoff filtration as well as forage and cover for wildlife. Replicating the natural characteristics of the mixed-grass prairie community should be the primary objective for establishing grassland communities in the understory of the cottonwood galleries. **Table 5** provides typical species that would be suitable for establishment in the understory of the cottonwood galleries.

Table 5 – Native Species Recommended for the Tree Stand Community

Scientific Name	Common Name
Trees	
Acer negundo (female species)	Box elder
Celtis reticulata	Netleaf hackberry
Populus deltoides	Plains cottonwood
Salix amygdaloides	Peachleaf willow
Shrubs	
Amelanchier arborea	Common serviceberry
Amorpha canescens	Leadplant
Artemisia frigida	Fringe sage
Atriplex canescens	Four-winged saltbush
Chrysothamnus nauseosus	Rubber rabbitbush
Prunus virginiana melanocarpa	Chokecherry
Prunus americana	Wild plum
Rhus trilobata	Skunkbush sumac
Ribes aureum	Golden currant
Ribes cereum	Wax currant
Rosa woodsii	Woods rose
Rubus deliciosus	Boulder raspberry
Salix exigua	Sandbar willow
Sambucus racemosa	Red elderberry
Symphoricarpos albus	Common snowberry
Yucca glauca	Yucca
Grass	
Andropogen gerardii	Big bluestem
Bouteloua curtipendula	Sideoats grama
Bouteloua gracilis	Blue grama
Buchloe dactyloides	Buffalo grass
Dalea candida	White prairie clover
Dalea purpurea	Native blanket flower
Gaillardia aristata	Purple prairie clover
Hordeum jubatum	Foxtail barley
Liatris punctata	Dotted gayfeather

Scientific Name	Common Name
Linum lewisii	Blue flax
Pascopyron smithii	Western wheatgrass
Poa palustris	Fowl bluegrass
Ratibida columnifera	Prairie coneflower
Schizachyrium scoparium	Little bluestem
Spartina pectinata	Prairie cordgrass
Sporobolus cryptandrus	Sand dropseed
Sporobolus heterolepis	Prairie dropseed
Stipa viridula	Green needlegrass

Costs for the riparian planting areas were estimated on a per acre basis. Costs assumed that the areas targeted for planting will require application of a herbicide to eliminate existing vegetation. All areas are then assumed to be tilled and soil amendments added. An appropriate native grass seed and mulch is assumed to cover the entire area. Forth eight (48) 2.5-inch caliper cottonwood trees were assumed to be planted approximately at 30' on center spacing per acre throughout the riparian plant zone. Details such as specific plant locations, beaver protection and fencing will need to be considered as part of the detailed design.

4.8 Gravel Pit Lake Shoreline Enhancement - Red Tail Lake Wetland

Plans call for a wetland creation area within Red Tail Lake. The wetland creation area will be constructed by raising the elevation of a portion of the lake near the outlet to within about 0.3 feet of the outlet elevation, and planting native wetland grass plugs. It is assumed that approximately 0.1 acres of new wetland habitat will be created. Fill used to raise the elevation of the area to be converted to wetlands is assumed to be obtained from dredge from within the lake itself of excavation as part of other work being completed on the enhancement plan. Costs for import of planting soil are not included in the estimated construction costs.

The existing abandoned gravel pit lakes throughout the SPP may not be considered a native habitat type but do create a unique and valuable habitat in the SPP. These lakes are all very similar in characteristic being of relatively uniform shape with steep (2H:1V) side slopes and limited natural vegetation. Ideally the shorelines of these lakes would be irregularly shaped transitioning gradually from an aquatic/emergent wetland habitat to a mesic grass/shrublands into dry grasslands. Creating a more natural landform, shallow emergent wetland fringe and more gentle, irregular transition side slope will be the primary objective for potential future lake shoreline enhancement and specifically the initial Red Tail Lake Wetland Enhancement project. A schematic depiction of this bank stabilization technique is provided in **Figure 14**.

Figure 14 – Red Tail Lake Wetland Enhancement

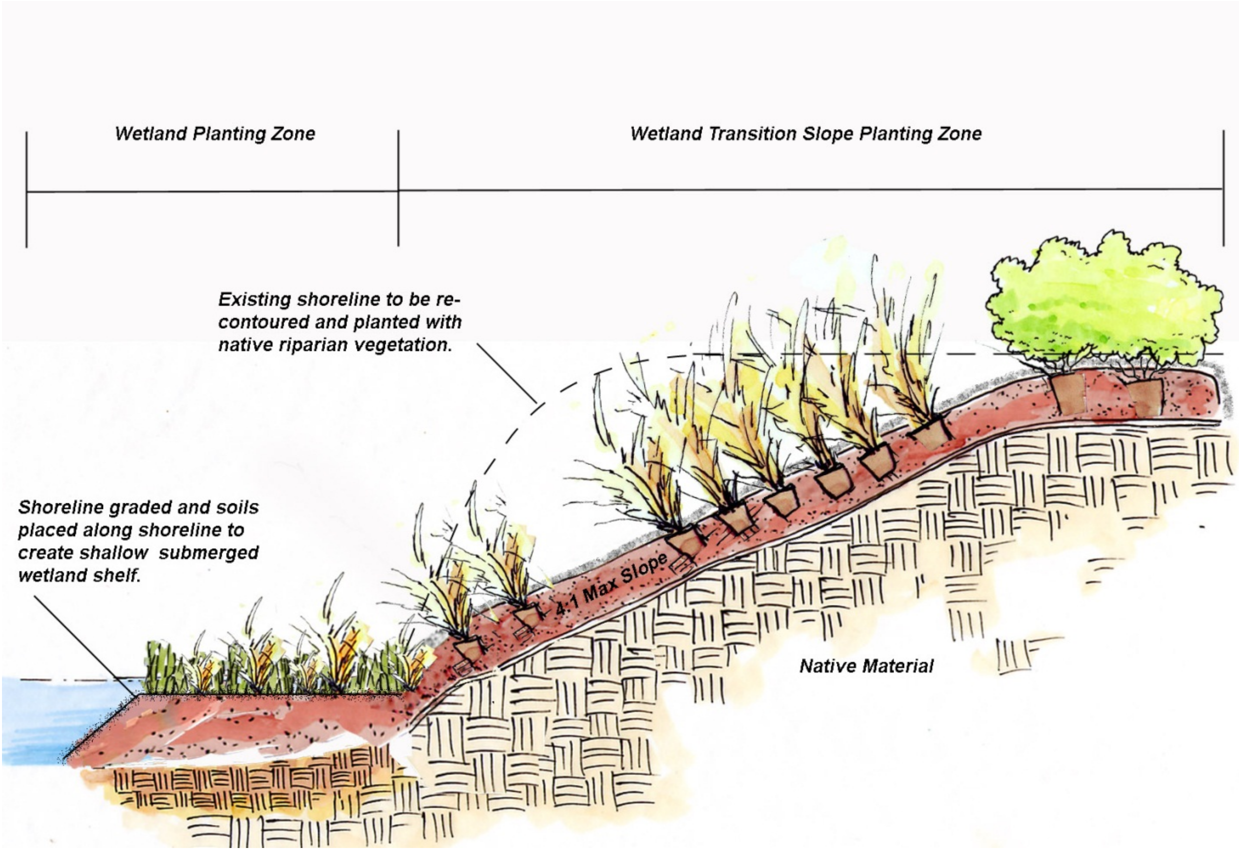


Photo example (left) of existing steep and abrupt lake shoreline along Redtail Lake with minimal native vegetation. Photo example (right) of well-developed constructed lake shoreline with emergent wetland habitat typical of the region and goal of the Redtail Lake Wetland Enhancement.

The proposed Red Tail Lake Wetland Enhancement activity would regraded more gentle slopes along a section of the lake edge, eradicate existing non-native plant species and develop a combination of emergent wetland and transitional wetland slope. Slopes would be graded a maximum slope of 4:1. Slopes would be graded through a balanced cut/fill operation with a dozer type equipment pushing excess slope spoils into lake edge creating a shallow inundated wetland shelf. The water line/slope interface shall be as flat as possible. Slopes shall be graded as determined in the field to create an irregular, undulating appearance as well as to preserve existing native vegetation were possible.

Emergent wetland plant species would be planted along the lake shelf (aquatic/terrestrial interface). The transitional slope from the wetland to the upland edge would be vegetated with a variety of native grasses, shrubs and trees adapted to more mesic soil moisture conditions.

The presence of a constant water supply provides an ideal condition for the establishment of shrub thickets along the water line. Willows, chokecherry, indigobush, wood's rose, wild plum, red-osier dogwood (*Cornus sericea*) and snowberry would all thrive along the transition slopes. A mixture of tall-grass and short-grass prairie species is recommended along the transition slope to create increased structural diversity/habitat complexity and slope stabilization. **Table 6** provides typical species that would be suitable for establishment in the wetland/transition slope habitats.

Table 6 – Recommended Wetland/Transition Slope Plant Species

Scientific Name	Common Name
Wetland Zone (-0.5' to +0.5' above waterline)	
Carex nabraskensis	Nebraska sedge
Eleocharis palustris	Spike rush
Glyceria striata	Fowl mannagrass
Juncus articus	Arctic rush
Juncus torreyi	Torrey rush
Schoenoplectus pungens	Common three square
Schoenoplectus tabernaemontain	Softstem bulrush
Scirpus maritmus	Alkali bulrush
Scirpus microcarpus	Panicled bulrush
Scirpus pallidus	Pale bulrush
Wetland Transition Slope (+0.5' to +3.0' above waterline)	
Amelanchier arborea	Common serviceberry
Beckmannia syzigachne	American sloughgrass
Cornus sericea	Red-osier dogwood
Elymus canadensis	Canada wildrye
Hordeum jubatum	Foxtail barley
Panicum virgatum	Switchgrass
Pascopyrum smithii	Western wheatgrass
Prunus americana	Wild plum
Prunus virginiana melanocarpa	Chokecherry
Rosa woodsii	Woods rose

Scientific Name	Common Name
Salix exigua	Coyote willow
Spartina pectinata	Prairie cordgrass
Sporabolus airoides	Alkali sacaton
Sporabolus cryptandrus	Sand dropseed

4.9 Red Tail Lake Outlet Grade Control

Enhancement plans include work on the outlet of Red Tail Lake. The purpose of this portion of the project is to establish a specific lake outlet elevation. Having a set outlet elevation that is not subject to downcutting will help to maintain the water level in the lake, ensure the appropriate water depth for the planned wetland plantings and allow the lake to maintain a direct hydraulic connection with the South Platte River so that the lake can continue to provide refuge for aquatic life looking to migrate into the lake at times of low flow in the river. As part of this work other low or unstable areas on the stream side bank of Red Tail Lake would require stabilization as well to ensure that a new outlet does not develop. Costs for the outlet at Red Tail Lake assume that riprap will be imported and used to set the grade control.

5.0 GEOMORPHOLOGY

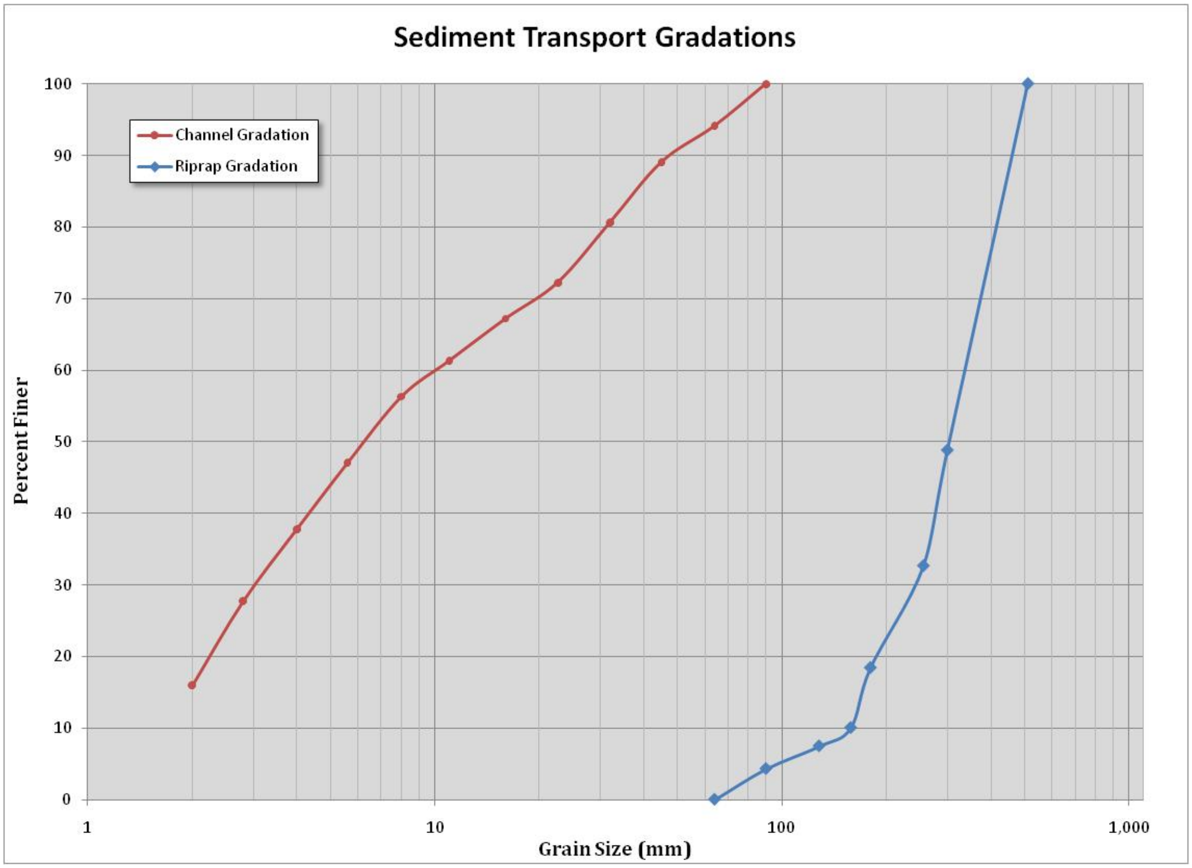
Sediment transport modeling was conducted to evaluate the sustainability of the proposed channel improvements. The modeling performed was intended to evaluate likely responses of the planned stream profile over time. As with any natural stream, some adjustments are expected and areas of sediment deposition and erosion are expected. The magnitude and location of these responses were quantified as a tool in assessing the likely success of maintaining the desired naturalize riffle/pool/glide sequences.

5.1 Grain Size Analysis

To determine the potential for sediment transport, a grain size analysis was performed within the channel reach. Surface sediment samples were collected using a variation of the Wolman pebble count method. A sediment sampling frame, which has been shown to reduce sampling bias, was utilized with selected material measured using a gravelometer following procedures outlined in Sampling Surface and Subsurface Particle-Size Distributions in Wadable Gravel- and Cobble-Bed Streams for Analysis in Sediment Transport, Hydraulics, and Streambed Monitoring (Bunte and Abt 2001). The surface sediment samples were used to develop particle size distributions for each site, which are presented in **Appendix C**. The resulting gradation was used as the channel gradation for non-riffle sections of the proposed channel in the sediment transport model. Results of the sediment sampling indicate that the channel material has a D_{50} of 6mm and is classified as poorly graded gravel with sand.

Riffles will need to be constructed from imported material to improve their long term stability as the native material was calculated to be mobile if placed at desired riffle slopes. For this reason, a separate gradation was used for riffle areas in the sediment transport model. Through a series of model runs it was determined that Type M riprap will remain stable through bankfull flows and the 100-year event. Type M riprap is listed in the UDFCD Criteria Manual as having a D50 of 12- inches. A typical gradation for Type M riprap was used for sediment transport modeling of the riffles. Gradations for both the channel material and Type M riprap are presented in **Figure 15**.

Figure 15 – Channel and Riprap Gradations



5.2 HEC-RAS Modeling Assumptions

HEC-RAS was also used to perform a mobile bed transport analysis to determine the long term sustainability of proposed channel modifications. A mobile bed transport analysis creates an updated HEC-RAS channel geometry file that incorporates changes to the channel geometry after each flow period. The updated geometry file is then used to evaluate channel hydraulics and changes to channel geometry during the next flow period. This process is carried out several times throughout the course of a year to predict changes that will occur during an annual flow pattern. Multiple years were evaluated by starting the flow year with the previous year's geometry file.

The Akers and White sediment transport function was used to determine sediment transport capacity within the HEC-RAS model. The Akers and White equation was developed for relatively uniform gradations ranging from sands to fine gravels. Equilibrium load boundary conditions were used at both the upstream and downstream ends of the sediment transport model and the downstream pass through boundary was used. Stream temperature data is also required for sediment transport analysis. The monthly average stream temperatures used were based on data collected as a part of the Colorado Division of Wildlife River Watch program and are presented in **Table 7**. A maximum annual erodible depth of 5 feet was set in the model and erosion was only allowed to occur within the channel banks. The HEC-RAS program defaults were used for all other sediment transport modeling options.

Table 7 – Monthly Water Temperature Data

Month	Temp (Degrees F)
January	37
February	36
March	47
April	53
May	54
June	65
July	64
August	70
September	63
October	46
November	43
December	41

5.3 Results and Discussion

The model was run over the course of one year using the summarized average daily flow data shown in **Figure 8**. The model was then run for subsequent years each time using the geometry predicted at the end of the previous year as the initial geometry in the subsequent year. Results of the sediment transport analysis after one year and five years are shown in **Figures 16** and **17**. **Figure 16** shows the proposed initial bed invert verses the bed inverts at the end of year one and at the end of year 5. **Figure 17** shows the predicted change in bed invert one year and five years after construction. **Figures 18** and **19** show the bed change after a year of flows in which the 100-year FIS flood of 2,700 cfs occurred. Stationing shown on these figures corresponds to the river stationing shown on the plan drawings (**Plan Sheets 1-5**).

Figure 16 – 5 Year Bed Invert Comparison

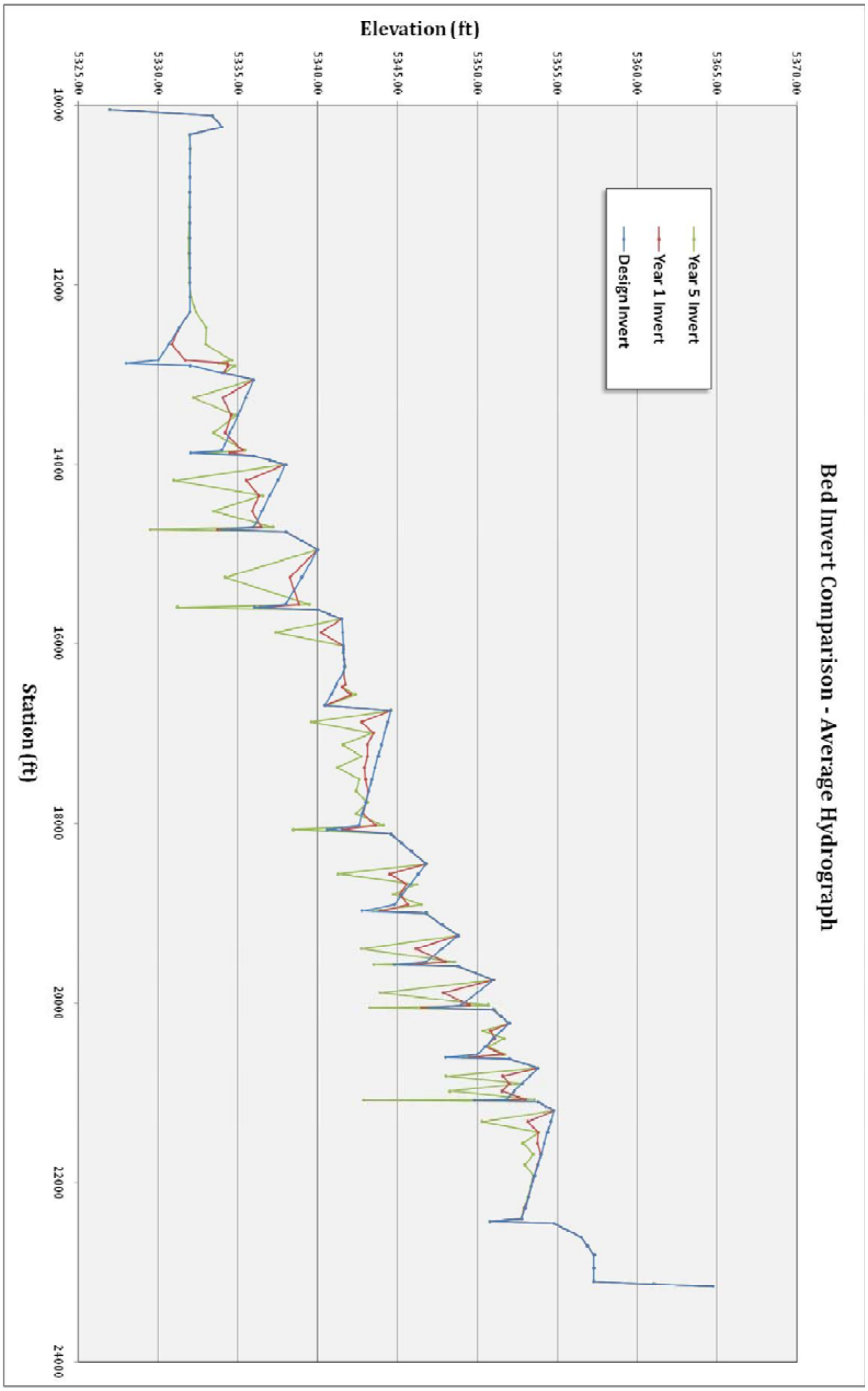


Figure 17 – 5 Year Bed Invert Change

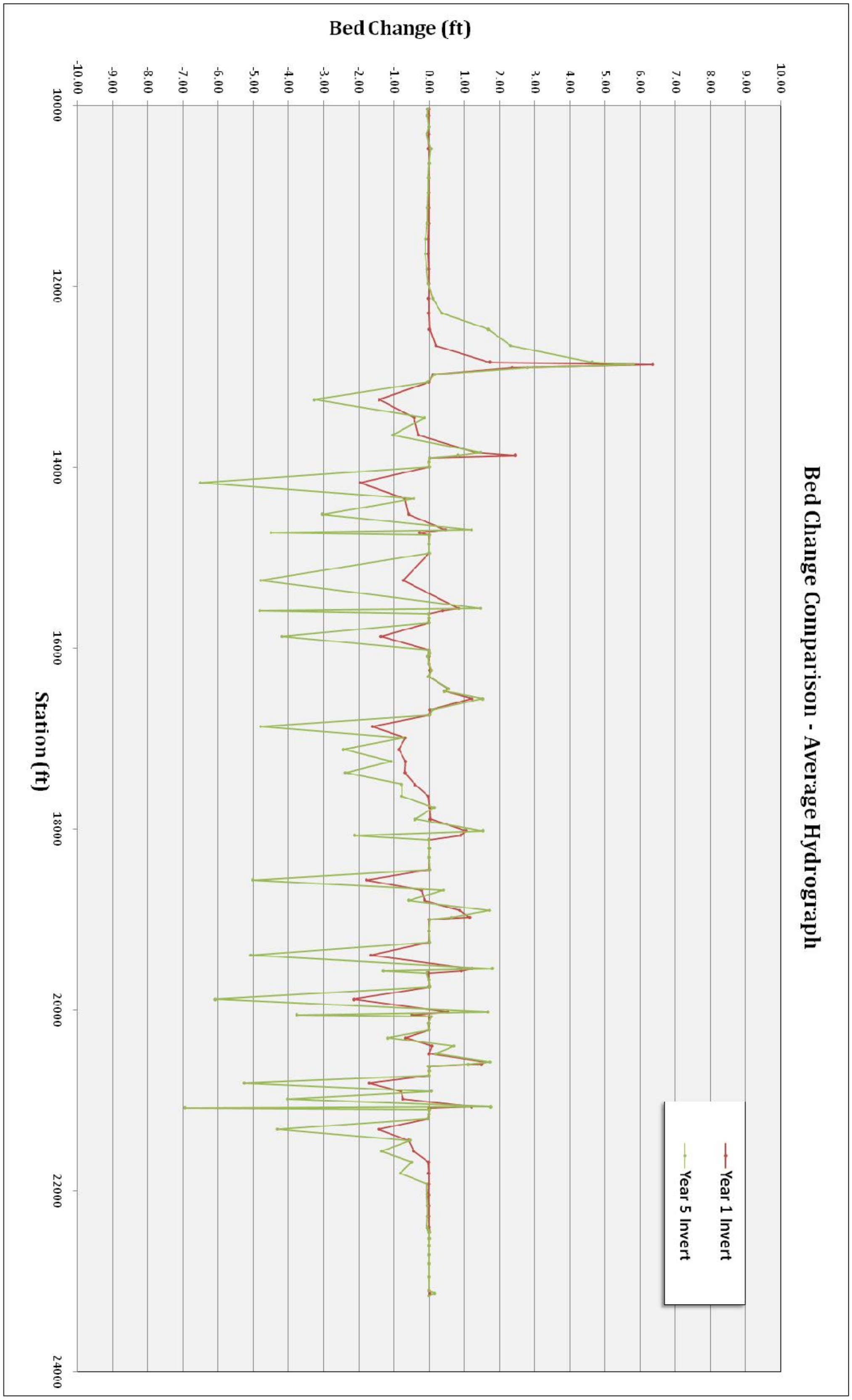


Figure 16 shows that the general pattern observed is erosion in the pool and glide areas (areas downstream of the pools) and stable riffles. The model indicates that the downstream most pool (pool 1) is the only pool where deposition rather than erosion is predicted. This is likely due to the boat chute at the downstream end of the project. The boat chute is outside of the project limits and will not be modified as a part of this project. The bed invert plots show the riffle locations remaining stationary over time. This is significant as maintaining stable riffle sections will provide the variability in the stream profile needed for instream habitat variety.

Figure 17 depicts the projected change in the channel thalweg after 1 and 5 years of average flow conditions. Positive values indicate areas of deposition and negative values indicate areas of erosion or downcutting. With the exception of Pool 1 and Pool 2, all areas experience approximately 1.5 feet or less of total elevation change within the first year. The model indicates approximately 4.5 feet of sedimentation may occur at Pool 1 and 2.0 feet of sedimentation may occur at Pool 2 in the first year. All of the aggradation in Pool 1 is predicted to occur in the first year, after the first year degradation is observed at Pool 1. Additionally, a glide depth of approximately 2.5 feet will be maintained between Pool 1 and the downstream end of the project. The aggradation predicted in Pool 2 is likely due to the lower gradient in the downstream portion of the project. These results are highly influenced by the downstream boat chute and more detailed modeling of the system including incorporation of the detailed geometry of that structure is recommended prior to final design of this downstream most segment.

Some additional erosion and downcutting is predicted from years 1 to 5 with a magnitude that is significantly less than what is predicted during the first year. In general, the riffles remain in place and pools maintain significant depth. An average of approximately four feet of erosion is predicted in the glide sections between pools and riffles in a few locations. Elevations through the glide sections are most prone to shift over time and larger variations are not expected to impact overall product success as upstream and downstream riffles will provide overall grade control. Similarly greater magnitudes of erosion are predicted at pools 3, 4, and 10. Additional erosion at these locations will provide deeper pool habitat that will be beneficial to the project, however detailed modeling should be completed as part of final design to ensure that erosion does not undercut the upstream grade control. Given that results show erosion of the glides could continue downstream towards the upper end of the riffle sections the stability at the upstream ends of each riffle section should be evaluated in detail as part of final design and the depth of the rundown at these locations may need to be adjusted. If required, additional armoring could be provided at these areas to ensure erosion is maintained at an acceptable level. The most important thing to observe in **Figures 17** and **18** is that while some shifting occurs, the general varied channel profile of repeating riffles, pools and glides are predicted to be maintained over time, indicating that the planned instream habitat will be sustained. Because the riffles do not degrade over time they will maintain the varied channel habitat. The increased flow velocity from the riffle upstream of the same glide should ensure sediment is moved through the system and a good pool depth is maintained. **Table 8** presents a summary of predicted bed invert change a key elevations over the modeled five years.

Table 8 - Predicted Bed Elevation Change

Location	Design Invert	Year 1		Year 2		Year 3		Year 4		Year 5	
		Invert	Change	Invert	Change	Invert	Change	Invert	Change	Invert	Change
G-1	5332.0	5332.0	0.0	5332.0	0.0	5331.9	-0.1	5331.9	-0.1	5331.9	-0.1
G-1	5332.0	5332.0	0.0	5332.0	0.0	5332.0	0.0	5332.0	0.0	5332.0	0.0
G-1	5332.0	5332.0	0.0	5332.0	0.0	5331.9	-0.1	5331.9	-0.1	5331.9	-0.1
G-1	5332.0	5332.0	0.0	5332.0	0.0	5332.0	0.0	5332.2	0.2	5332.4	0.4
P-1	5330.0	5331.7	1.7	5333.5	3.4	5334.5	4.5	5334.6	4.6	5334.6	4.6
RE-1	5328.0	5334.4	6.4	5334.4	6.4	5334.4	6.4	5334.0	6.0	5333.8	5.8
RB-1	5332.0	5334.4	2.4	5334.5	2.4	5334.7	2.7	5334.7	2.7	5334.8	2.8
G-2	5336.0	5336.0	0.0	5336.0	0.0	5336.0	0.0	5336.0	0.0	5336.0	0.0
G-2	5335.0	5334.6	-0.4	5334.7	-0.3	5334.8	-0.2	5334.8	-0.2	5334.9	-0.1
P-2	5334.0	5335.3	1.3	5335.6	1.6	5335.2	1.2	5335.4	1.4	5335.5	1.5
RE-2	5332.0	5334.5	2.4	5334.3	2.3	5333.5	1.4	5332.9	0.9	5332.8	0.8
RB-2	5336.0	5336.0	0.0	5336.0	0.0	5336.0	0.0	5336.0	0.0	5336.0	0.0
G-3	5338.0	5338.0	0.0	5338.0	0.0	5338.0	0.0	5338.0	0.0	5338.0	0.0
G-3	5337.0	5336.3	-0.7	5336.1	-0.9	5336.4	-0.6	5336.5	-0.5	5336.6	-0.4
P-3	5336.0	5336.5	0.5	5336.9	0.9	5337.1	1.1	5337.3	1.3	5337.2	1.2
RE-3	5334.0	5333.7	-0.3	5333.3	-0.7	5331.5	-2.5	5330.2	-3.8	5329.5	-4.5
RB-3	5338.0	5338.0	0.0	5338.0	0.0	5338.0	0.0	5338.0	0.0	5338.0	0.0
G-4	5340.0	5340.0	0.0	5340.0	0.0	5340.0	0.0	5340.0	0.0	5340.0	0.0
G-4	5338.0	5338.8	0.8	5339.0	1.0	5339.3	1.3	5339.4	1.4	5339.5	1.5
P-4	5336.0	5336.4	0.4	5335.4	-0.6	5333.2	-2.8	5332.2	-3.8	5331.2	-4.8
RE-4	5340.0	5340.0	0.0	5340.0	0.0	5340.0	0.0	5340.0	0.0	5340.0	0.0
RB-4	5341.5	5341.5	0.0	5341.5	0.0	5341.5	0.0	5341.5	0.0	5341.5	0.0
G-5	5343.6	5342.9	-0.7	5342.3	-1.3	5341.9	-1.7	5341.6	-2.0	5341.2	-2.4
G-5	5342.6	5343.6	1.0	5343.9	1.3	5344.1	1.5	5344.1	1.5	5344.1	1.5
P-5	5340.6	5341.5	0.9	5341.4	0.8	5340.2	-0.4	5339.0	-1.6	5338.5	-2.1
RE-5	5344.6	5344.6	0.0	5344.6	0.0	5344.6	0.0	5344.6	0.0	5344.6	0.0
RB-5	5346.8	5346.8	0.0	5346.8	0.0	5346.8	0.0	5346.8	0.0	5346.8	0.0
G-6	5345.8	5345.6	-0.2	5345.7	-0.1	5345.8	0.0	5346.0	0.2	5346.2	0.4
G-6	5344.8	5345.7	0.9	5346.2	1.4	5346.4	1.6	5346.4	1.6	5346.5	1.7
P-6	5342.8	5343.9	1.1	5344.1	1.3	5344.1	1.3	5344.1	1.3	5343.4	0.6
RE-6	5346.8	5346.8	0.0	5346.8	0.0	5346.8	0.0	5346.8	0.0	5346.8	0.0
RB-6	5348.8	5348.8	0.0	5348.8	0.0	5348.8	0.0	5348.8	0.0	5348.8	0.0

Notes: Listed change is difference from initial invert
RB denotes the beginning of a riffle, RE denotes the end of a riffle, P denotes a pool and G denotes a glide

Table 8 - Predicted Bed Elevation Change (Cont.)

Location	Design Invert	Year 1		Year 2		Year 3		Year 4		Year 5	
		Invert	Change	Invert	Change	Invert	Change	Invert	Change	Invert	Change
G-7	5347.8	5346.1	-1.7	5344.9	-2.9	5344.5	-3.3	5343.6	-4.2	5342.7	-5.1
G-7	5346.8	5348.0	1.2	5348.1	1.3	5348.7	1.9	5348.6	1.8	5348.6	1.8
P-7	5344.8	5345.7	0.9	5345.8	1.0	5344.6	-0.2	5344.0	-0.8	5343.5	-1.3
RE-7	5348.8	5348.8	0.0	5348.8	0.0	5348.7	-0.1	5348.7	-0.1	5348.7	-0.1
RB-7	5351.0	5351.0	0.0	5351.0	0.0	5351.0	0.0	5351.0	0.0	5351.0	0.0
G-8	5350.0	5347.9	-2.1	5347.0	-3.0	5345.4	-4.6	5344.7	-5.3	5343.9	-6.1
G-8	5349.0	5349.5	0.5	5350.1	1.1	5350.4	1.4	5350.5	1.5	5350.7	1.7
P-8	5347.0	5346.5	-0.5	5345.6	-1.4	5344.5	-2.5	5344.0	-3.0	5343.2	-3.8
RE-8	5351.0	5351.0	0.0	5351.0	0.0	5351.0	0.0	5351.0	0.0	5351.1	0.1
RB-8	5352.0	5352.0	0.0	5352.0	0.0	5352.0	0.0	5352.0	0.0	5352.0	0.0
G-9	5351.0	5351.1	0.1	5351.3	0.3	5351.4	0.4	5351.4	0.4	5351.4	0.4
G-9	5350.0	5351.6	1.6	5351.7	1.7	5351.7	1.7	5351.7	1.7	5351.7	1.7
P-9	5348.0	5349.5	1.5	5349.5	1.5	5349.3	1.3	5349.2	1.2	5349.1	1.1
RE-9	5352.0	5352.0	0.0	5352.0	0.0	5352.0	0.0	5352.0	0.0	5352.0	0.0
RB-9	5353.8	5353.8	0.0	5353.8	0.0	5353.8	0.0	5353.8	0.0	5353.8	0.0
G-10	5352.8	5352.0	-0.8	5352.1	-0.7	5352.3	-0.5	5352.6	-0.2	5352.9	0.1
G-10	5351.8	5353.0	1.2	5353.5	1.6	5353.6	1.7	5353.6	1.8	5353.6	1.8
P-10	5349.8	5349.8	0.0	5347.9	-1.9	5346.1	-3.7	5344.4	-5.4	5342.9	-6.9
RE-10	5353.8	5353.8	0.0	5353.8	0.0	5353.8	0.0	5353.8	0.0	5353.8	0.0
RB-10	5354.8	5354.8	0.0	5354.8	0.0	5354.8	0.0	5354.8	0.0	5354.8	0.0
G-11	5353.8	5353.8	0.0	5353.8	0.0	5353.5	-0.3	5353.3	-0.5	5353.0	-0.8
G-11	5352.8	5352.8	0.0	5352.8	0.0	5352.8	0.0	5352.8	0.0	5352.7	-0.1
P-11	5350.8	5350.8	0.0	5350.8	0.0	5350.8	0.0	5350.8	0.0	5350.8	0.0
RE-11	5354.8	5354.8	0.0	5354.8	0.0	5354.8	0.0	5354.8	0.0	5354.8	0.0
RB-11	5356.5	5356.5	0.0	5356.5	0.0	5356.5	0.0	5356.5	0.0	5356.5	0.0

Figure 18 – 100 Year FIS Flood Invert Comparison

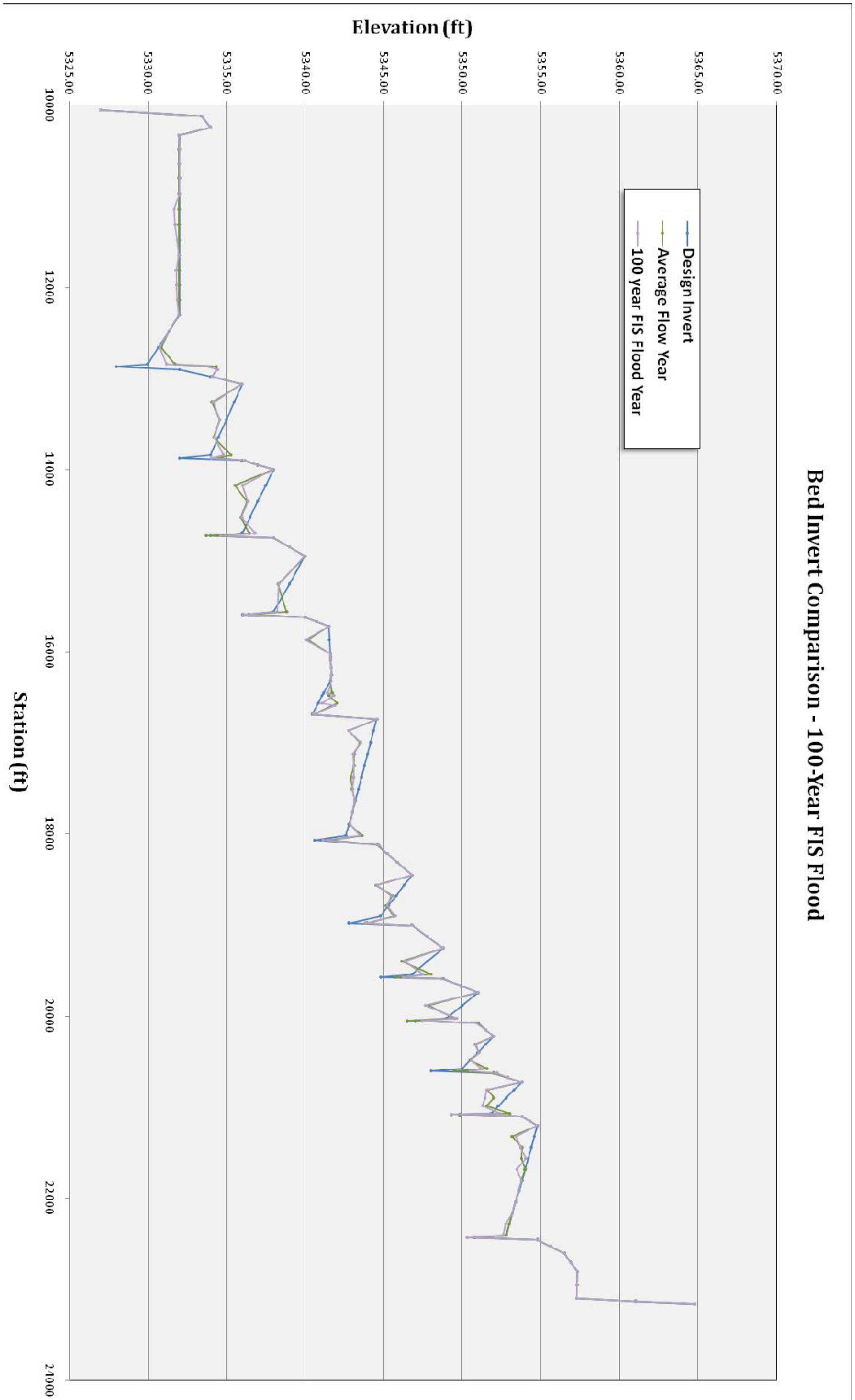


Figure 19 – 100 Year FIS Flood Bed Change Comparison

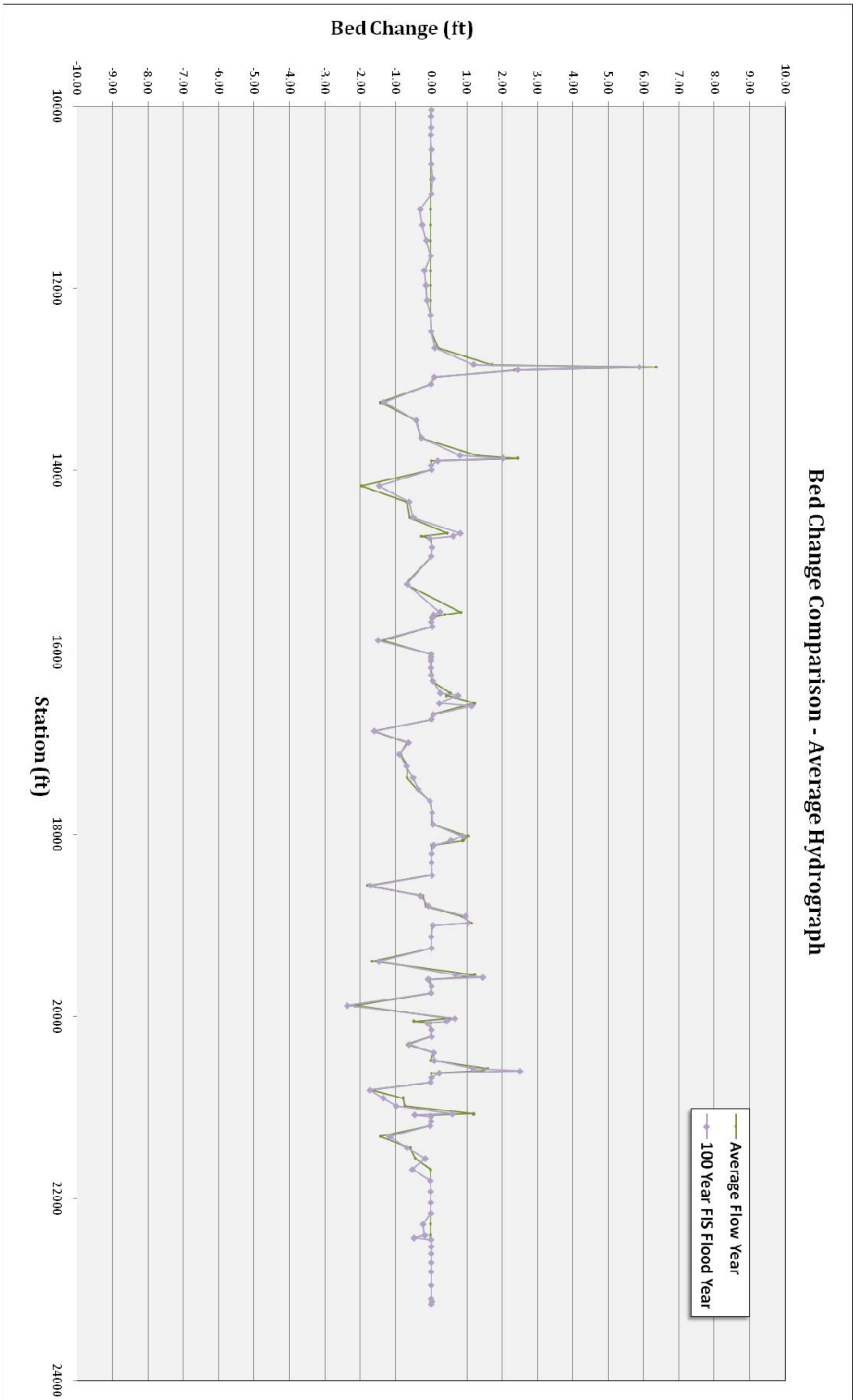


Figure 18 depicts the predicted bed invert after a year in which the 100-year peak flood flow occurred compared with the predicted bed invert after a year with average flows. **Figure 19** depicts the predicted bed change for the same two flow scenarios. The 100-year flow was simulated by replacing the single daily peak of the average annual hydrograph with a flow of 2,700 cfs. This flow was assumed to occur for a time period of 24 hours which is conservative because the peak flow would likely not be sustained for that period of time. **Figures 18 and 19** indicates that erosion occurring during a year in which the 100-year flow occurs does not vary significantly from a year of average flows. Differences in erosion between the average year and 100-year flows do not vary significantly and are generally within 0.5 foot.. Most importantly, the model indicates that the riffles will remain in place during the 100-year flow, indicating that the riprap size selected for riffle construction should be stable during this peak flow event.

6.0 COST ESTIMATE

Cost estimates were developed for the individual elements of the overall Plan. As the improvements presented herein are conceptual in nature, all costs should be considered budgetary level costs. More detailed costs can be developed as part of the final design for improvements as they occur. Costs contained in this Plan are based on 2011 prices. Estimates were generated from material costs, discussions with contractors, costs for completed river improvement projects and engineering judgment.

Unit construction costs (per linear foot, per ton, per each, etc.) were prepared for each specific Plan improvement. A table summarizing unit costs for each improvement type is shown on **Table 9**.

Table 9 – Project Cost Estimate

Item	Unit	Quantity	Unit Cost	Sub-Total
INSTREAM IMPROVEMENTS				**$1,843,300.00**
Channel Regrading	Cubic Yard	28400	$12.00	$340,800.00
Type M Riprap to Convert Drop Structures to Riffles (Supply & Stage)	Ton	2400	$25.00	$60,000.00
Type M Riprap for New Riffles (Supply & Stage)	Ton	7800	$25.00	$195,000.00
Construct New Riffle/Pool/Glide Sequences	Each	7	$38,000.00	$266,000.00
Construct Converted Drop Structures to Riffles	Each	4	$38,000.00	$152,000.00
Type M Riprap for Terrace Creation (Supply & Stage)	Ton	23300	$25.00	$582,500.00
Terrace Construction	Acre	8	$29,000.00	$232,000.00
Red Tail Lake Outlet Grade Control	Lump Sum	1	$15,000.00	$15,000.00
BANK STABILIZATION				**$338,315.00**
Type M Riprap for Bank Stabilization (Supply &	Ton	4600	$25.00	$115,000.00

Item	Unit	Quantity	Unit Cost	Sub-Total
Stage)				
Type A Bank Stabilization Grading and Riprap Placement	Linear Foot	2135	$26.00	$55,510.00
Type B Bank Stabilization Grading and Riprap Placement	Linear Foot	1820	$36.00	$65,520.00
Type A Bank Stabilization Revegetation	Linear Foot	2135	$7.00	$14,945.00
Type B Bank Stabilization Revegetation	Linear Foot	1820	$37.00	$67,340.00
Vegetation Weed Control and Irrigation	Lump Sum	1	$20,000.00	$20,000.00
RIPARIAN PLANTING ZONES				**$245,000.00**
Seeding, Shrubs and Trees	Acre	5	$31,000.00	$155,000.00
Staging and Access Reclamation	Lump Sum	1	$40,000.00	$40,000.00
Weed Control and Irrigation	Lump Sum	1	$50,000.00	$50,000.00
MISCELLANEOUS ITEMS				**$678,000.00**
Red Tail Lake Wetland Construction and Planting	Lump Sum	1	$40,000.00	$40,000.00
Material Removal, Grading and Spoil Site Reclamation*	Cubic Yard	44600	$5.00	$223,000.00
Construction BMPs	Lump Sum	1	$50,000.00	$50,000.00
Diversions and Water Control	Lump Sum	1	$350,000.00	$350,000.00
Red Tail and Spoils Area Weed Control and Irrigation	Lump Sum	1	$15,000.00	$15,000.00
CONSTRUCTION SUBTOTAL				**$3,104,615.00**
ASSOCIATED COSTS				**$1,117,000.00**
Final Design and Permitting (10% of construction subtotal)	Lump Sum	1	$302,000.00	$310,000.00
Construction Management (5% of construction subtotal)	Lump Sum	1	$151,000.00	$155,000.00
Construction Survey Control (1% of construction subtotal)	Lump Sum	1	$30,000.00	$31,000.00
Mob/Demob (5% of construction subtotal)	Lump Sum	1	$151,000.00	$155,000.00
Contingency (15% of construction subtotal)	Lump Sum	1	$453,000.00	$466,000.00
TOTAL				**$4,221,615.00**

Estimated costs assume that a volume of material equal to the amount of riprap imported for construction of the riffles and cobble bars will need to be exported to maintain the flood conveyance of the reach. It is assumed that a disposal site for this material can be located within SPP, reducing haulage and disposal costs. Costs for weed control and irrigation of riparian areas and vegetation planted as part of the bank stabilization was included in the cost estimate.

The total estimated cost for implementing all aspects of the Proposed Enhancement Plan is $4,221,615. This cost includes a 15% contingency as well as 21% for minor items including final design/permitting, construction management, survey control and mobilization/demobilization. Subtracting out the contingency and these minor costs, the total construction subtotal is estimated to be $3,104,615.

It is worth noting that diversions and water control account for a significant portion of the overall cost of the project given the need to implement the enhancement strategies using means that will minimize downstream turbidity. It is anticipated that phasing and timing of planned work to coincide with work schedules that minimize the water control requirements of this project will be important to the overall project budget.

Given the high cost of the overall plan it is anticipated that the enhancement plan will not be undertaken all at once but rather implemented in phases as money becomes available. At this point in time it is unknown what portions of the project would be completed at different times, so it is not possible to break the overall cost into phases. To help in planning, however, the approximate costs for each of the major project elements have been estimated. These costs are based on an average of the overall project cost estimate. Note that none of these costs include the 15% contingency or the 21% for minor items or any allowances for construction BMPs or diversion and water control, which will all need to be considered as part of the overall costs.

Channel Shaping: $115 per linear foot
This includes regrade channel to appropriate width and construct adjacent terraces, including necessary riprap import and excess material removal.

Convert Existing Drop Structure to a Riffle: $75,000 per riffle
This includes the import of rock required for the structure, construction of the riffle, excess material removal and the associated channel shaping and terrace creation along the length of the riffle.

Create New Riffle: $100,000 per riffle
This includes the import of rock required for the structure, construction of the riffle and the associated channel shaping and terrace creation along the length of the riffle.

Type A Bank Stabilization: $62 per linear foot
This includes the import of rock required for stabilization, bank grading and riparian planting along the top of the stabilized slope section.

Type B Bank Stabilization: $91 per linear foot
This includes the import of rock required for stabilization, bank grading and riparian planting along the top of the stabilized slope section and regrading and revegetation of the upper slope area.

Riparian Zone Planting: $31,000 per acre
This includes all herbicides, ground preparation, soil amendments, seeding, mulch and tree plantings.

7.0 REFERENCES

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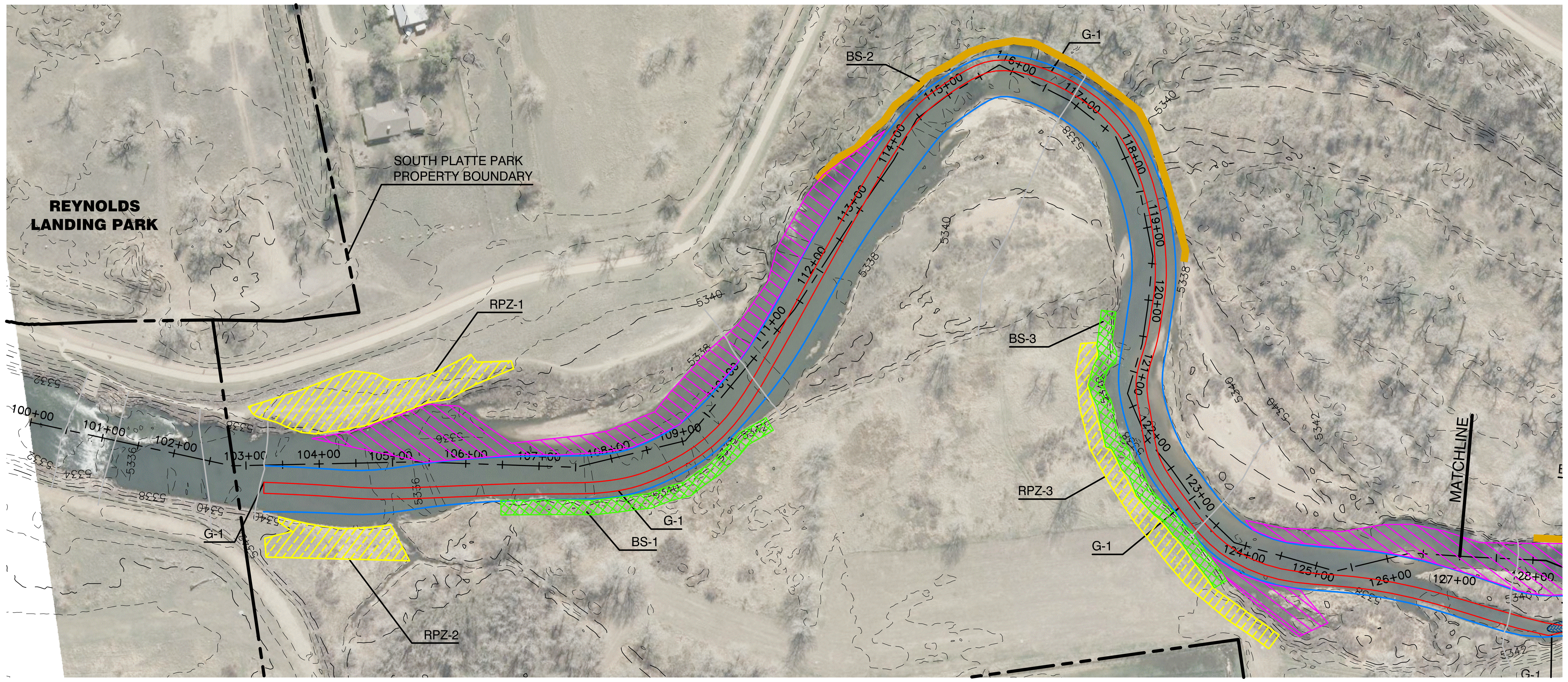
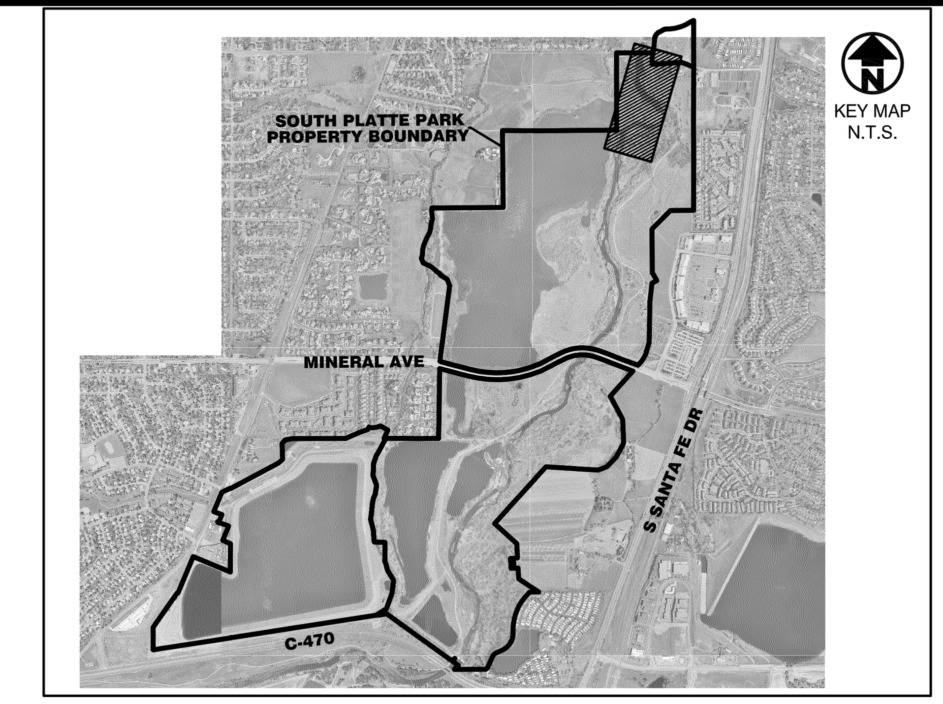
APPENDIX A
Proposed Enhancement Plans





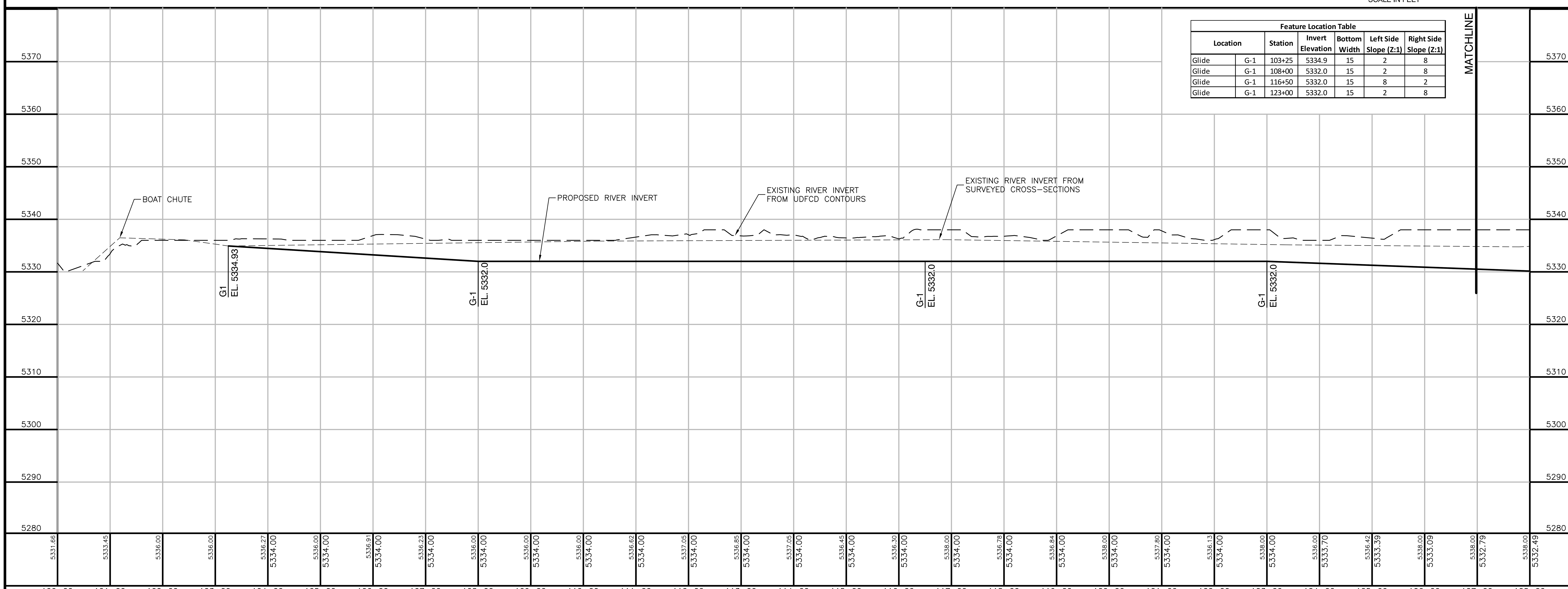
LEGEND

- SOUTH PLATTE PARK PROPERTY BOUNDARY
- SURVEYED CROSS-SECTION LOCATION
- TYPICAL BANKFULL WIDTH
- THALWEG LOCATION
- TYPE A BANK STABILIZATION
- TYPE B BANK STABILIZATION
- CONSTRUCTED POINT BAR
- RIPARIAN PLANTING ZONES
- POOL
- RIFFLE

100 50 0 100 200 300

SCALE IN FEET

Feature Location Table						
Location		Station	Invert Elevation	Bottom Width	Left Side Slope (Z:1)	Right Side Slope (Z:1)
Glide	G-1	103+25	5334.9	15	2	8
Glide	G-1	108+00	5332.0	15	2	8
Glide	G-1	116+50	5332.0	15	8	2
Glide	G-1	123+00	5332.0	15	2	8



South Platte Park
South Platte River Proposed Enhancement Plan

Plan & Profile

Sta: 100+00 to 127+00

Ecological Resource Consultants, Inc.
25715 US Hwy 40
Evergreen, CO 80439
303-679-4820
www.ercolorado.net

REVISIONS				
No	Date	By	Chk	Description

DRAFTING BY:
J&T Consulting, Inc.

Job #	825-111
Date	11/04/11
Drawn By	WSS
Designed By	TSS
Checked By	TT/TB
File	JT-South platte profile
Scale	1" = 100'h/10'v

Sheet: 1 Of: 10

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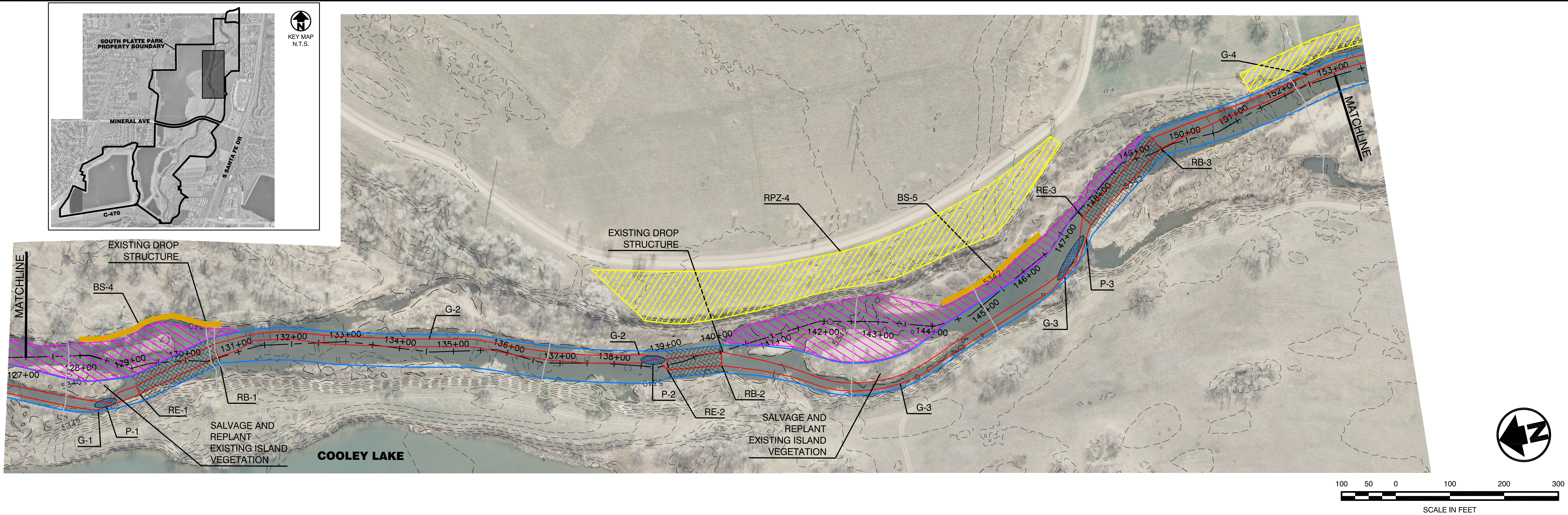

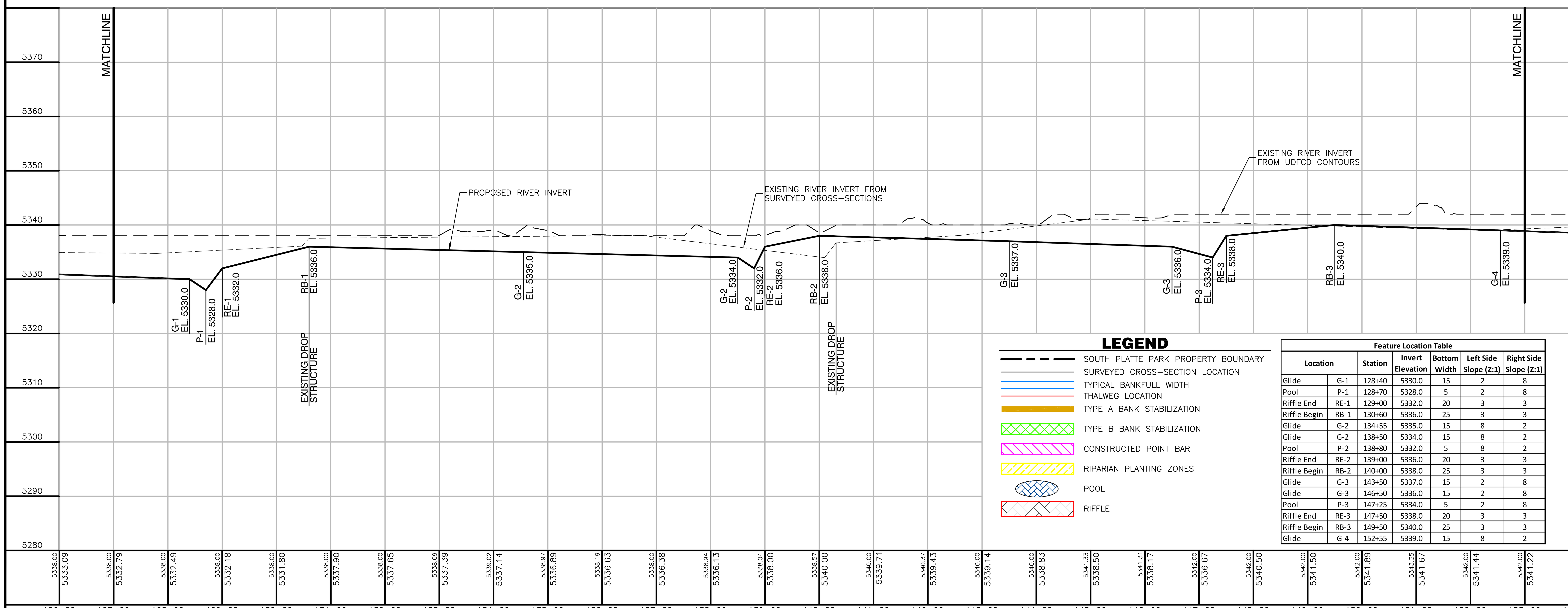

LEGEND

- SOUTH PLATTE PARK PROPERTY BOUNDARY
- SURVEYED CROSS-SECTION LOCATION
- TYPICAL BANKFULL WIDTH
- THALWEG LOCATION
- TYPE A BANK STABILIZATION
- TYPE B BANK STABILIZATION
- CONSTRUCTED POINT BAR
- RIPARIAN PLANTING ZONES
- POOL
- RIFFLE

Feature Location Table

Location		Station	Invert Elevation	Bottom Width	Left Side Slope (Z:1)	Right Side Slope (Z:1)
Glide	G-1	128+40	5330.0	15	2	8
Pool	P-1	128+70	5328.0	5	2	8
Riffle End	RE-1	129+00	5332.0	20	3	3
Riffle Begin	RB-1	130+60	5336.0	25	3	3
Glide	G-2	134+55	5335.0	15	8	2
Glide	G-2	138+50	5334.0	15	8	2
Pool	P-2	138+80	5332.0	5	8	2
Riffle End	RE-2	139+00	5336.0	20	3	3
Riffle Begin	RB-2	140+00	5338.0	25	3	3
Glide	G-3	143+50	5337.0	15	2	8
Glide	G-3	146+50	5336.0	15	2	8
Pool	P-3	147+25	5334.0	5	2	8
Riffle End	RE-3	147+50	5338.0	20	3	3
Riffle Begin	RB-3	149+50	5340.0	25	3	3
Glide	G-4	152+55	5339.0	15	8	2

South Platte Park
South Platte River Proposed Enhancement Plan

Plan & Profile
Sta: 127+00 to 153+00

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Date	11/04/11
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Designed By	TSS
Checked By	TT/TB
File	JT-South platte profile
Scale	1" = 100'h/10'v

Sheet: 2 Of: 10

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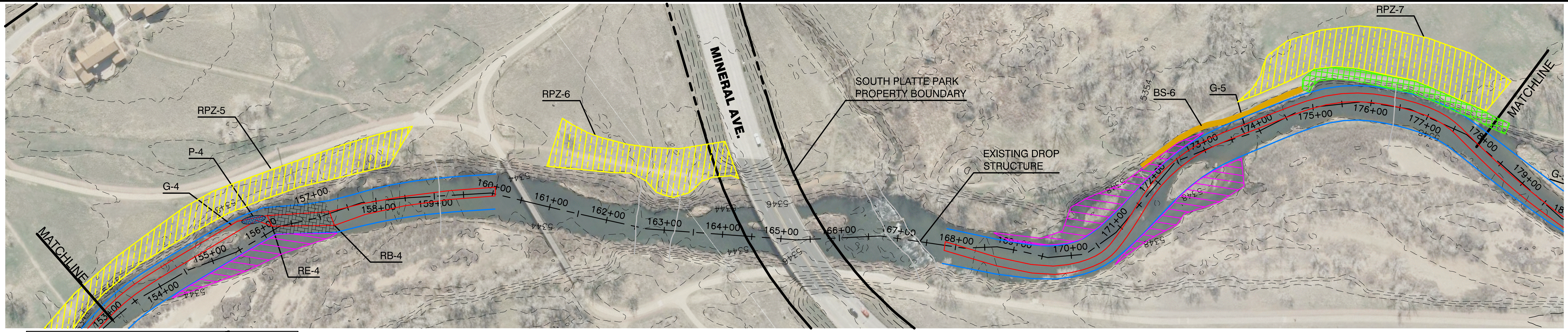
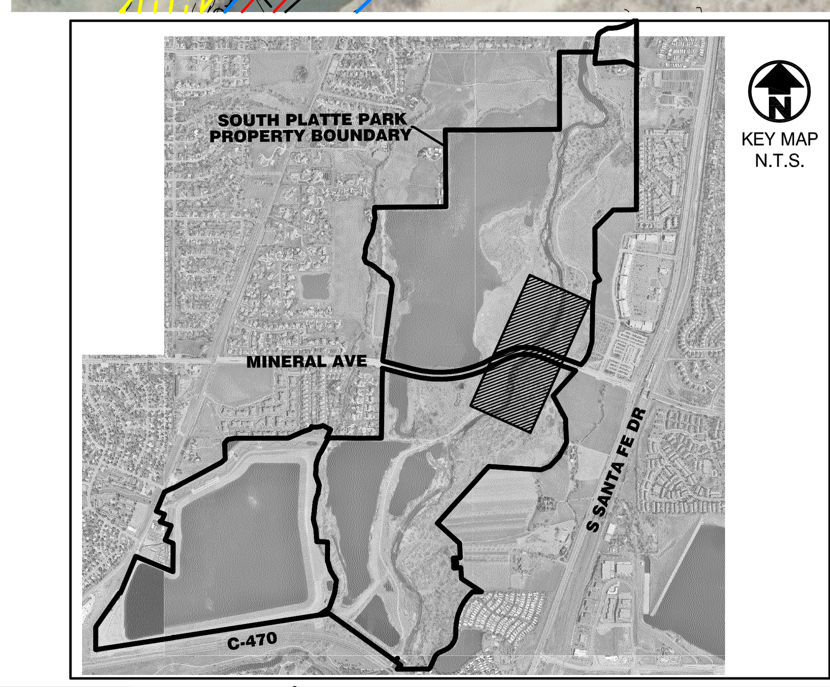


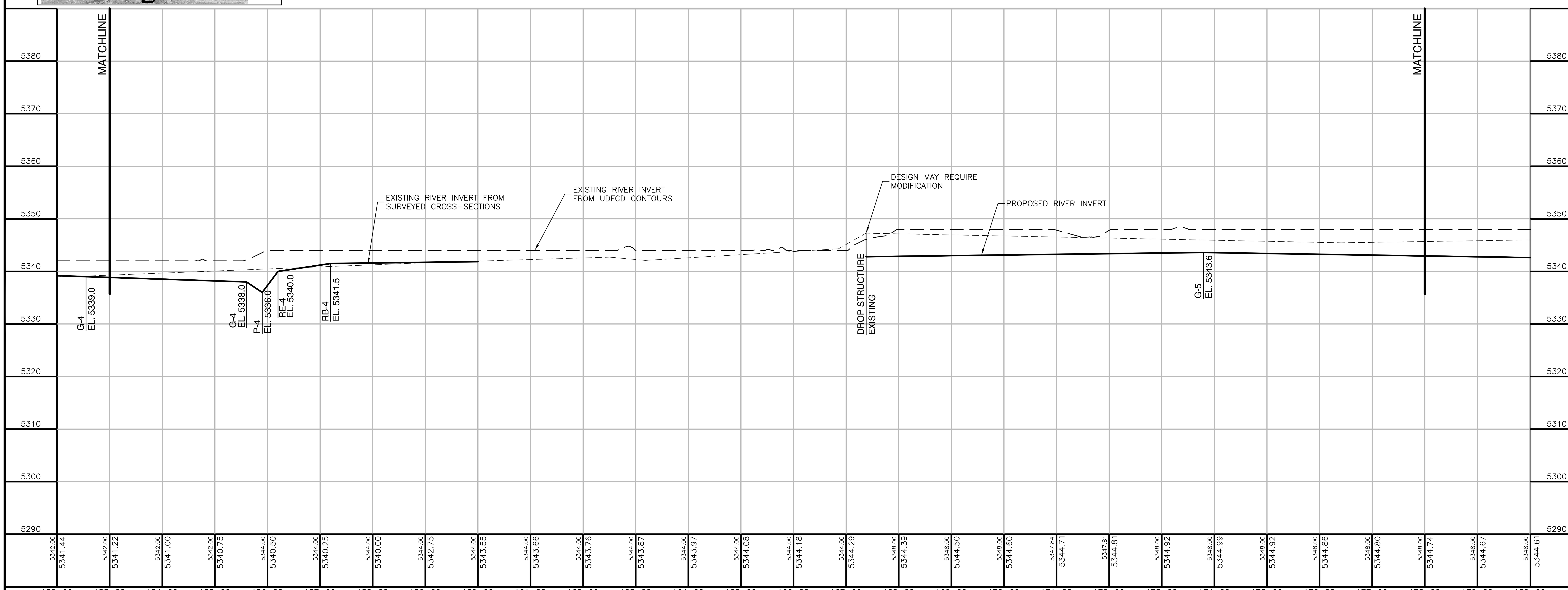


LEGEND

- SOUTH PLATTE PARK PROPERTY BOUNDARY
- SURVEYED CROSS–SECTION LOCATION
- TYPICAL BANKFULL WIDTH
- THALWEG LOCATION
- TYPE A BANK STABILIZATION
- TYPE B BANK STABILIZATION
- CONSTRUCTED POINT BAR
- RIPARIAN PLANTING ZONES
- POOL
- RIFFLE

Feature Location Table						
Location		Station	Invert Elevation	Bottom Width	Left Side Slope (Z:1)	Right Side Slope (Z:1)
Glide	G-4	155+60	5338.0	15	8	2
Pool	P-4	155+90	5336.0	5	8	2
Riffle End	RE-4	156+20	5340.0	20	3	3
Riffle Begin	RB-4	157+20	5341.5	25	3	3
Glide	G-5	173+79	5343.6	15	2	8

100 50 0 100 200 300
SCALE IN FEET



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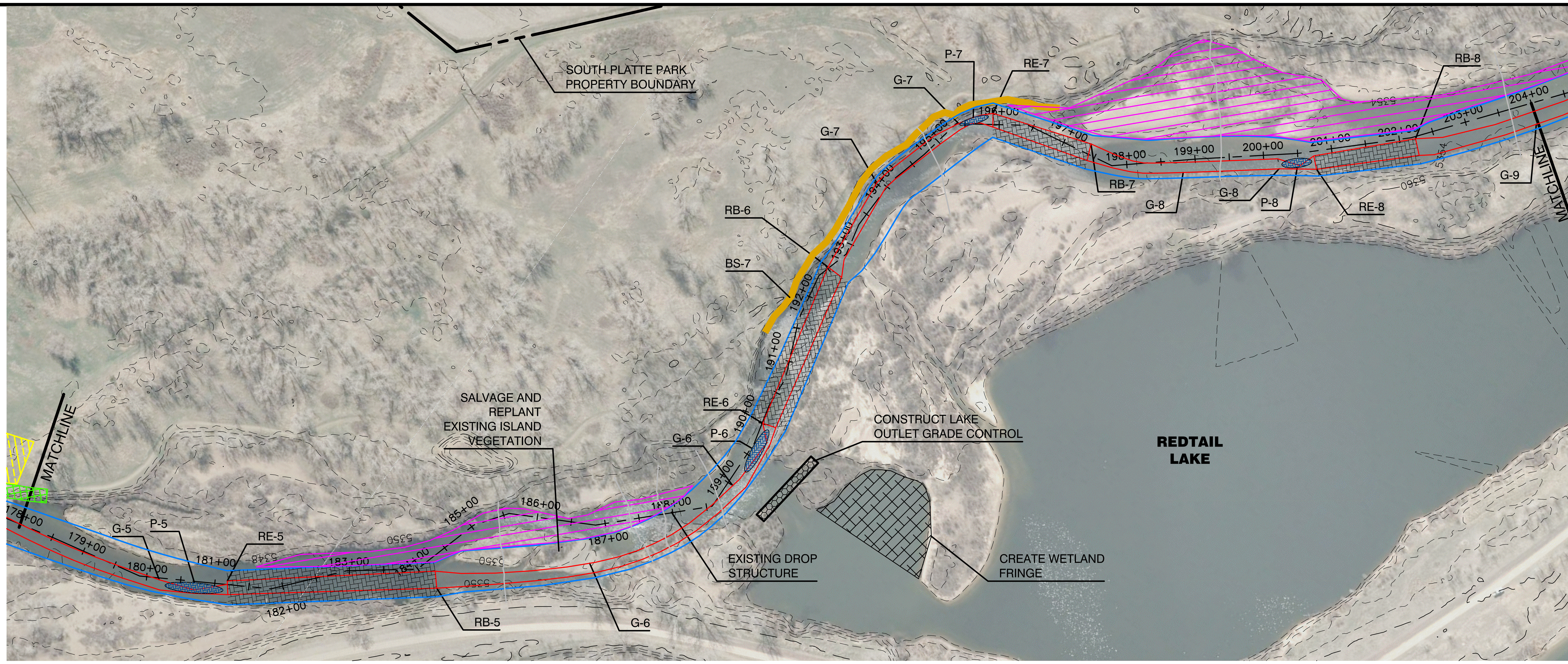
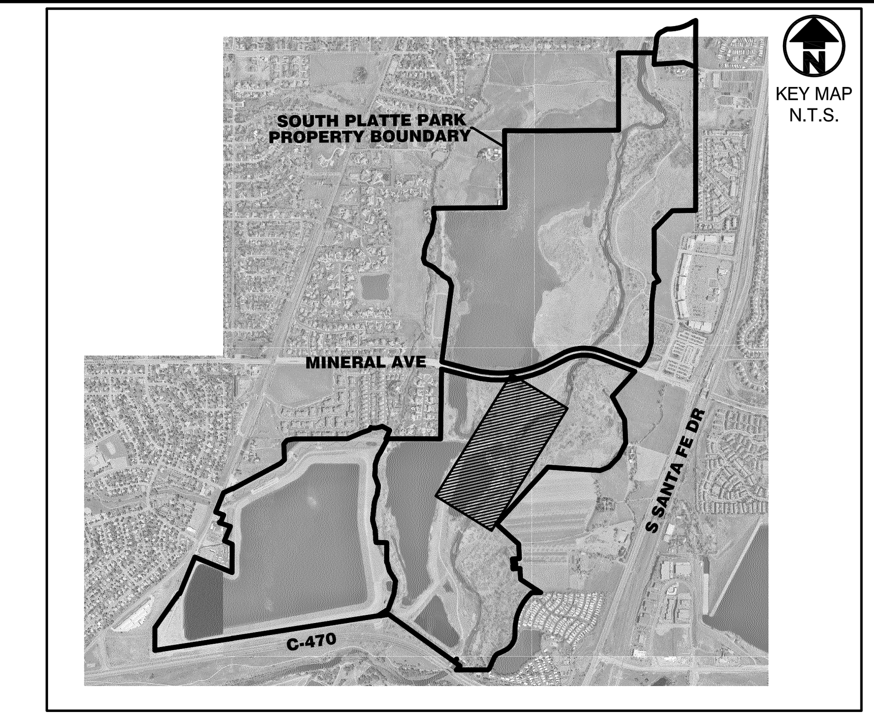
File	JT-South platte profile
Scale	1" = 100'h/10'v

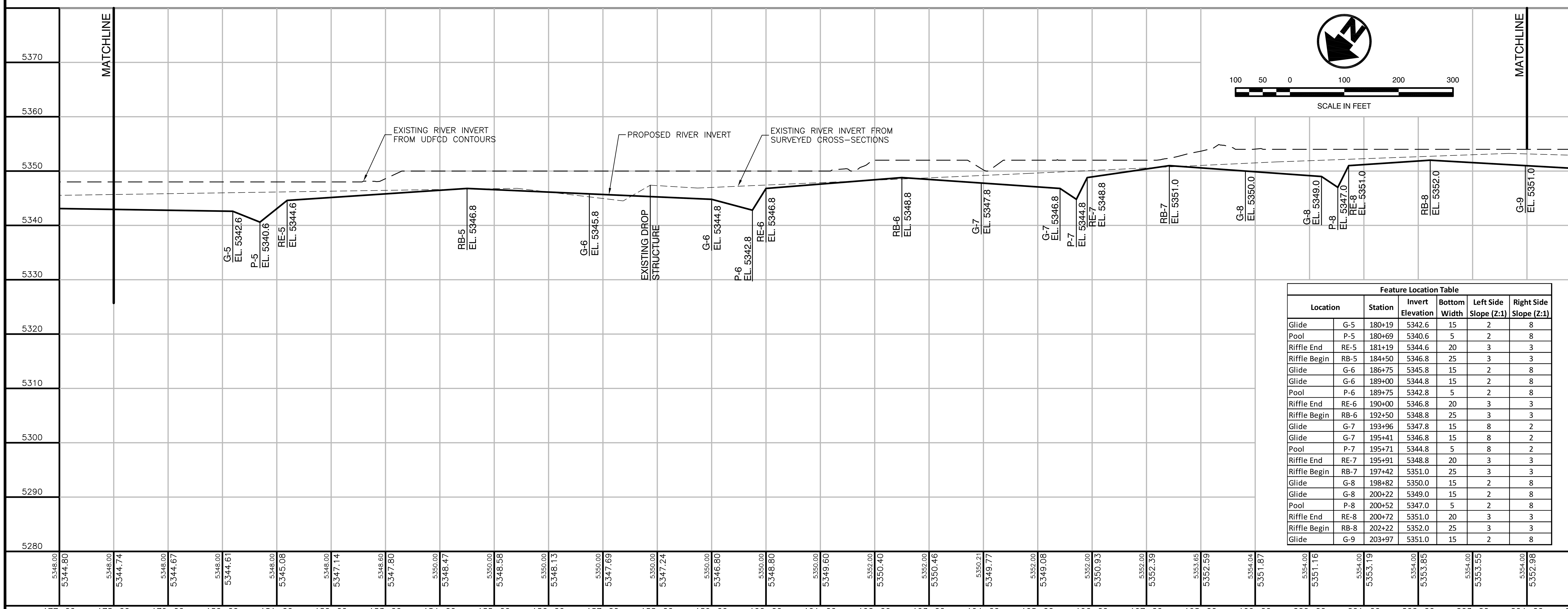
Sheet: 3 Of: 10





LEGEND

- SOUTH PLATTE PARK PROPERTY BOUNDARY
- SURVEYED CROSS–SECTION LOCATION
- TYPICAL BANKFULL WIDTH
- THALWEG LOCATION
- TYPE A BANK STABILIZATION
- TYPE B BANK STABILIZATION
- CONSTRUCTED POINT BAR
- RIPARIAN PLANTING ZONES
- POOL
- RIFFLE
- WETLAND FRINGE
- OUTLET GRADE CONTROL



Feature Location Table

Location		Station	Invert Elevation	Bottom Width	Left Side Slope (Z:1)	Right Side Slope (Z:1)
Glide	G-5	180+19	5342.6	15	2	8
Pool	P-5	180+69	5340.6	5	2	8
Riffle End	RE-5	181+19	5344.6	20	3	3
Riffle Begin	RB-5	184+50	5346.8	25	3	3
Glide	G-6	186+75	5345.8	15	2	8
Glide	G-6	189+00	5344.8	15	2	8
Pool	P-6	189+75	5342.8	5	2	8
Riffle End	RE-6	190+00	5346.8	20	3	3
Riffle Begin	RB-6	192+50	5348.8	25	3	3
Glide	G-7	193+96	5347.8	15	8	2
Glide	G-7	195+41	5346.8	15	8	2
Pool	P-7	195+71	5344.8	5	8	2
Riffle End	RE-7	195+91	5348.8	20	3	3
Riffle Begin	RB-7	197+42	5351.0	25	3	3
Glide	G-8	198+82	5350.0	15	2	8
Glide	G-8	200+22	5349.0	15	2	8
Pool	P-8	200+52	5347.0	5	2	8
Riffle End	RE-8	200+72	5351.0	20	3	3
Riffle Begin	RB-8	202+22	5352.0	25	3	3
Glide	G-9	203+97	5351.0	15	2	8

South Platte Park
South Platte River Proposed Enhancement Plan

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Job #	825-111
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Scale	1" = 100'h/10'v

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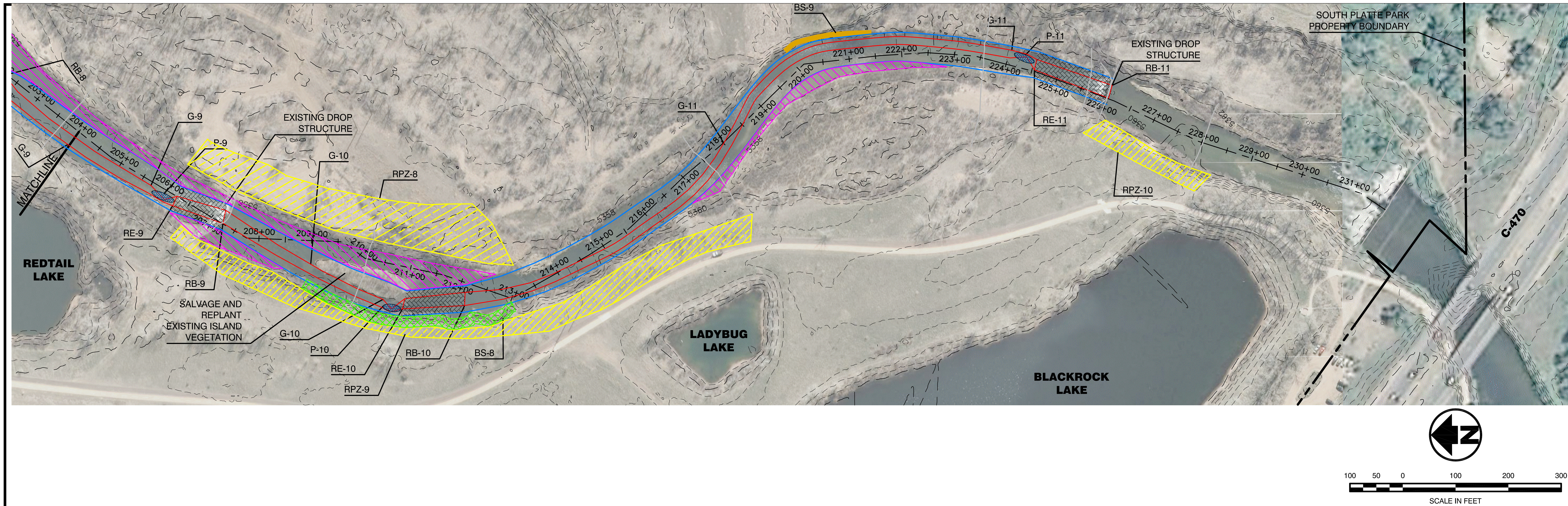
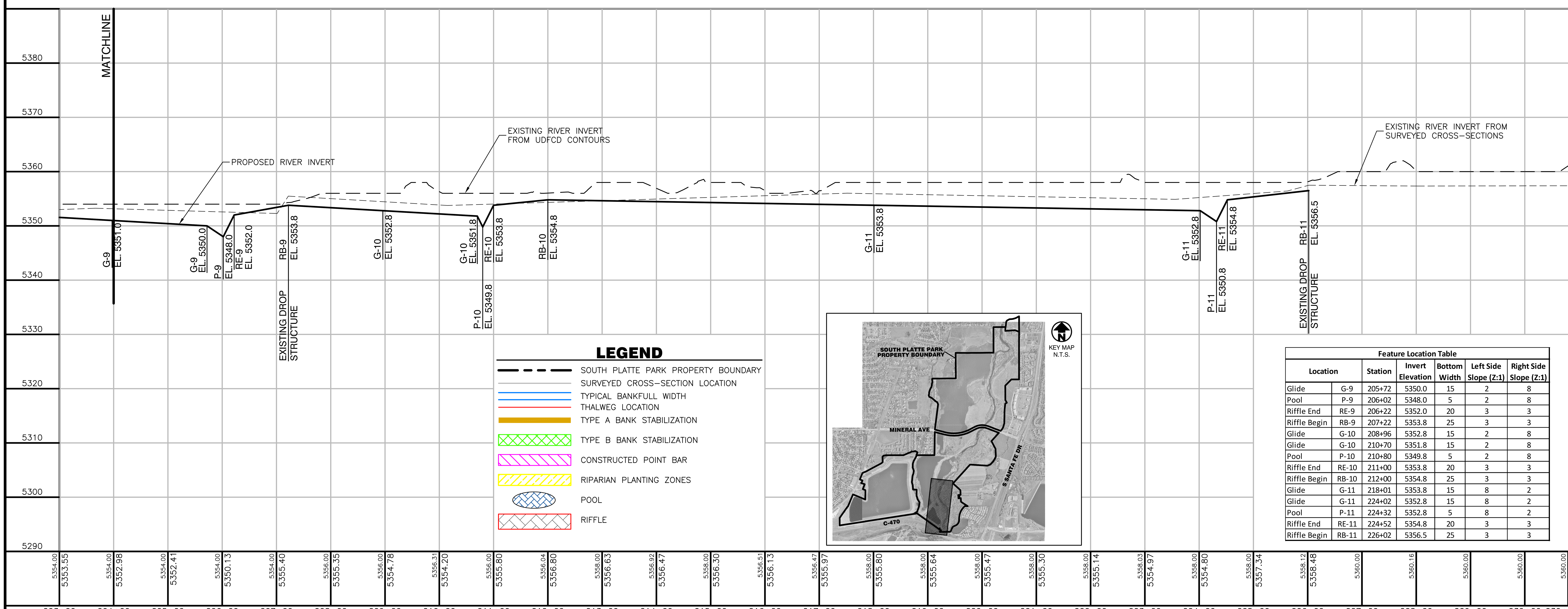
South Platte Park
South Platte River Proposed Enhancement Plan

Plan & Profile
Sta: 204+00 to 226+00





Feature Location Table						
Location		Station	Invert Elevation	Bottom Width	Left Side Slope (Z:1)	Right Side Slope (Z:1)
Glide	G-9	205+72	5350.0	15	2	8
Pool	P-9	206+02	5348.0	5	2	8
Riffle End	RE-9	206+22	5352.0	20	3	3
Riffle Begin	RB-9	207+22	5353.8	25	3	3
Glide	G-10	208+96	5352.8	15	2	8
Glide	G-10	210+70	5351.8	15	2	8
Pool	P-10	210+80	5349.8	5	2	8
Riffle End	RE-10	211+00	5353.8	20	3	3
Riffle Begin	RB-10	212+00	5354.8	25	3	3
Glide	G-11	218+01	5353.8	15	8	2
Glide	G-11	224+02	5352.8	15	8	2
Pool	P-11	224+32	5352.8	5	8	2
Riffle End	RE-11	224+52	5354.8	20	3	3
Riffle Begin	RB-11	226+02	5356.5	25	3	3

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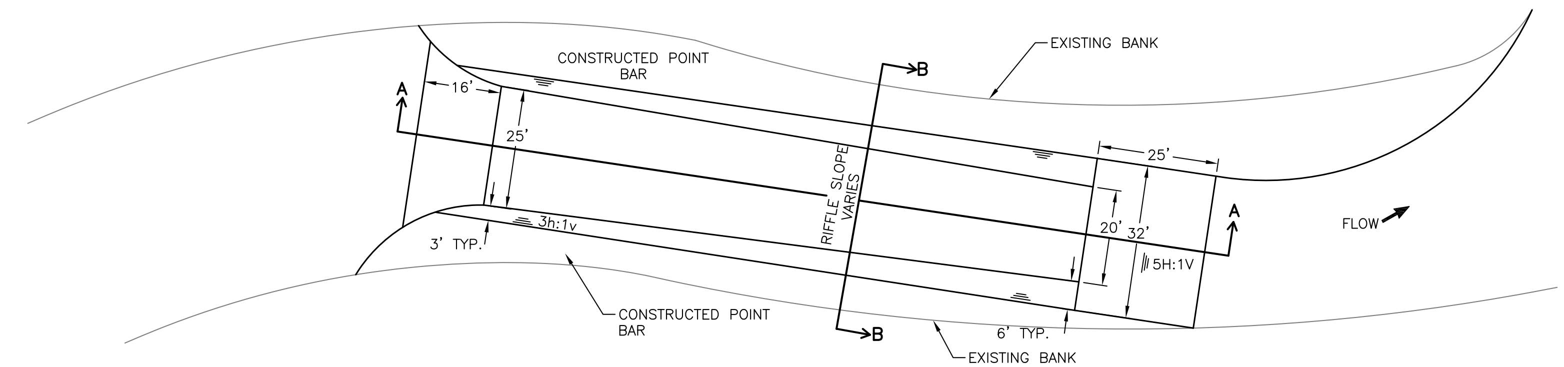
Scale	1" = 100'h/10'v



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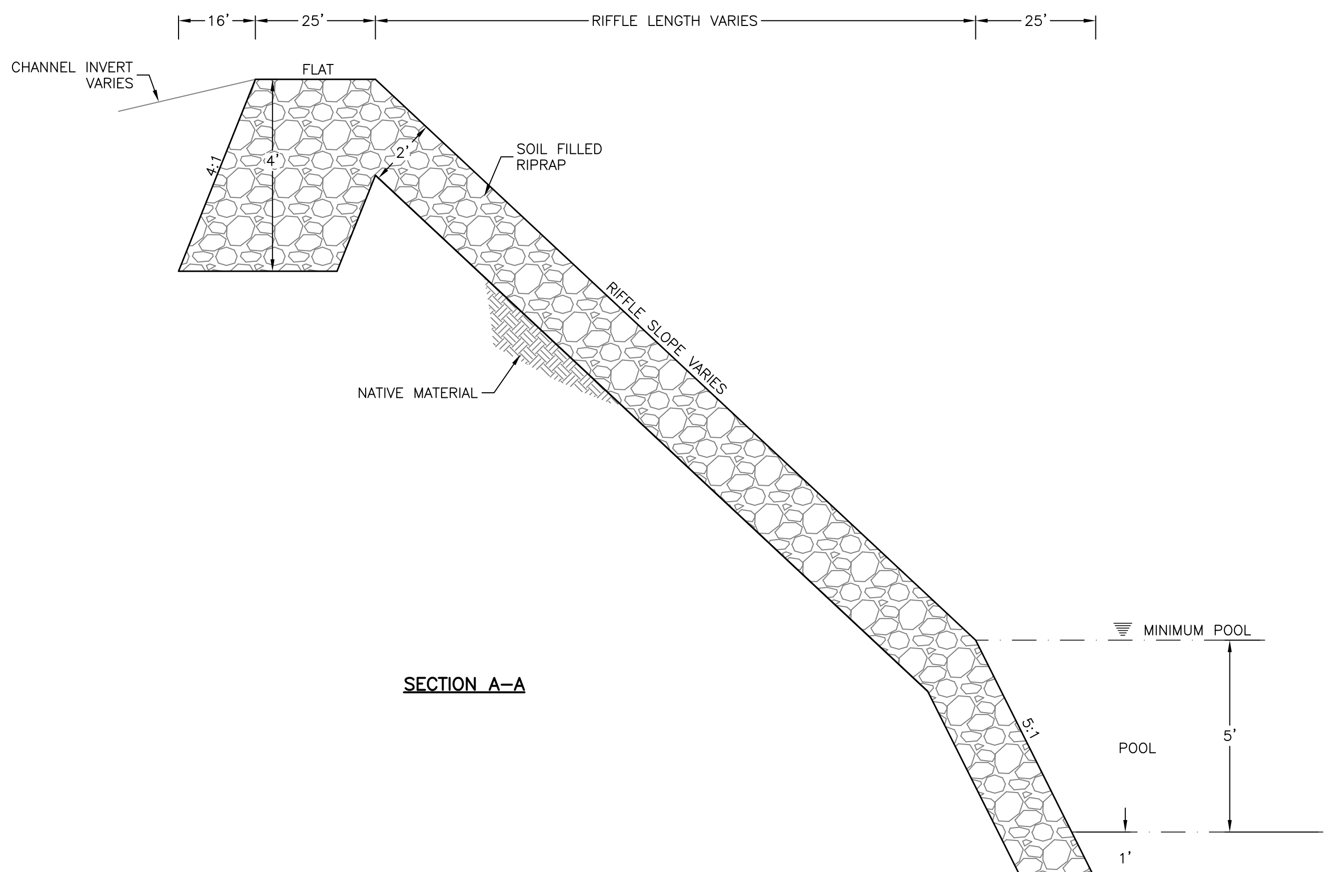

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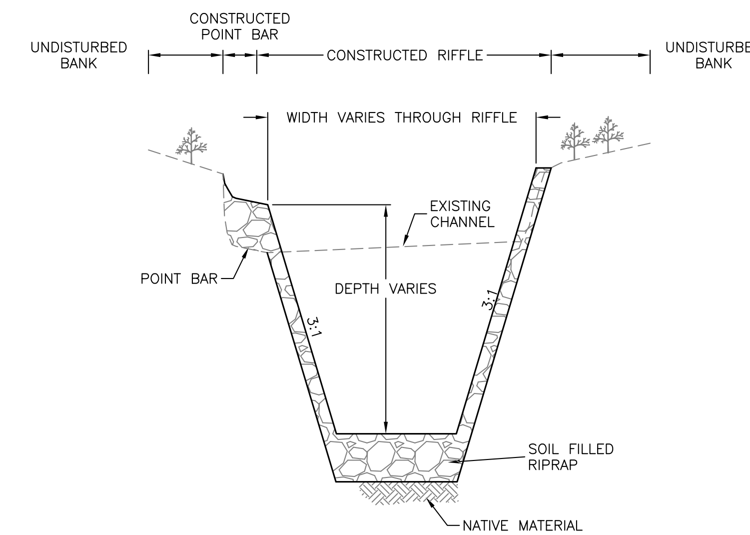

SECTION B–B

RIFFLE DETAIL

SCALE 1" = 20'h/2'v

NOTES:

1. RIFFLE SLOPE WILL VARY FROM 0.7 TO 1.5 PERCENT.
2. RIFFLE LENGTH WILL VARY FROM 100 TO 330 FEET.
3. SOIL FILLED RIPRAP SHOULD CONSIST OF A MIXTURE OF UDFCD TYPE M RIPRAP AND NATIVE SOIL.

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Riffle Details

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File	JT-Riffle and pool
Scale	1" = 20'

Sheet: 6 Of: 10

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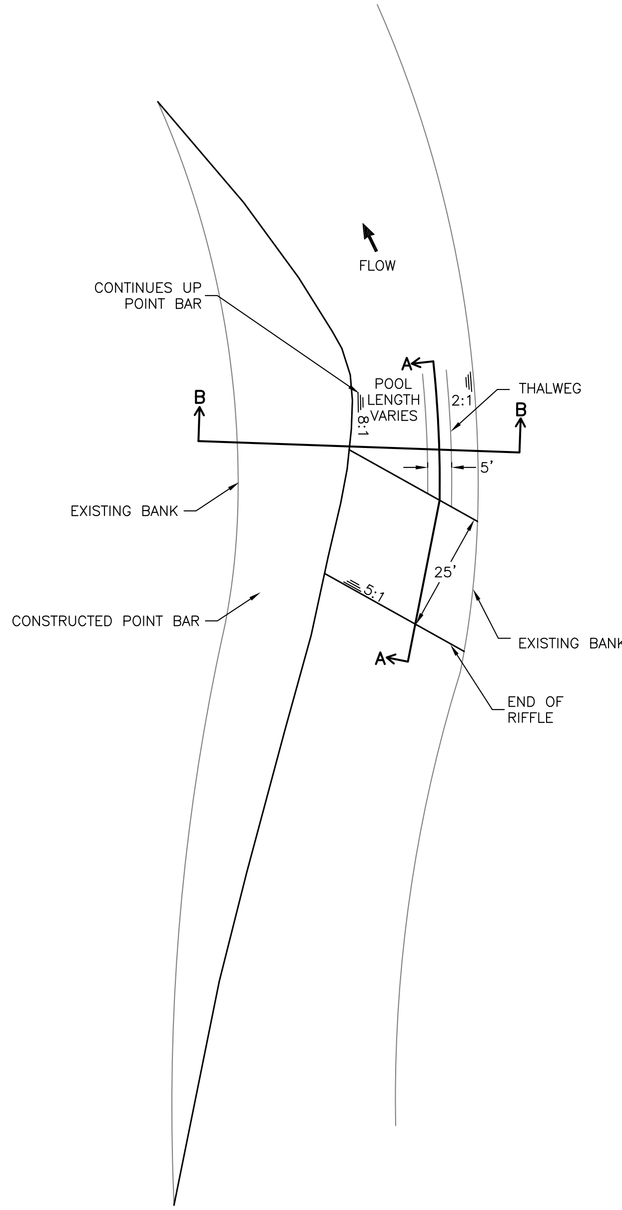

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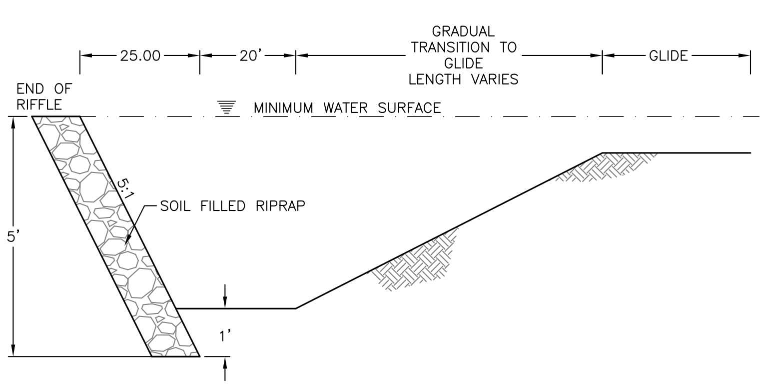

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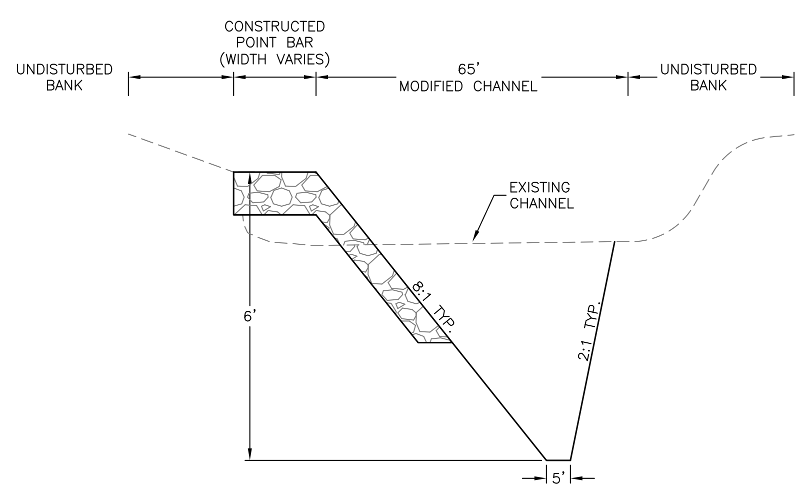
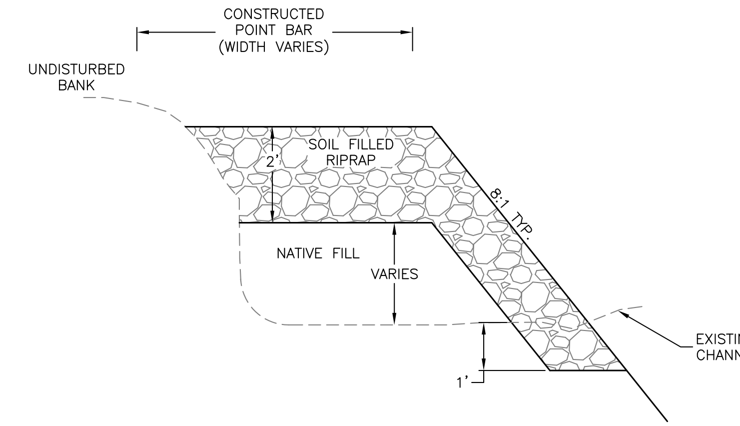


SECTION B–B

POOL DETAIL

SCALE 1" = 20'h/2'v



CONSTRUCTED POINT BAR DETAIL

SCALE 1" = 20'h/2'v

NOTES:

1. MINIMUM CONSTRUCTED POOL DEPTH IS 4 FEET.
2. DIMENSIONS OF COBBLE TERRACES WILL VARY WITH EXISTING CHANNEL GEOMETRY.
3. BANK SIDE OF CONSTRUCTED POINT BAR SHOULD TIE INTO EXISTING BANK BELOW EXISTING AND DESIGN BANKFULL ELEVATION.
4. CONSTRUCTED POINT BARS SHOULD HAVE MINIMUM 5 PERCENT SLOPE TOWARDS CHANNEL.
5. SOIL FILLED RIPRAP SHOULD CONSIST OF A MIXTURE OF UDFCD TYPE M RIPRAP AND NATIVE SOIL.

South Platte Park
South Platte River Proposed Enhancement Plan

Pool and Constructed Point Bar Details

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File	JT-Riffle and pool
Scale	1" = 20'

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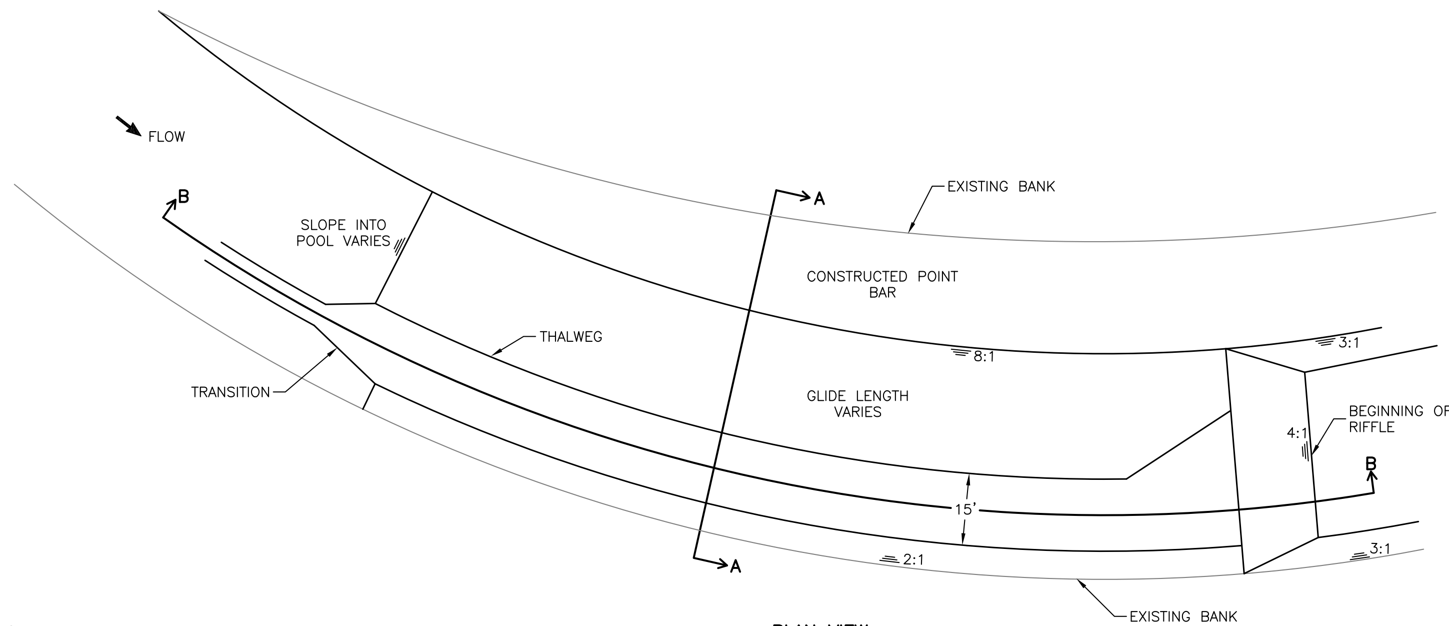

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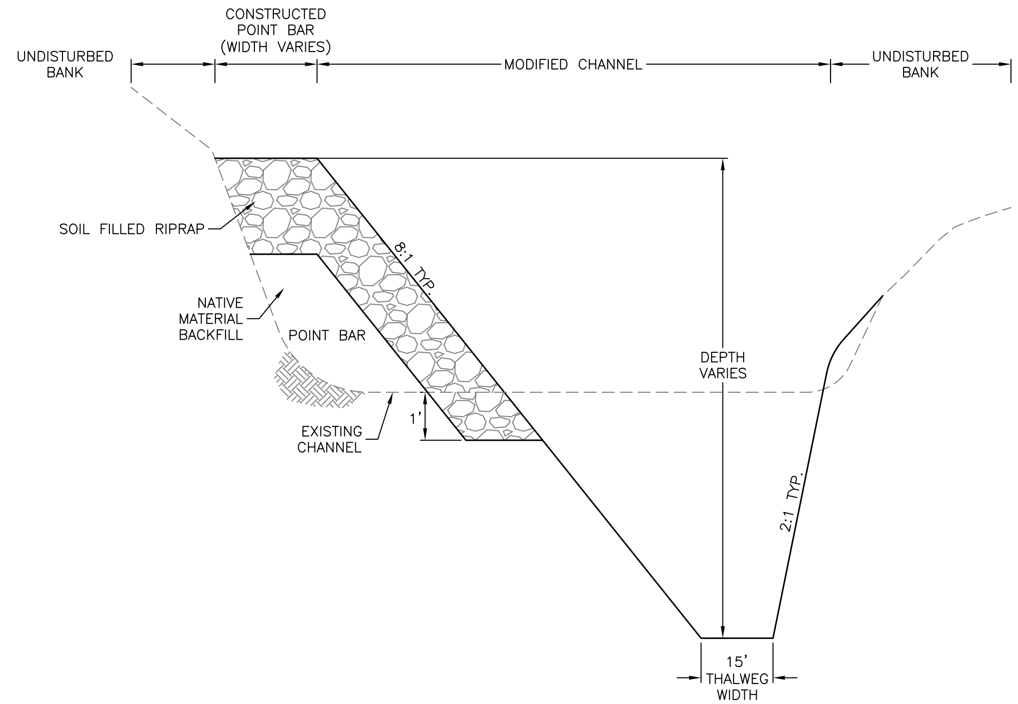

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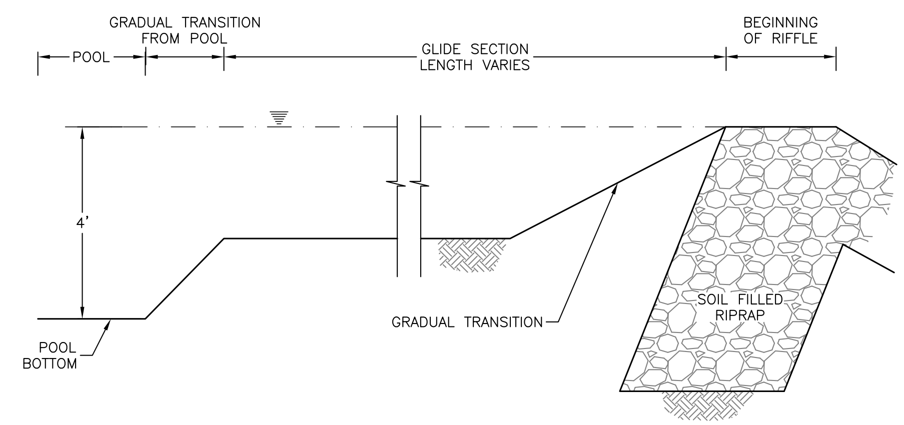

SECTION B–B (THALWEG)

GLIDE DETAIL

SCALE 1" = 20'h/2'v

NOTE:

1. GLIDE WIDTH AND DEPTH WILL VARY WITH EXISTING GEOMETRY.
2. SOIL FILLED RIPRAP SHOULD CONSIST OF A MIXTURE OF UDFCD TYPE M RIPRAP AND NATIVE SOIL.

South Platte Park
South Platte River Proposed Enhancement Plan

Glide Details

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File	JT-details
Scale	1" = 20'

Sheet: 8 Of: 10

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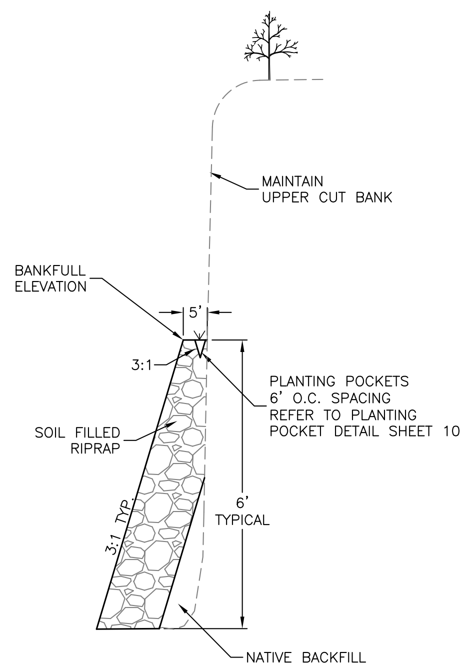
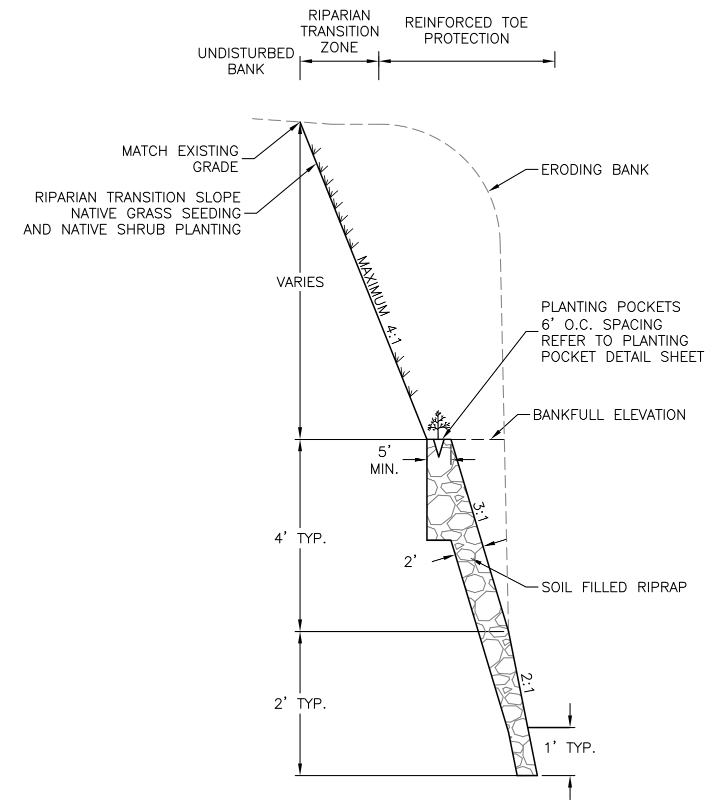


TYPE A BANK STABILIZATION DETAIL
SCALE 1" = 20'h/2'v



TYPE B BANK STABILIZATION DETAIL
SCALE 1" = 20'h/2'v

NOTE:

1. TOP OF BANK STABILIZATION SHOULD BE SET AT DESIGN BANKFULL ELEVATION.
2. SOIL FILLED RIPRAP SHOULD CONSIST OF A MIXTURE OF UDFCD TYPE M RIPRAP AND NATIVE SOIL.

South Platte Park
South Platte River Proposed Enhancement Plan

Type A and B Bank Stabilization Details

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Scale	1" = 20'

Sheet: 9 Of: 10

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APPENDIX B
Manning's n Calculations

825-111 SPP Calibrated Riffle Manning's Values
Manning's n-value Evaluation
9/28/2011

$n=AS^bR^c$
A=0.393
b=0.38
c=-0.16
S=Slope
R =Hydraulic Radius

Riffle Manning's N = 0.045

Feature		Station	WS (18 cfs)	Depth	Hydraulic Radius (ft)	Riffle Slope (ft/ft)	Manning N	Avg N per riffle
Riffle End	RE1	13011	5336.41	2.41	1.39	0.0612	0.12898575	
Riffle Mid	RM1	13036	5336.4	0.87	0.78	0.0612	0.14147802	0.146
Riffle Begin	RB1	13060	5337.27	0.27	0.26	0.0612	0.16866632	
Riffle End	RE2	13900	5337.77	0.77	0.69	0.0200	0.09431225	
Riffle Mid	RM2	13950	5338.4	0.40	0.38	0.0200	0.10375728	0.101
Riffle Begin	RB2	14000	5339.36	0.36	0.34	0.0200	0.10562028	
Riffle End	RE3	14800	5339.74	0.74	0.66	0.0050	0.05608854	
Riffle Mid	RM3	14900	5340.08	0.58	0.54	0.0050	0.05791861	0.058
Riffle Begin	RB3	15000	5340.53	0.53	0.5	0.0050	0.05863622	
Riffle End	RE4	15850	5340.7	0.70	0.63	0.0150	0.08578527	
Riffle Mid	RM4	15900	5341.16	0.41	0.38	0.0150	0.09301261	0.091
Riffle Begin	RB4	15950	5341.88	0.38	0.36	0.0150	0.09382073	
Riffle End	RE5	18119	5347.31	0.71	0.64	0.0066	0.06280435	
Riffle Mid	RM5	18285	5348.21	0.51	0.48	0.0066	0.06576275	0.065
Riffle Begin	RB5	18450	5349.28	0.48	0.45	0.0066	0.06644534	
Riffle End	RE6	19000	5349.40	0.60	0.55	0.0080	0.06904126	
Riffle Mid	RM6	19125	5350.28	0.48	0.45	0.0080	0.07129396	0.071
Riffle Begin	RB6	19250	5351.26	0.46	0.43	0.0080	0.07181444	
Riffle End	RE7	19591	5351.42	0.62	0.57	0.0113	0.07816493	
Riffle Mid	RM7	19667	5352.10	0.44	0.42	0.0113	0.08207899	0.081
Riffle Begin	RB7	19742	5352.92	0.42	0.39	0.0113	0.08305802	
Riffle End	RE8	20072	5353.10	0.60	0.55	0.0067	0.06441987	
Riffle Mid	RM8	20147	5353.52	0.52	0.48	0.0067	0.0658384	0.066
Riffle Begin	RB8	20222	5353.99	0.49	0.46	0.0067	0.06628826	
Riffle End	RE9	20622	5354.15	0.65	0.59	0.0180	0.09290943	
Riffle Mid	RM9	20672	5354.81	0.41	0.39	0.0180	0.09927177	0.098
Riffle Begin	RB9	20722	5355.66	0.36	0.35	0.0180	0.10100554	
Riffle End	RE10	21100	5355.92	0.62	0.57	0.0150	0.08717004	
Riffle Mid	RM10	21150	5356.46	0.41	0.38	0.0150	0.09301261	0.091
Riffle Begin	RB10	21200	5357.18	0.38	0.36	0.0150	0.09382073	
Riffle End	RE11	22452	5357.66	0.86	0.77	0.0113	0.07468097	
Riffle Mid	RM11	22527	5358.09	0.44	0.42	0.0113	0.0822865	0.080
Riffle Begin	RB11	22602	5358.92	0.42	0.39	0.0113	0.083268	

Iteration 1

Feature		Station	WS (18 cfs)	Depth	Hydraulic Radius (ft)	Riffle Slope (ft/ft)	Manning N	Avg N per riffle
Riffle End	RE1	13011	5336.41	2.41	1.39	0.0612	0.12898575	
Riffle Mid	RM1	13036	5336.42	0.89	0.79	0.0612	0.14118995	0.146
Riffle Begin	RB1	13060	5337.27	0.27	0.26	0.0612	0.16866632	
Riffle End	RE2	13900	5338.24	1.24	1.06	0.0200	0.08805115	
Riffle Mid	RM2	13950	5338.6	0.60	0.55	0.0200	0.09779709	0.095
Riffle Begin	RB2	14000	5339.56	0.56	0.53	0.0200	0.09837841	
Riffle End	RE3	14800	5340.03	1.03	0.9	0.0050	0.05337309	
Riffle Mid	RM3	14900	5340.24	0.74	0.67	0.0050	0.05595375	0.056
Riffle Begin	RB3	15000	5340.63	0.63	0.58	0.0050	0.05726018	
Riffle End	RE4	15850	5340.8	0.80	0.71	0.0150	0.08416003	
Riffle Mid	RM4	15900	5341.37	0.62	0.57	0.0150	0.08717004	0.086
Riffle Begin	RB4	15950	5342.08	0.58	0.54	0.0150	0.0879274	
Riffle End	RE5	18119	5347.31	0.71	0.64	0.0066	0.06280435	
Riffle Mid	RM5	18285	5348.34	0.64	0.59	0.0066	0.06362711	0.064
Riffle Begin	RB5	18450	5349.40	0.60	0.56	0.0066	0.0641606	
Riffle End	RE6	19000	5349.53	0.73	0.66	0.0080	0.06705632	
Riffle Mid	RM6	19125	5350.44	0.64	0.59	0.0080	0.06827008	0.068
Riffle Begin	RB6	19250	5351.40	0.60	0.56	0.0080	0.0688425	
Riffle End	RE7	19591	5351.57	0.77	0.69	0.0113	0.07581167	
Riffle Mid	RM7	19667	5352.28	0.62	0.57	0.0113	0.07816493	0.078
Riffle Begin	RB7	19742	5353.09	0.59	0.55	0.0113	0.07861291	
Riffle End	RE8	20072	5353.29	0.79	0.7	0.0067	0.06198151	
Riffle Mid	RM8	20147	5353.66	0.66	0.61	0.0067	0.06336145	0.063
Riffle Begin	RB8	20222	5354.11	0.61	0.57	0.0067	0.06405277	
Riffle End	RE9	20622	5354.27	0.77	0.69	0.0180	0.09061086	
Riffle Mid	RM9	20672	5355.01	0.61	0.56	0.0180	0.09368844	0.093
Riffle Begin	RB9	20722	5355.87	0.57	0.53	0.0180	0.09451744	
Riffle End	RE10	21100	5356.17	0.87	0.77	0.0150	0.08307469	
Riffle Mid	RM10	21150	5356.66	0.61	0.57	0.0150	0.08717004	0.086
Riffle Begin	RB10	21200	5357.38	0.58	0.54	0.0150	0.0879274	
Riffle End	RE11	22452	5357.94	1.14	0.99	0.0113	0.0717376	
Riffle Mid	RM11	22527	5358.29	0.64	0.59	0.0113	0.07793134	0.076
Riffle Begin	RB11	22602	5359.09	0.59	0.55	0.0113	0.07881165	

Iteration 2

Feature		Station	WS (18 cfs)	Depth	Hydraulic Radius (ft)	Riffle Slope (ft/ft)	Manning N	Avg N per riffle
Riffle End	RE1	13011	5336.41	2.41	2.14	0.0612	0.12038099	
Riffle Mid	RM1	13036	5336.42	0.89	0.79	0.0612	0.14118995	0.143
Riffle Begin	RB1	13060	5337.27	0.27	0.26	0.0612	0.16866632	
Riffle End	RE2	13900	5338.24	1.24	1.06	0.0200	0.08805115	
Riffle Mid	RM2	13950	5338.57	0.57	0.53	0.0200	0.09837841	0.095
Riffle Begin	RB2	14000	5339.54	0.54	0.51	0.0200	0.09898576	
Riffle End	RE3	14800	5340	1.00	0.88	0.0050	0.05356535	
Riffle Mid	RM3	14900	5340.22	0.72	0.65	0.0050	0.05622572	0.056
Riffle Begin	RB3	15000	5340.61	0.61	0.57	0.0050	0.05741973	
Riffle End	RE4	15850	5340.78	0.78	0.7	0.0150	0.08435125	
Riffle Mid	RM4	15900	5341.35	0.60	0.55	0.0150	0.08766964	0.087
Riffle Begin	RB4	15950	5342.06	0.56	0.52	0.0150	0.08845995	
Riffle End	RE5	18119	5347.31	0.71	0.64	0.0066	0.06280435	
Riffle Mid	RM5	18285	5348.33	0.63	0.58	0.0066	0.06380138	0.064
Riffle Begin	RB5	18450	5349.39	0.59	0.55	0.0066	0.06434584	
Riffle End	RE6	19000	5349.52	0.72	0.65	0.0080	0.06722033	
Riffle Mid	RM6	19125	5350.42	0.62	0.57	0.0080	0.06864782	0.068
Riffle Begin	RB6	19250	5351.38	0.58	0.54	0.0080	0.06924425	
Riffle End	RE7	19591	5351.55	0.75	0.68	0.0113	0.07598896	
Riffle Mid	RM7	19667	5352.27	0.61	0.56	0.0113	0.0783866	0.078
Riffle Begin	RB7	19742	5353.08	0.58	0.54	0.0113	0.07884405	
Riffle End	RE8	20072	5353.27	0.77	0.69	0.0067	0.06212437	
Riffle Mid	RM8	20147	5353.64	0.64	0.59	0.0067	0.06370031	0.063
Riffle Begin	RB8	20222	5354.10	0.60	0.55	0.0067	0.06441987	
Riffle End	RE9	20622	5354.25	0.75	0.68	0.0180	0.09082276	
Riffle Mid	RM9	20672	5354.99	0.59	0.55	0.0180	0.09395893	0.093
Riffle Begin	RB9	20722	5355.85	0.55	0.52	0.0180	0.09480594	
Riffle End	RE10	21100	5356.15	0.85	0.75	0.0150	0.08342523	
Riffle Mid	RM10	21150	5356.64	0.59	0.55	0.0150	0.08766964	0.087
Riffle Begin	RB10	21200	5357.36	0.56	0.52	0.0150	0.08845995	
Riffle End	RE11	22452	5357.91	1.11	0.97	0.0113	0.07197223	
Riffle Mid	RM11	22527	5358.27	0.62	0.57	0.0113	0.07836254	0.077
Riffle Begin	RB11	22602	5359.07	0.57	0.53	0.0113	0.07928012	

Appendix C
Sediment Sampling Data

825-111 South Platte Park Master Plan
Sediment Sampling Data
11/3/2011

D_s (mm)	# Retained	% of Total	# Finer	% Finer
fine	19	16.0		
2	14	11.8	19	15.97
2.8	12	10.1	33	27.73
4	11	9.2	45	37.82
5.6	11	9.2	56	47.06
8	6	5.0	67	56.30
11	7	5.9	73	61.34
16	6	5.0	80	67.23
22.6	10	8.4	86	72.27
32	10	8.4	96	80.67
45	6	5.0	106	89.08
64	7	5.9	112	94.12
90	0	0.0	119	100.00
128	0	0.0	119	100.00
180	0	0.0	119	100.00
300	0	0.0	119	100.00