Middle South Platte River Restoration Master Plan

Prepared for:

The Middle South Platte River Alliance

Prepared by:

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November 2015

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City of Evans, Colorado

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

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Acronyms

AEP	annual exceedance probability
Alliance	Middle South Platte River Alliance
BMPs	best management practices
CDOT	Colorado Department of Transportation
CEM	Channel Evolution Model
cfs	cubic feet per second
COGCC	Colorado Oil & Gas Conservation Commission
CPDS	Colorado Pollution Discharge System
CPW	Colorado Parks and Wildlife
CSCB	Colorado State Conservation Board
CWCB	Colorado Water Conservation Board
DHM	DHM Design
DU	Ducks Unlimited
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FWS	U.S. Fish and Wildlife Service
GIS	geographic information system
HEC-RAS	Hydrologic Engineering Center – River Analysis System
HUC	Hydrologic Unit Code
LiDAR	light detection and ranging
Master Plan	South Platte River Restoration Master Plan
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
OPCC	opinion of probable construction cost
Poudre River	Cache La Poudre River
SEM	Stream Evolution Model
SVAP2	Stream Visual Assessment Protocol Version 2
SWMP	Stormwater Management Plan
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

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Glossary Terms[1]

Aggradation: A persistent rise in the elevation of a streambed caused by sediment deposition.

Bank Armoring: An approach to strengthening the streambank soil or improving its erosion resistance by utilizing rock, live plant materials, mostly woody shrubs and trees, or a combination. In the case of the Middle South Platte River, concrete rubble and car bodies were also used to armor the river bank.

Bankfull Discharge: The ordinary high-water discharge, with a recurrence interval of approximately 1.5 years for most streams. It is the flow that transports the most sediment for the least amount of energy.

Bar: Accumulation of sand, gravel, cobble, or other alluvial material found in the channel, along the banks, or at the mouth of a stream where a decrease in velocity induces deposition.

Bioengineering: An approach to strengthening the streambank soil or improving its erosion resistance by utilizing live plant materials, mostly woody shrubs and trees. Although non-living materials such as wood or fabric may also be part of the design, bioengineering technique relies mostly on the long-term integrity of the live plants and their rooting systems for its streambank stabilization function.

Channel Stability: A relative measure of the resistance of a stream to aggradation or degradation. Stable streams do not change appreciably from year to year. An assessment of stability helps determine how well a stream will adjust to and recover from mild to moderate changes in flow or sediment transport.

Cubic Foot per Second (cfs): A unit of stream discharge. It represents one cubic foot of water moving past a given point in one second.

Degradation: The geologic process by which streambeds are lowered in elevation and streams are detached from their floodplains. Also referred to as entrenched or incised streams.

Deposition: The settlement or accumulation of material out of the water column and onto the streambed or floodplain. This process occurs when the energy of flowing water is unable to transport the sediment load.

Effective Discharge: The discharge responsible for the largest volume of sediment transport over a long period of record. Effective discharge is computed from long-term flow statistics and the sediment transport to discharge relationship. It is typically in the range of a 1- to 3-year flood event, in many settings has been shown to correspond to the bankfull discharge.

Entrenchment: The vertical containment of the river and the degree in which it is incised in the valley floor. A stream may also be entrenched by the use of levees or other structures.

Fine Sediment: Clay, silt and sand sized particles.

Floodplain: The nearly flat area adjoining a river channel that is constructed by the river in the present climate and overflows upon during events greater than bankfull discharge.

Geomorphology: The scientific study of landforms and the process that shape them.

HEC-RAS: one-dimensional finite difference hydraulic model developed by the U.S. Army Corps of Engineers.

Incised Channel: A stream channel that has deepened and as a result is disconnected from its floodplain.

Instream Wood: Wood material accumulated or placed in a steam channel, providing opportunity for habitat, and enhanced bedforms and flow resistance.

Low-flow: The lowest discharge recorded over a specified time period.

Point Bar: Usually the side opposite the concave bank. The point bar is the depositional feature that facilitates the movement of bedload from one meander to the next. The point bar extends at the loss of the near bank region.

Reach: (A) Any specified length of stream. (B) A relatively homogeneous section of a stream having a repetitious sequence of physical characteristics and habitat features. (C) A regime of hydraulic units whose overall profile is different from another reach.

Riffle: A shallow, rapid section of streams where the water surface is broken into waves by submerged or partially submerged objects.

Riparian: Relating to flora and fauna located on or near the banks of a river or stream.

Riprap: The layering of rocks along a stream bank to counteract erosional forces.

Sediment Transport: The rate of sediment movement through a given reach of stream.

Sinuosity: The ratio of stream channel length (measured in the thalweg) to the down-valley distance, or is also the ratio of the valley slope to the channel slope. When measured accurately from aerial photos, channel sinuosity may also be used to estimate channel slope (valley slope/sinuosity).

Stage: Elevation of water surface above any chosen reference plane. Also known as water level or gage height.

Thalweg: The line connecting the lowest points along a streambed, as a longitudinal profile. The path of maximum depth in a river or stream.

Toe: The base of a streambank or terrace slope.

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[1] Adapted from Yochum, Steven E. 2015. **Guidance for Stream Restoration and Rehabilitation.** Technical Note TN-1021. Fort Collins, CO. U.S. Department of Agriculture. Forest Service, National Stream & Aquatic Ecology Center. 89 p.

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Section 1

Introduction

1.1 Project Background

In September 2013, the segment of the Middle South Platte River that flows through Weld County, including the municipalities of Milliken, Evans, and LaSalle, experienced a record flood event that resulted in significant damage to the river corridor and surrounding communities. Peak flow rates during the flood were estimated to be 57,500 cubic feet per second (cfs) estimated from the U.S. Geological Survey (USGS) gage data at Kersey, Colorado. The record high peak flow, in combination with the extended duration of the event (approximately 7 days), caused considerable damage to local infrastructure and significantly altered the river corridor. In numerous locations, the floodwaters scoured away waterlines, septic systems, roads, and flood-control structures. These damages are estimated to have reached into the hundreds of millions of dollars. Within the river corridor, the South Platte experienced significant sediment deposition creating new and expanding existing point and mid-channel bars, and abandoning the pre-flood channel in numerous places by breaching its banks. These changes have had adverse impacts on the communities along the Middle South Platte River.

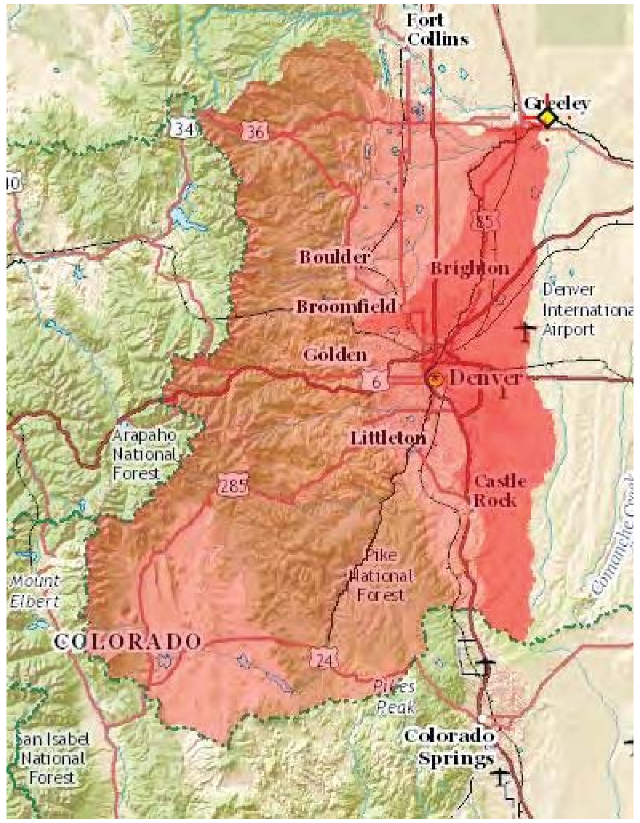


Figure 1-1. Watershed for South Platte River at Cache La Poudre River.

The Middle South Platte River plays an important role in the communities and economies of Weld County. The South Platte River Restoration Master Plan (Master Plan) was initiated by the City of Evans and the Middle South Platte River Alliance following the September 2013 flood. The purpose of the Master Plan is to provide guidance to the City of Evans, the Alliance, and local communities to identify and prioritize stream restoration and rehabilitation projects to reduce impacts from future flooding events. The project area includes the main stem of the South Platte River corridor from St. Vrain Creek to the confluence with the Cache La Poudre River; a distance of approximately 20 miles. **Figure 1-1** shows the watershed for the South Platte River at the confluence with the Cache La Poudre (generated from the USGS StreamStats website). **Figure 1-2** shows the approximate subwatershed for the study area based on hydrologic unit data from the USGS National Hydrography Dataset, this is the approximate subbasin boundary for the study area as it extends past the confluence with the Cache La Poudre River. **Figure 1-3** shows the extent of the study reach.

The Middle South Platte River Alliance (Alliance) is a group of individuals and organizations that organized in response to the September 2013 South Platte River flood event. The goals of the Alliance include preserving natural habitat, restoring the natural floodplain, and rehabilitating infrastructure along the Middle South Platte River. The policies and strategies developed in the Master Plan will be used by the Alliance to guide restoration and rehabilitation efforts along the Middle South Platte River.

The Master Plan provides a comprehensive, integrated watershed approach to mitigating geomorphic and flood hazards, as well as ecosystem degradation impacts. The goal of the Master Plan, from an ecological restoration standpoint, is to allow the river and associated systems to migrate back to the flow regimes and the dynamics that make this eastern plains river system so unique. By allowing the historical flow regimes to connect to the floodplain, the entire ecological system can follow the transition. This would be the ideal future view of the system in both the short and very long term. To accomplish this vision, there needs to be a realization that this will be a long process. The opportunities, however, exist to embark upon a journey in which small projects and key partners begin to revisit the South Platte and find a context to where the river can once again find a natural flow regime and the ecological systems that have evolved to react to that flow regime can be released.

The goal of the Master Plan, related to ecological process of the future South Platte is to encourage partnerships and opportunities to revisit the historical ecologic system where possible. The job is immense, but so is the opportunity. Well placed demonstration projects with multiple collaborators and interests can show the way to the future ecological condition of the South Platte River Corridor. The assessment points out and defines some of the best opportunities within the corridor to advance this mission and provides some important "starting points". The results presented in this report will be used to develop feasible projects in collaboration with watershed stakeholders and the public. This report documents the process and methods used to identify and prioritize the proposed projects.

1.2 Project Scope

The City of Evans and the Alliance hired CDM Smith to assist in the development of the Master Plan. The following objectives were included within the scope of work for this project:

- Acquisition of hydrologic and hydraulic data and geomorphic and ecological data along the Middle South Platte River,
- Identification and prioritization of potential mitigation and restoration projects,
- Review of previously completed floodplain analyses for the existing and proposed channel changes
- Delineation of floodplain maps for average annual discharge as well as 2-year and 100-year discharge events (note the channel has capacity for the annual and 2-year discharge so mapping was not performed),
- Alternatives analysis and conceptual design, and
- Cost estimation for proposed rehabilitation and restoration projects.

These objectives were executed in tandem with a public/stakeholder engagement process, including project identification and prioritization. The public process was used to build an alliance for project implementation and long-term ongoing maintenance.

The Master Plan is intended to support local agencies and stakeholders in the prioritization and implementation of projects to reduce the impact of future floods and increase the resiliency and health of the Middle South Platte River ecosystem.

1.3 Master Plan Overview

The Master Plan presented here represents months of extended collaboration and effort between CDM Smith, the City of Evans, the Alliance, and the public. This document will serve as a roadmap for the Alliance and communities of the Middle South Platte River to identify and prioritize restoration and rehabilitation projects in the coming years.

This Master Plan is divided into the following sections:

1.0 **Introduction:** Master Plan purpose and scope

2.0 **Planning Process:** Master Plan objectives and public outreach efforts

3.0 **Project Area Description:** Project area description, background on the September 2013 flood, and description of river reaches

4.0 **Stream Corridor Evaluations:** Description of the data collection process as well as hydrologic and hydraulic data summary and analysis

5.0 **Risk Assessments:** Description of risk assessment methodology, scoring criteria, and results of the fluvial geomorphic, flood risk, and ecological risk surveys including final risk scores

6.0 **Risk Scores and Prioritization Ranking:** Overall risk scores and reach prioritization

7.0 **Recommendations and Conclusions:** Strategies and project recommendations to address risks

8.0 **References**

Appendix A: Reaches and Property Information

Appendix B: Data Collection Figures

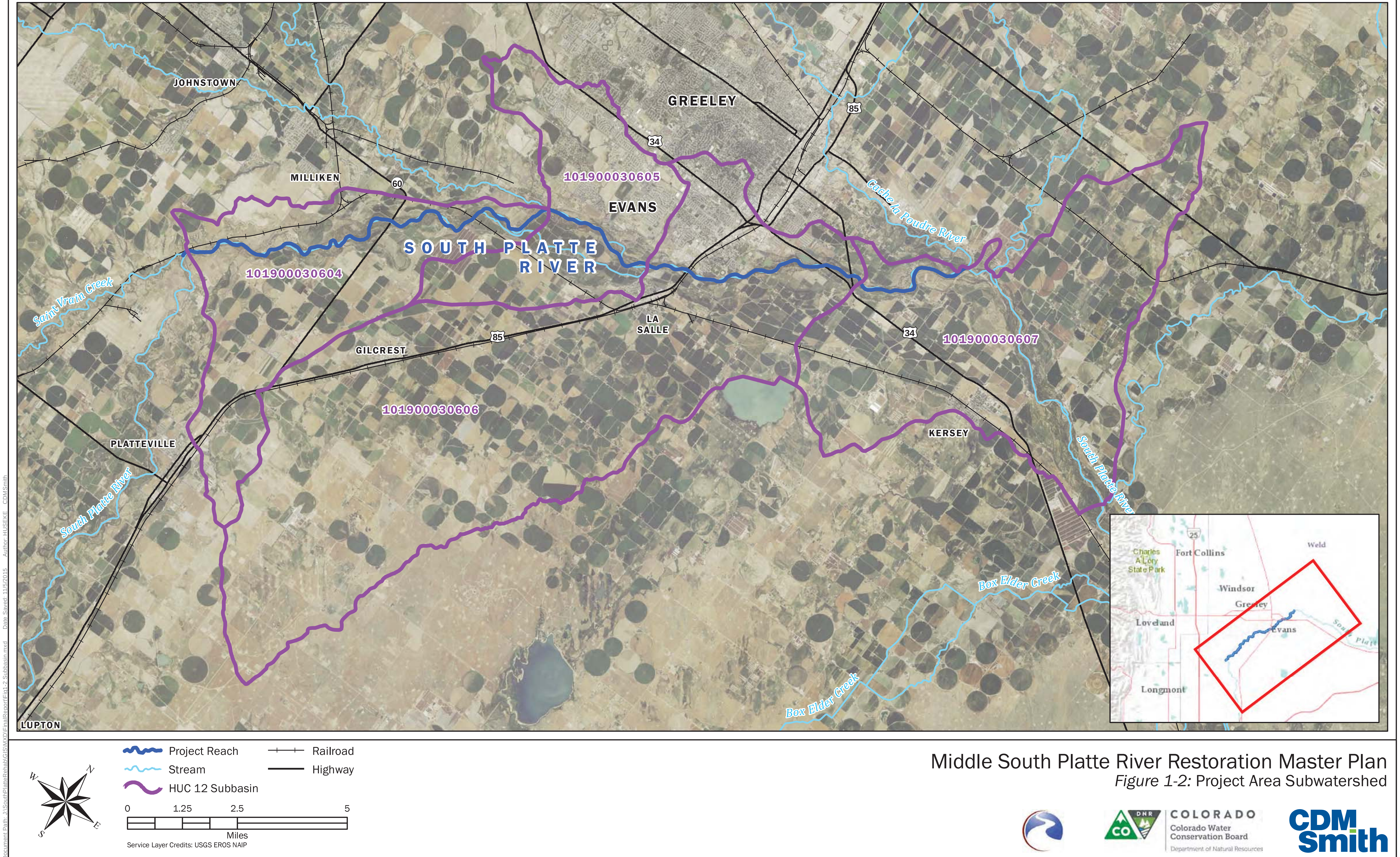
Appendix C: Effective Discharge

Appendix D: Ecological Risk Assessment Report

Appendix E: Geomorphic Risk Analysis Figures

Appendix F: Flood Hazard Risk Analysis Figures

Appendix G: Planning Level Opinion of Probable Construction Costs Breakdowns



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Middle South Platte River Restoration Master Plan

Figure 1-2: Project Area Subwatershed

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Project Reach

Stream

Canal/Ditch

Railroad

Highway

0 1.25 2.5 5
Miles

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Figure 1-3: Project Area

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Section 2

Planning Process

2.1 Objectives

The Master Plan was developed to identify long-term recovery and rehabilitation projects along the Middle South Platte River following the flood events of September 2013. The development of the Master Plan involved regular communication and coordination between local agencies, various stakeholders, and the community at-large through public meetings and outreach events during the planning cycle.

The goals of the Master Plan are to:

- Reduce the risk of future flood damage to persons and property along the Middle South Platte River
- Increase the resiliency of affected communities, economies, and ecosystems along the Middle South Platte River
- Identify risks and prioritize projects necessary to mitigate identified risks

These goals were developed in cooperation with the public and all participating stakeholders during numerous outreach events that were organized throughout the planning process.

2.2 Public Engagement Process

The development of the Master Plan incorporated feedback from the community and members of the Alliance obtained at public outreach events and Alliance meetings. This section summarizes the public outreach activities conducted during the development of the Master Plan. Meeting materials, including PowerPoint presentations and meeting notes presented and gathered at these public outreach events, have been provided to the City of Evans in digital format.

The Alliance represents individuals and organizations intent on restoring the Middle South Platte River and enhancing its ecological, economic, and cultural value. Financial and administrative support for the Alliance is provided by the City of Evans and the Colorado Water Conservation Board (CWCB). Current Alliance members include representatives from the following stakeholders, the Alliance welcomes all stakeholders to attend meetings and to get involved:

- Agricultural Ditch Companies
- Big Thompson River Coalition
- City of Greeley
- Colorado Oil and Gas Association
- Colorado Watershed Assembly
- Ducks Unlimited
- Energy producers
- Property owners
- Town of Milliken
- Weld County
- Weld Air and Water

Three public outreach events were held during the development of the Master Plan (September 4, 2014, November 6, 2014, and February 5, 2015). These events served as opportunities for the public to provide information and feedback that was used to develop the Master Plan. Attendees at the September 4, 2014 and November 6, 2014 public meeting were invited to participate in an informal survey designed to help identify the participant's views on which issues are the most important for the restoration of the Middle South Platte River. Approximately 50 local landowners and community officials participated in the survey. The results of the survey suggest that property protection, infrastructure protection and improvements, natural habitat conservation, and irrigation were among the most important issues to residents along the Middle South Platte River. **Figure 2-1** summarizes the results of the informal survey.

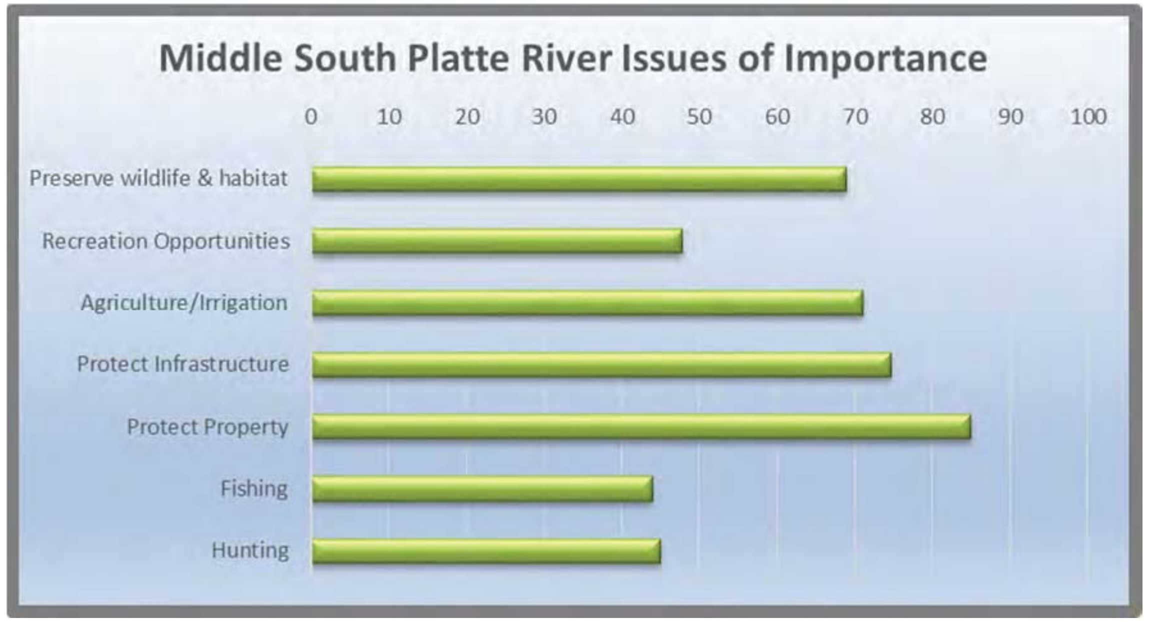

Figure 2-1. Results of Informal Survey of Attendees from Public Meetings

Members of the Alliance also met periodically with representatives of CDM Smith between September 2014 and March 2015 to explore options and issues related to post-flood rehabilitation and restoration activities along the Middle South Platte River. The feedback from Alliance members was of critical importance to the development of the Master Plan.

In addition, a series of in-person meetings were held with landowners that live in the high and medium priority reaches. The meetings were held on the dates for the reaches noted below:

- August 17, 2015: Reaches 13 – 15
- August 24, 2015: Reaches 10 – 12
- August 31, 2015: Reaches 6 – 8

The City of Evans with the assistance of CWCB (Rachel Theler) led the landowner outreach on behalf of the Alliance. Each landowner in the reaches noted above was contacted via letter, email, or telephone. The meetings were used as an opportunity to discuss the draft Master Plan and how the river affects (adversely or beneficially) property adjacent to it. More specifically, the letter or phone call explained that the plan had broken this section of river into 18 reaches, 5 of which are considered high-priority. Additionally, the message indicated a landowner's property falls within a high-priority or medium-priority reach of the river, meaning that there is a combination of high flood risk, potential for river movement, and/or environmental degradation in your area. Flood, fluvial geomorphic, and ecological risks have all been evaluated; furthermore, the message noted that the river corridor has been evaluated and some suggested projects have been identified, which can be found in the draft Master Plan at http://www.middlesouthplatte.org/projects.html.

The city, Ms. Theler, and CDM Smith staff developed discussion questions for each of the meetings. The questions were as follows:

- What do you feel are the more pressing issues along the South Platte River?
- What specific concerns do you have on your property?
- We're working to reduce the impacts of flooding along the river. Would you be willing to work with us even if that means that there will likely be some associated monetary costs for these projects and/or in some cases the loss of small amounts of agricultural land?
- How else could we as an alliance help you to preserve and protect your property interests?

Below is a summary of comments made at the meeting. The points and concerns brought up throughout all the meeting were quite similar.

1. Dredging was brought up frequently at every meeting by a variety of landowners. There was a general sentiment that if the river was dredged the flooding problems would go away.
2. The bridges that cross the river, and their piers, are a source of concern with regards to sediment buildup.
3. There was concern about dike repair. Some landowners are doing it and are upset because others are not, making their efforts futile in the event of the flood. Explaining how high-priority reach projects would help the river corridor as a whole it would be helpful as well as encouraging stakeholders to involve their neighbors.
4. A request was made to change the steering committee meetings to the evening when people are off work.
5. Some stakeholders would like to see more public education about the river corridor.
6. There is a general feeling that city/county/federal governments are not doing what they are supposed to do. The U.S. Army Corps of Engineers (USACE) and Colorado Department of Transportation (CDOT) were brought up frequently.

In addition to the broad comments, the landowners did provide input on problem areas along the river and on their property. Specific projects to address these problems were discussed, especially at the second meeting because this meeting had the largest attendance. The projects discussed are described in Section 7.

The Alliance provided the following suggestions to address the broad comments and concerns.

Comment Nos. 1 and 2:

To address the dredging and sedimentation issue, the Alliance should work with USACE and CWCB to develop a concise message to explain why dredging the river is not feasible or practical. In addition, the sediment study that is just starting should be leveraged to explain the reasons dredging is not a long-term solution and what is actually feasible to address sedimentation. This information could help the Alliance talk with landowners and turn their attention to practical projects.

Comment No. 3:

Explain how the interaction of projects along the river corridor have the potential to improve the river as a whole and encourage stakeholders to involve their neighbors in the process.

Comment Nos. 4 and 5:

The Alliance should host quarterly public meetings in the evenings. This approach would allow the monthly steering committee meetings to focus on Alliance business and actions, and give the public a forum for public comment. In addition, once a watershed coordinator is hired, he/she can spearhead the public outreach process.

Comment No. 6:

The Alliance and stakeholders should invite representatives from USACE, CWCB, CDOT, and Weld County to attend public meetings to foster dialogue and answer questions.

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Section 3

Project Area Description

3.1 Project Area Boundaries

The Master Plan focuses on the section of the South Platte River from the confluence with St. Vrain Creek to the confluence with the Cache La Poudre River (Poudre River), a distance of approximately 20 miles. Included within the project area are the municipalities of Evans, LaSalle, and Milliken, along with residents of unincorporated Weld County. The geomorphological, ecological, and flood-risk analyses presented in the Master Plan focuses on lands along both banks of the South Platte River within the previously described project area. These locations were among the most adversely impacted by the September 2013 floods and remain highly vulnerable to future flood events. The index map, **Figure 3-1**, shows the project area boundaries and reaches divisions. The corresponding reach specific figures are provided in **Appendix A.**

3.2 Project Area Description

Within the project area, the South Platte River flows in a relatively well-defined, braided channel ranging from 300 to 600 feet wide and from 6 to 8 feet deep (Federal Emergency Management Agency [FEMA] 1999). The stream gradient is approximately 7 feet per mile (0.1 percent) in this area. Riparian vegetation includes stands of mature trees such as cottonwood (*Populus deltoides*) and river birch (*Betula nigra*) and grasses such as sedges (*Carex* spp.) and rushes (*Juncas* spp.) along the river bank with row crops and pastureland adjacent to the floodplain (FEMA 1999). The primary soil types within the project area are loam and sandy loam soils (Colorado State Conservation Board [CSCB] 2011). The soils directly adjacent to the river are classified as Aquolls and Aquents, with gravelly substratum, and also include sandy loam soils from the Bankard series (Natural Resources Conservation Service [NRCS] 2015). These soil types are relatively similar, although the Aquolls and Aquents are more poorly drained than the Bankard series. Both soil types have relatively moderate soil erodibility factors (K-factor) of 0.24 and 0.15, respectively (NRCS 2015).

The three principle tributaries of the Middle South Platte River within the project area are the St. Vrain Creek, the Big Thompson River, and the Poudre River. The St. Vrain Creek and Poudre River form the upstream and downstream boundaries of the Master Plan project area, respectively. The drainage area of the river at the confluence with the St. Vrain is 6,070 square miles while the drainage area at the confluence with the Cache La Poudre is 7,180 square miles.

The St. Vrain Creek begins in the Front Range Mountains in Boulder County near the Town of Lyons, Colorado, and descends from the uplands for approximately 32 miles until it joins the South Platte River from the west. The Big Thompson River begins within Rocky Mountain National Park in Larimer County and joins the South Platte River approximately 5 miles upstream of Greeley, Colorado. The Poudre River headwaters are located in the northern Front Range Mountains; the river descends from the foothills through the City of Fort Collins and joins the South Platte River approximately 5 miles east of Greeley.

The elevation of the Middle South Platte River ranges from 4,740 feet at the St. Vrain Creek confluence to 4,602 feet at the confluence with the Poudre River. The project area has a semi-arid, continental climate, with average annual precipitation of 15.13 inches at Evans. About 75 percent of precipitation falls as rain between April and September (CSCB 2011). Intense, localized thunderstorms occur throughout the summer months and generate high runoff (CSCB 2011). Average annual snowfall in the area is approximately 40 inches (CSCB 2011). The average daily temperature in summer is 70° F, with an average daily maximum temperature of 87° F. The average daily temperature in winter is approximately 28° F, with an average daily minimum of approximately 15° F (CSCB 2011). This region experiences persistent winds between 7 and 10 miles per hour, with much higher wind speeds in advance of storm fronts that generate a strong soil erosive force (CSCB 2011). The high winds and low relative humidity drive annual open water evaporation rates of up to 70 inches per year (CSCB 2011).

Recorded settlement in Weld County dates back to the 1830s when a series of forts were built along the South Platte River to facilitate the beaver pelt trade. These trading outposts were abandoned as the market for beaver pelts crashed, although settlers continued to migrate into the area. The City of Evans was established in 1869 and consisted of approximately 600 inhabitants and 60,000 acres of farmland by 1872. The town was founded during the construction of the Denver Pacific Railroad, which connected the City of Denver with the Transcontinental Railroad in Cheyenne, Wyoming, and is named after John Evans, the territorial governor who spearheaded the railroad initiative. Today, Weld County is currently the leading producer of cattle, grain, and sugar beets in Colorado. The predominant land uses within the project area include residential, commercial, industrial, and agricultural. In addition, recent advancements in hydraulic fracturing for oil and natural gas extraction have led to extensive oil and gas operations within the county.

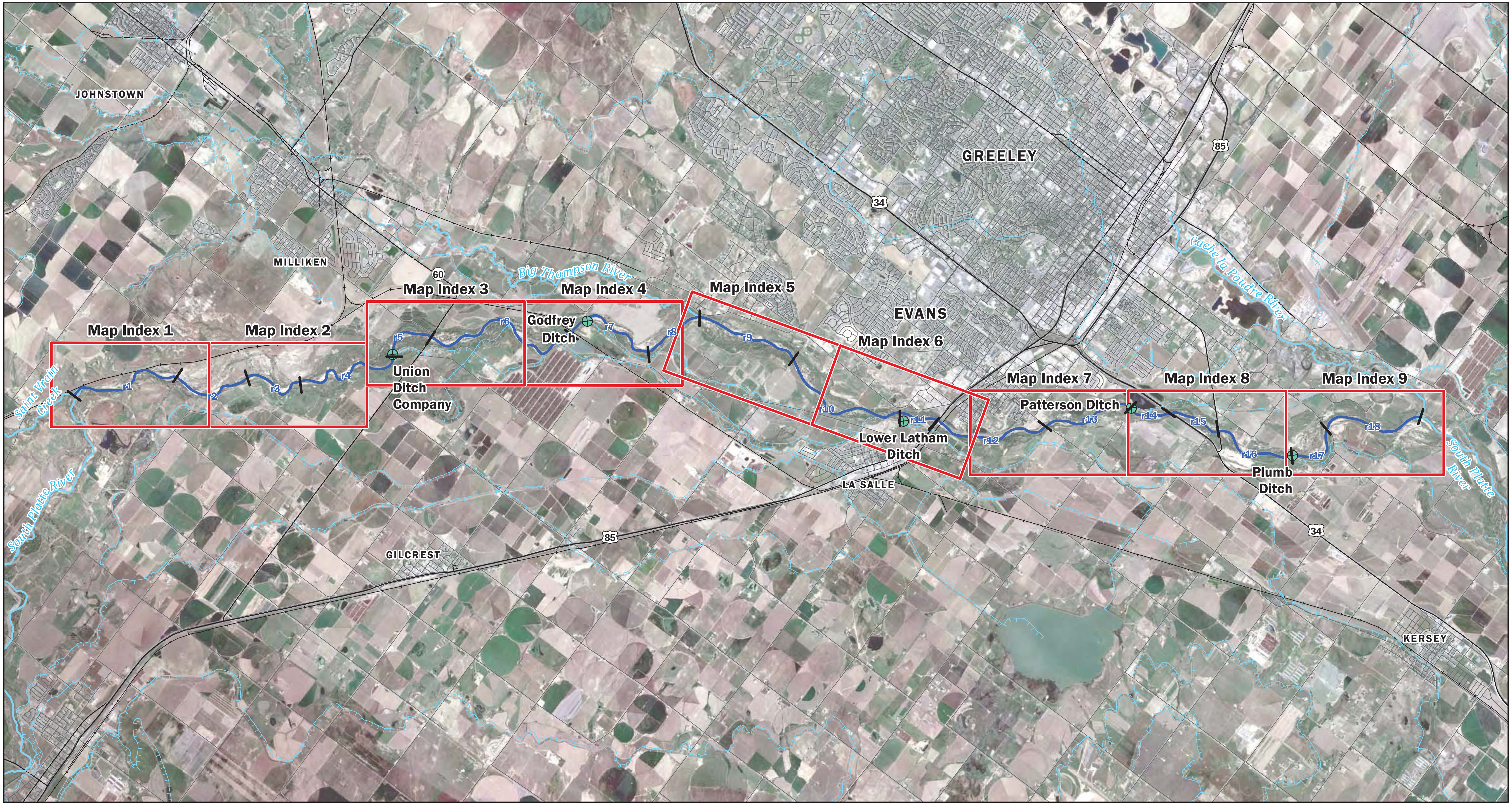
3.3 Historical and Current Ecological Conditions of the Lower South Platte River

The current ecological condition of the South Platte River is markedly different from pre-settlement conditions. Changes in land use and irrigation practices have altered hydrology, floodplain connection, sediment transport, and riparian vegetation and, consequentially, the form of the river itself.

Historically, the natural vegetation of the plains surrounding the South Platte River consisted of shortgrass prairie grasses, with patches of cottonwood and willows, and the river itself was broad and braided, with numerous side channels and islands (Mutel and Emerick 1984). The characteristic cottonwood (*Populus deltoids*) galleries that currently line the river developed in response to the establishment of irrigation canals and reservoirs throughout the adjacent farm and ranch lands.

Irrigation diversions and impoundments reduced peak flows on the South Platte, which promoted the establishment of cottonwoods and willows in areas that were previously unsuitable due to seasonal high flows and ice flows during the winter months. By the late 1930s, vegetation had occupied most of the river channel (Kittel et al. 1998). In turn, with more vegetation present, the river channel became narrower. As of 1969 no significant declines in channel area have occurred due to the expansion of cottonwood and willow species, and by 1986, channel-to-woodland proportions were relatively uniform throughout the Platte River system (Johnson 1994).

Currently the South Platte River within the study area contains a highly modified floodplain that is largely disconnected from the river. Large stretches of the river have been channelized through the installation of rip-rap and other structures designed to prevent bank erosion. Armored banks often increase velocities due to a lack of riparian vegetation, which help dissipate flows, and lead to increased rates of erosion.



Project Reach
Stream
Canal/Ditch
Railroad
Highway
Diversion Structures
Map Index Page

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Middle South Platte River Restoration Master Plan

Figure 3-1: Index Map

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The lack of a wide, natural riparian corridor along the South Platte River is detrimental to overall stream health. A healthy riparian corridor of the proper width minimizes the impacts of erosion and nonpoint source pollution and also provides spawning habitat for fish and movement corridors for wildlife (Fischer 2000). An emerging concern is that the riparian area may begin to narrow as the mature cottonwoods, which were established around the turn of the 20th Century, begin to die at a rate faster than they are replaced by regeneration (Kittel et al. 1998, Johnson 1994). If this trend continues, the riparian corridor will become narrower and the South Platte itself will be further channelized (Johnson 1994).

3.4 September 2013 Flood

In late summer 2013, the Colorado Front Range experienced an extensive rainstorm event spanning approximately 10 days from September 9th to September 18th. The event generated widespread flooding as the long-duration storm saturated soils and increased runoff potential. Flooding resulted in substantial erosion, bank widening, and realigning of stream channels; transport of mud, rock and debris; failures of dams; landslides; damage to roads, bridges, utilities, and other public infrastructures; and flood impacts to many residential and commercial structures.

Runoff associated with these rain events sent a pulse of floodwater downstream that led to historic flooding along the Middle South Platte River. The river crested on September 14 at a height of 18.79 feet, well exceeding the previous record flood height of 11.7 feet recorded in 1973. The river remained in flood stage (above 12 feet in height) until September 19. At its peak stage, the South Platte River was estimated to span nearly one mile in width and reached 500-year to 1,000-year flood levels.

The peak discharges on the South Platte River for the September 2013 flood exceeded the 100-year event storm from the confluence of the St. Vrain to Ft. Morgan. The upper portions of the river from the confluence with the Big Thompson River to Orchard (State Highway 144) were close to or exceeded the 500-year event. The flows downstream of Ft. Morgan were estimated to be below the existing Flood Insurance Study (FIS) 100-year flow.

The City of Evans experienced significant damage to property and infrastructure during the flood. A total of 56 homes were severely damaged, and 203 mobile homes were completely destroyed. Riverside Park, located adjacent to the South Platte River, suffered extensive damage. The flood waters uncovered a previously unknown landfill in the area and mobilized a significant quantity of landfill debris. Additionally, the City of Evans' Wastewater Treatment Plant Number 1 was rendered non-functional as a result of the flood. Although there were no serious injuries or loss of life, an estimated 600 to 1,000 residents of Evans were displaced.

Historically, other flood events along the Middle South Platte River have been caused by intensive rainstorms or cloud bursts that normally occur between May and August, with most floods occurring in June (FEMA 1999). Major flood events have occurred as follows: May 1876, June 1894, May-June 1914, June 1921, August-September 1938, April-May 1942, May-June 1949, May 1951, June 1965, May 1969, and May 1973 (FEMA 1999). The flood events of June 1921 and May 1973 are estimated to have frequencies of approximately 1 percent annual chance (i.e., 100-year flood).

Following the event, CDOT partnered with the CWCB to initiate hydrologic analyses in several key river systems impacted by the floods, including the South Platte River. The purpose of the analyses were to ascertain the approximate magnitude of the September flood event in key locations throughout the watersheds and to prepare estimates of peak discharge that can serve to guide the design of permanent roadway and other infrastructure improvements along the impacted streams. Further information on CDOT's hydrologic analysis is included in Section 4.

3.5 Overview of Reaches

The Middle South Platte River within the project area was divided into 18 reaches in order to facilitate project identification and prioritization. Reach breaks were primarily determined based on structures within the river corridor (e.g., bridges, railroad crossings, and diversion structures), as well as major tributary junctions (Big Thompson River), large-scale bends, or significant changes in adjacent land use. The locations of each reach are shown in **Figure 3-1** and in more detail in **Appendix A**. Each reach is briefly described below. A detailed description of each reach, as well as photos, is included in Section 4.

- **Reach 1:** Confluence with St. Vrain Creek to 8,000 feet downstream at old road crossing, approximately 1.5 miles in length. Mostly private land ownership.
- **Reach 2:** 8,000 feet downstream of the confluence with St. Vrain Creek to 13,800 feet downstream, approximately 1.0 miles in length. Mostly private land ownership.
- **Reach 3:** 13,800 feet downstream of the confluence with St. Vrain Creek to 18,500 feet downstream, approximately 0.70 miles in length. Mostly private land ownership.
- **Reach 4:** 18,500 feet downstream of the confluence with St. Vrain Creek to the Union Ditch Co. Diversion Structure, approximately 2.0 miles in length. Mostly private land ownership.
- **Reach 5:** Union Ditch Co. Diversion Structure to County Road 27/State Highway 60 (County Road 27/State Highway 60) Bridge, approximately 0.75 miles in length. Mostly private land ownership.
- **Reach 6:** County Road 27/ State Highway 60 Bridge to a railroad crossing 12,000 feet downstream of the bridge, approximately 0.75 miles in length. Mostly private land ownership.
- **Reach 7:** Railroad crossing to 6,900 feet downstream, approximately 1.0 miles in length. Mostly private land ownership.
- **Reach 8:** 4,400 feet upstream of the confluence with the Big Thompson River to the confluence with the Big Thompson River, approximately 0.80 miles in length. Mostly private land ownership.
- **Reach 9:** Confluence with the Big Thompson River to 7,500 feet downstream, approximately 1.40 miles in length. Mostly private land ownership.
- **Reach 10:** 7,450 feet downstream of the confluence of the Big Thompson River to the Lower Latham diversion structure, approximately 1.6 miles in length. Mostly private land ownership with some public parcels (Evans, Evans Fire Protection District).
- **Reach 11:** Lower Latham diversion structure to US Highway 85, approximately 0.50 miles in length. Mostly private land ownership with some public parcels (Evans, Evans Fire Protection District).
- **Reach 12:** US Highway 85 to 37th Street, approximately 1.40 miles in length. Mostly public property ownership (Evans, Evans Fire Protection District; Department of Transportation; La Salle, La Salle Fire Protection District).
- **Reach 13:** 37th Street (County Highway 54) to Patterson Ditch diversion structure, approximately 1.15 miles in length. Mostly private land ownership, with Ducks Unlimited and Colorado Game, Fish and Parks Commission parcels.

- **Reach 14:** Patterson Ditch diversion structure to US Highway 34, approximately 0.55 miles in length. Mostly private land ownership.
- **Reach 15:** US Highway 34 to US Highway 34 Business Route, approximately 0.70 miles in length. Mostly private land ownership on the north bank, with CDOT property on the south bank.
- **Reach 16:** US Highway 34 Business Route to Plumb Ditch diversion structure, approximately 1.10 miles in length. Mostly private land ownership.
- **Reach 17:** Plumb Ditch diversion structure to County Road 58 (18th Street), approximately 0.60 miles in length. Mostly private land ownership.
- **Reach 18:** County Road 58 to confluence with Poudre River, approximately 1.30 miles in length. Mostly private land ownership with parcels of public property owned by Weld County; Colorado Game, Fish, and Parks Commission; and Ducks Unlimited public lands.

3.6 Threatened and Endangered Species

At present there are no areas designated as critical habitat within the project area boundaries (U.S. Fish and Wildlife Service [USFWS] 2015). However, project effect analyses may be required to determine potential project impacts to threatened and endangered species located downstream of the project area. Additional information relating to nearby threatened and endangered species is discussed in the Ecological Risk Assessment in Section 5.

Section 4

Data Collection and Analysis

Data used in the development of the Master Plan were collected from project stakeholders as well as multiple federal, state, and local agencies. Every effort was made to ensure that the most current and accurate data were incorporated into the evaluation process.

4.1 GIS Data

Geographic information system (GIS) data used for geospatial analyses were obtained from the following agencies and organizations:

- Colorado Oil & Gas Conservation Commission (COGCC)
- Colorado Parks and Wildlife (CPW)
- Colorado Water Conservation Board (CWCB)
- Ducks Unlimited (DU)
- Federal Emergency Management Agency (FEMA)
- U.S. Department of Agriculture Natural Resources Conservation Service (NRCS)
- U.S. Fish and Wildlife Services (FWS)
- U.S. Geological Survey (USGS)
- Weld County Property Assessor

Table 4-1 summarizes the GIS data collected. This information is also available electronically in a geodatabase provided in the CD attached to this report. Several sets of maps, developed to display the following key assets and relevant datasets, are also included in **Appendix B**:

- Preliminary FEMA Floodplains (Figures B-1 through B-9)
- Wetlands (Figures B-10 through B-18)
- Native Fish Passage Priorities (Figure B-19)
- Oil and Gas Wells (Figure B-20)
- Historic Stream Centerlines and Banklines (Figures B-21 through B-29)

Table 4-1 GIS Data Collected

Data Description	Source
Historical Aerials: 1937, 1953, 1971, 1993, 1998, 2001, 2003, 2005, 2008, 2011, 2012, 2013 (pre-flood), 2013 (immediately post flood), and 2014	University of Colorado Map Library (scanned and geo-referenced), Weld County, CWCB, USGS, and Google Earth
Parcels	Weld County
Land Use Features: Includes land use information such as City Parks and State Wildlife Areas	Ducks Unlimited
Riparian Features: riparian channel, riparian canopy, and wet meadows	Ducks Unlimited
Waterbodies	USGS
Hydrologic Units	USGS
Wetlands	US Fish and Wildlife
Soils	NRCS
SPRRC Program Boundary	Ducks Unlimited
Landcover	Ducks Unlimited
Diversion Structures	CWCB
LiDAR	CWCB
Oil wells	COGCC
Native Fish Passage Priorities	Colorado Parks and Wildlife
Preliminary FEMA Floodplains	FEMA

4.2 Previous Reports

The following reports were used throughout the development of the Master Plan:

- Lower South Platte Watershed Plan – CSCB (2011)
- A Plan for The South Platte River Corridor Platteville to Milliken – DHM Design [DHM] (2013)
- 2013 Evans, Colorado Flood Story – City of Evans, Colorado (2014)
- Evans, Colorado Hydraulic Modeling Memorandum – FEMA (2014)
- Weld County Flood Insurance Study (preliminary) – FEMA (2014)
- Riverside Park Master Plan – City of Evans (2015)
- Final Hydraulics Report for US 34A Permanent Repairs – Tsiouvaras Simmons Holderness for CDOT (2015)
- Conditional Letter of Map Revision for US34A Permanent Repairs – Tsiouvaras Simmons Holderness for CDOT (2015)

Digital copies of each report is included in the CD attached to this report.

4.3 Field Visits

CDM Smith and DHM conducted several reconnaissance site visits between October 2014 and March 2015 along the project reach to document current conditions of the reach and riparian zone. A summary of observations and field notes is included in **Appendix B**. Field photographs of each reach (similar to **Figures 4-1** and **4-2**) are included in Section 5 of this report.

4.4 Hydrology

4.4.1 Hydrologic Statistics

Hydrologic statistics, including annual discharge, peak flows, and recurrence intervals, were calculated for two USGS streamflow gages located near the project area: the South Platte River at Ft. Lupton (USGS 06721000) and the South Platte River near Kersey (USGS 06754000). The Ft. Lupton gage is located approximately 11 miles upstream of the study area and includes a catchment area of 5,043 square miles. The Kersey gage is located on the South Platte River approximately 2.5 miles downstream of the confluence with the Poudre River and has a total catchment area of 9,659 square miles.

The hydrological statistics for the Ft. Lupton gage upstream of the study area are shown in **Table 4-2**. The peak flow measured at this gage occurred on September 13, 2013, at a discharge of 10,300 cfs.

Table 4-2. Hydrologic Statistics for Ft. Lupton Gage

Statistic	Discharge, cfs (based on WY 1929-2013)
Annual mean	378
Maximum Peak Flow	10,300 (September 13, 2013)
10% exceeds*	736
50% exceeds*	214
90% exceeds*	68
2-year Discharge (50% RI)	3,757
5-year Discharge (20% RI)	6,349
10-year Discharge (10% RI)	8,166
25-year Discharge (4% RI)	10,500

* Based on daily peak flows

Figure 4-1. State Highway 60 Bridge

Figure 4-2. Bank Protection with Car Bodies

The annual exceedance probabilities for the South Platte River at the Ft. Lupton gage are shown in **Figure 4-3**. The red line describes the annual exceedance probability (AEP), which is the probability that a flood event of a given magnitude would occur in a given year. For example, a flood with an AEP of 1 percent is typically referred to as the 100-year flood event. Furthermore, a flood with an AEP of 4 percent is referred to as the 25-year flood event.

Table 4-3 summarizes the hydrologic statistics for the streamflow gage located on the South Platte River near Kersey. The peak flow at this gage (31,000 cfs) was measured on June 7, 1921. During the September 2013 floods, this gage was damaged and no peak flow was recorded. The AEP for the South Platte River at the Kersey gage are shown in **Figure 4-4.**

Table 4-3. Hydrologic Statistics for the Kersey Streamflow Gage

Statistic	Discharge, cfs (based on 1901 - 2013)
Annual mean	891
Maximum Peak Flow	59,000 (September 2015)*
10% exceeds**	1,500
50% exceeds**	549
90% exceeds**	140
2-year Discharge (50% RI)	7,191
5-year Discharge (20% RI)	12,380
10-year Discharge (10% RI)	16,340
25-year Discharge (4% RI)	21,870

* Estimated

* *Based on daily peak flows

4.4.2 Hydrologic Models

The hydrologic models for the reach of the South Platte River in the study area were developed by USACE in 1977. No updates to these models have occurred since 1977. As noted in Section 3, CDOT partnered with the CWCB to initiate hydrologic analyses in several key river systems impacted by the floods, including the South Platte River.

The primary tasks of the hydrologic analyses included:

- Estimate peak discharges that were believed to have occurred during the flood event at key locations along the study streams. Document the approximate return period associated with the September flood event based on current regulatory discharges.
- Prepare updated flood frequency analyses using available gage data and incorporate the estimated peak discharges from the September 2013 event.
- Compare results to updated flood frequency analyses and unit discharge information and estimate as appropriate.

The hydrologic analyses were divided into two phases of work. Phase 1 focused on the mountainous areas in the upper portion of the watersheds, extending from the headwaters of the Big Thompson River, Little Thompson River, St. Vrain Creek, Lefthand Creek, Coal Creek, and Boulder Creek watersheds to the mouth of their respective canyons. Phase 2 of the hydrologic analyses focused on the plains region of the Big Thompson River, Boulder Creek, Little Thompson River, and St. Vrain Creek from the downstream limit of the Phase 1 studies at the mouth of the

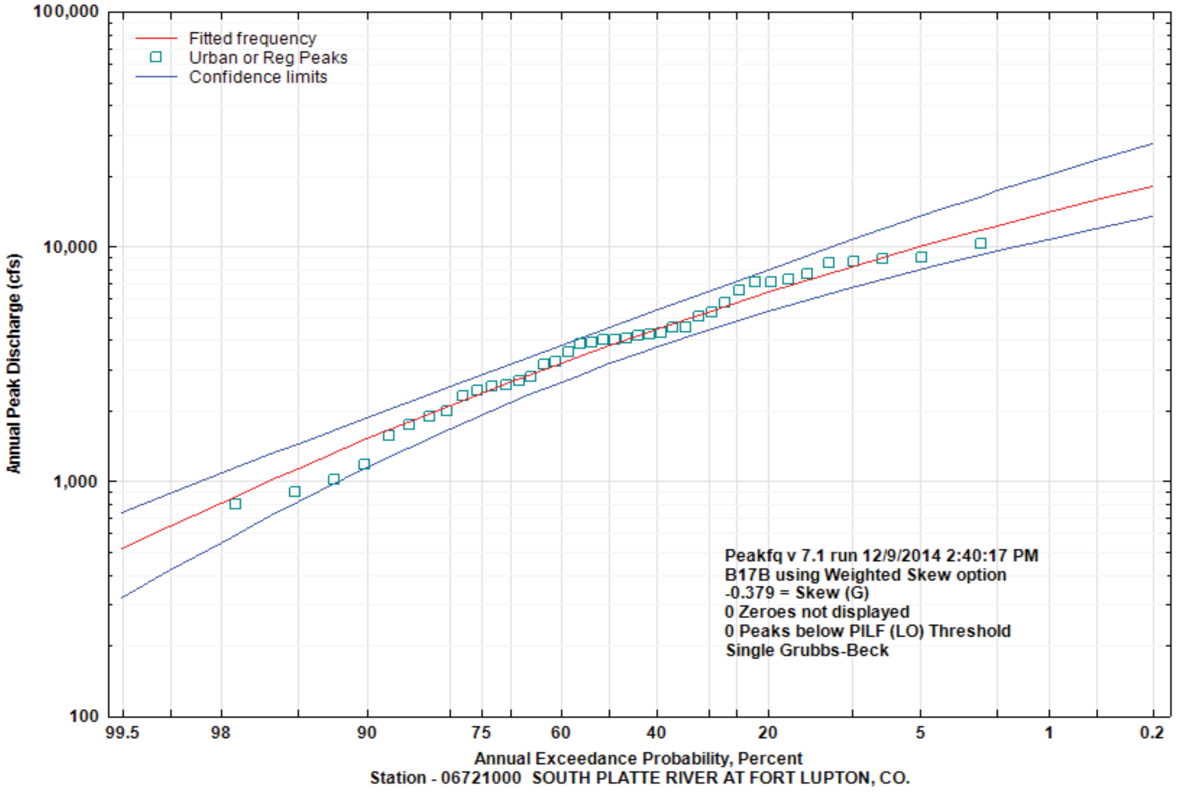

Figure 4-3. Ft. Lupton Gage Annual Exceedance Probability

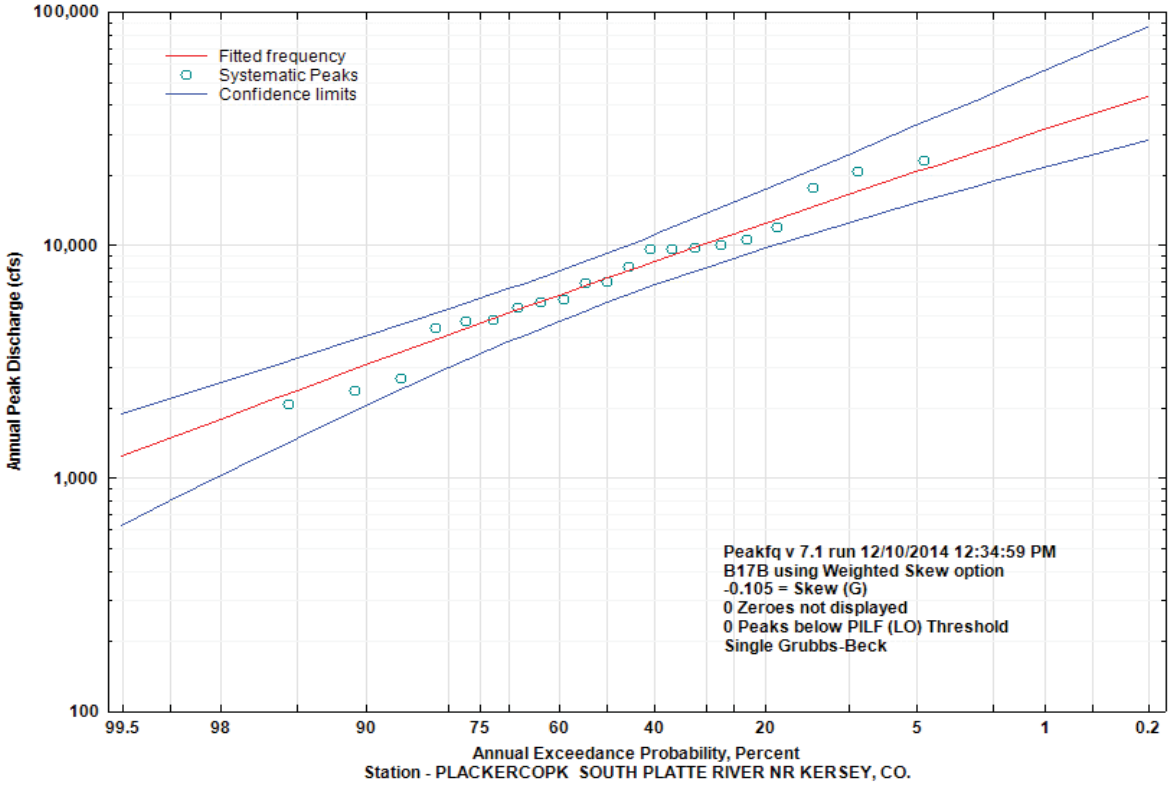

Figure 4-4. Kersey Gage Annual Exceedance Probability

canyons to the downstream confluences of the watersheds with their respective receiving streams. In addition, a hydrologic study of the South Platte River from Ft. Lupton to the Nebraska state line was included. The South Platte River study incorporates the flows from both the St. Vrain and Big Thompson.

Two independent analyses were performed to estimate the channel flows for the September 2013 flooding. The first based on empirical data and the second based on flood hydrograph modeling.

The first method involved using aerial photographs from CDOT and other sources, high water marks, and contour data developed from light detection and ranging (LiDAR) data. Both the LiDAR data and the aerial photograph were obtained shortly after the flood event. Discharge levels during the September 2013 flood were estimated by matching flood extents from aerial photographs in the cross-sections in HEC-RAS. The flow at a given cross-section was varied until water surface elevation and floodplain width was representative of the aerial photograph.

The second method comprised of combining flood hydrographs for the 2013 flood event. The hydrographs developed from the rainfall/runoff models for the St. Vrain and Big Thompson Rivers were used in conjunction with recorded stream gage hydrographs from Ft. Lupton and the Cache la Poudre to estimate the 2013 peak discharges on the South Platte River. The peak flow values at the confluence of St. Vrain River, Big Thompson River, and Cache La Poudre, were estimated by shifting the respective stream hydrographs by the estimated travel time between reach points. The hydrographs were then added to determine the peak flows at each location. The downstream portion of the model included the recorded gage data from Ft. Morgan and Julesburg, which were functional and collecting data during the 2013 Flood event.

The estimated discharges from both methods were compared to each other for relative accuracy. The estimated September 2013 flow values used in the Flood Frequency Analysis are a combination of hydrographic and photogrammetric methods. The upper reaches incorporated the data from the detailed hydrologic study as it was assumed to be a more accurate estimate of peak flows. The lower portions of the South Platte, from the Kersey Gage to Julesburg, used the flow estimates from the aerial photographic method. Between the gage sites, natural attenuation occurred. The peak flow in the river was reduced over time due to a spreading, or dispersion, of the flood wave. Reduction also occurred from storage within the channel and floodplain area.

CDOT's draft South Platte River Watershed, Phase 2 Hydrologic Evaluation report (2015) documents the Phase 2 hydrologic evaluation for the South Platte watershed from Ft. Lupton to the Nebraska state line. Because the report is still in draft form, the report has not been released to the general public yet, and the flows from that report have not been included in this Master Plan. However, the preliminary results show an increase in peak flows within the study area. Increases for the 100-year peak discharge range between 9 and 15 percent. The difference can be attributed to having a great period of record for the stream gages used in the flood frequency analysis. The original studies for the South Platte River were performed in the 1970s with updates, for some locations, in the late 1980s. This study had up to an additional 40 years of gage data. The increase in data sampling generally results in a better statistical estimation of peak flows.

The FEMA FIS references the USACE (1977) study when summarizing the discharges used to establish regulatory floodplains. A preliminary FIS being developed by FEMA also uses the same hydrologic models developed by the USACE. Two flow locations identified in the FIS are within the Master Plan study area (**Table 4-4** is derived from the preliminary FIS report).

Table 4-4. FEMA FIS 100-year Peak Flows

Location	Discharge, cfs
South Platte River at US Highway 85	32,500
South Platte River at 37th Street	32,500

4.4.3 Hydrologic Considerations

Hydrology used in future projects should consider the low (i.e., average) flow conditions, channel-forming flow, and design flood flow. The low flow and seasonal flow design discharges are important for sediment transport considerations while the flood flow is key to channel stability and regulatory flood elevations.

Low Flow

The low flow should be used to determine the minimum depth and velocities for critical fish species. Low-flow rates are particularly critical for aquatic habitat because they may not sufficiently inundate habitat areas.

Channel-Forming Flow

The seasonal flow should be used to determine the appropriate channel cross-sections for active channel within the main channel (see Channel Modifications in Section 7). Bankfull flow is often used as the representative discharge for channel design since it is the maximum discharge, typically between the 1.5- and 2-year events, that the channel can convey without overflow onto the floodplain. Seasonal flows are considered a reasonably accurate representation of the flow that will dominate the "active channel" form and process. This channel-forming discharge will have the greatest impact on channel planform, cross-sectional geometry, and bedforms.

A value of approximately 6,000 cfs should be used in the design of channel modifications. The velocity associated with this flow will be used as an indicator of the streambed stability and potential scour that may impact sediment transport characteristics.

Design Flood Flow

Design flood flow for future projects is the 1-percent recurrence interval storm event, which is approximately 32,500 cfs as identified by FEMA.

4.5 Hydraulics

In support of the Master Plan, CDM Smith has collected all available hydraulic data within the project area for use in informing the master planning effort. Similar to the hydrologic models, the hydraulic models for the reach of the South Platte River in the study area were developed by USACE in 1977. A digital version of the model was not available. As a result, the detailed hydraulic analyses were not performed. Furthermore, elevations and/or exact inundation limits from hydraulic model data were not completed except on a case-by-case basis to evaluate floodplain mitigation and management implications.

The USACE hydraulic study is the basis for the regulatory FEMA floodplains and the flood insurance rate maps (i.e., FIRMs). The FEMA floodplain maps designate flood hazard areas prone to flood damage during major flood events (i.e., 1 percent annual exceedance probability or 100-year). Upstream of the Highway 85 Bridge, FEMA uses an approximate methodology to define the extent of the 100-year flood event. Downstream of the Highway 85 Bridge to the confluence with the Poudre River, FEMA has performed a detailed study using a hydraulic model to define the floodplain extent. The detailed study also produces 100-year and 500-year (i.e., 0.2 percent annual exceedance probability) water surface elevations and delineation of the high-hazard zone (i.e., the floodway). **Appendix B** contains the approximate (i.e., Zone A) floodplain map for the region upstream of the Highway 85 Bridge. **Table 4-5** summarizes the best available data for the Middle South Platte River.

As part of the recovery effort for the 2013 September Flood, the CWCB developed a HEC-RAS model through the City of Evans. CDM Smith used this model to evaluate the floodplains of the effective discharge (discussed in the next section), the 10-year, and 50-year floods. **Figure 4-5** shows the approximate limits of flooding during these events.

Table 4-5. Summary Table of Existing Hydraulic Analyses in the Middle South Platte River Watershed

Study Name	Performed by	Date	Reach	Digital Copy (Y/N)	Comments
Special Flood Hazard Information Report, South Platte River, Volume I, Weld County Colorado	USACE	1977	10 (Partial), 11-18 (complete)	N	Regulatory
CWCB Flood Recovery Mapping	CWCB	2014	10-12 (complete), 13 (Partial)	Y	Post Flood

4.6 Geomorphology

The Middle South Platte River flows through an alluvial floodplain straddled by Quaternary alluvial terraces formed by episodic aggradation and degradation (Holliday 1987). Through the past two centuries the South Platte has undergone drastic changes in flow and sediment regime as a result of anthropogenic influences, including channel bank stabilization, construction of inline channel structures (i.e., diversions and bridges), irrigation of adjacent land, and control of upstream flows. These changes have caused a significant shift to river morphology, often referred to as river metamorphosis (Schumm 1969).

Based on accounts by explorers in the early 1800s, the South Platte River was a shallow, wide braided stream (Schumm 1985). As agricultural activities began to flourish in the mid to late 1800s, diversion of water decreased peak flows, and irrigation adjacent to the channel caused a rise in groundwater levels. Schumm (1985) provided the following description of the South Platte River and Arkansas River metamorphosis in Eastern Colorado:

"The hydrologic nature and type of floodplain vegetation of both rivers changed appreciably. As water tables rose, stream flows became perennial, flood peaks decreased, and floodplains were able to sustain denser vegetation. According to early descriptions, woody vegetation was sparse along the rivers. However, the floodplains are now occupied by cottonwoods, and it is apparent that there is more vegetation along the rivers today. This increase in vegetation probably reflects a higher water table, a result of increased irrigation activity. In addition, salt cedars invaded the Arkansas River Valley. These hydrologic and vegetative changes produced major morphologic changes along both rivers.

Figure 10 depicts the manner of the South Platte River metamorphosis, which is characterized by stream narrowing and floodplain construction by vertical accretion. The thalweg did not aggrade, but a floodplain was formed adjacent to the thalweg by island construction (Figure lOB) and channel filling. When flood peak decreased, vegetation quickly colonized areas below the mean high water level of the channel (Figure 1OC). In this way, newly formed bars were stabilized by vegetation and became islands. The channels, which surrounded these islands, no longer shifted, because vegetation had fixed the position of the banks and islands. Channel abandonment and island attachment to the floodplain followed (Figure lOD)."

Schumm's (1985) Figure 10 is included below as **Figure 4-6**. Today we see a meandering river that is further locked in place by extensive armoring of the banks. The large sediment load and construction of in-channel structures has resulted in sediment deposition, formation of medial bars, and a decrease in channel capacity. In addition, eroding cut banks bordered by a riparian forest are more common than cut banks along agricultural fields. Bank erosion is a natural process in a meandering river, as the South Platte used to be, so managing the sediment load becomes a balance between protecting private property and giving the room to move its water and sediment.

The current state of river morphology is discussed in more detail in Section 4.7.

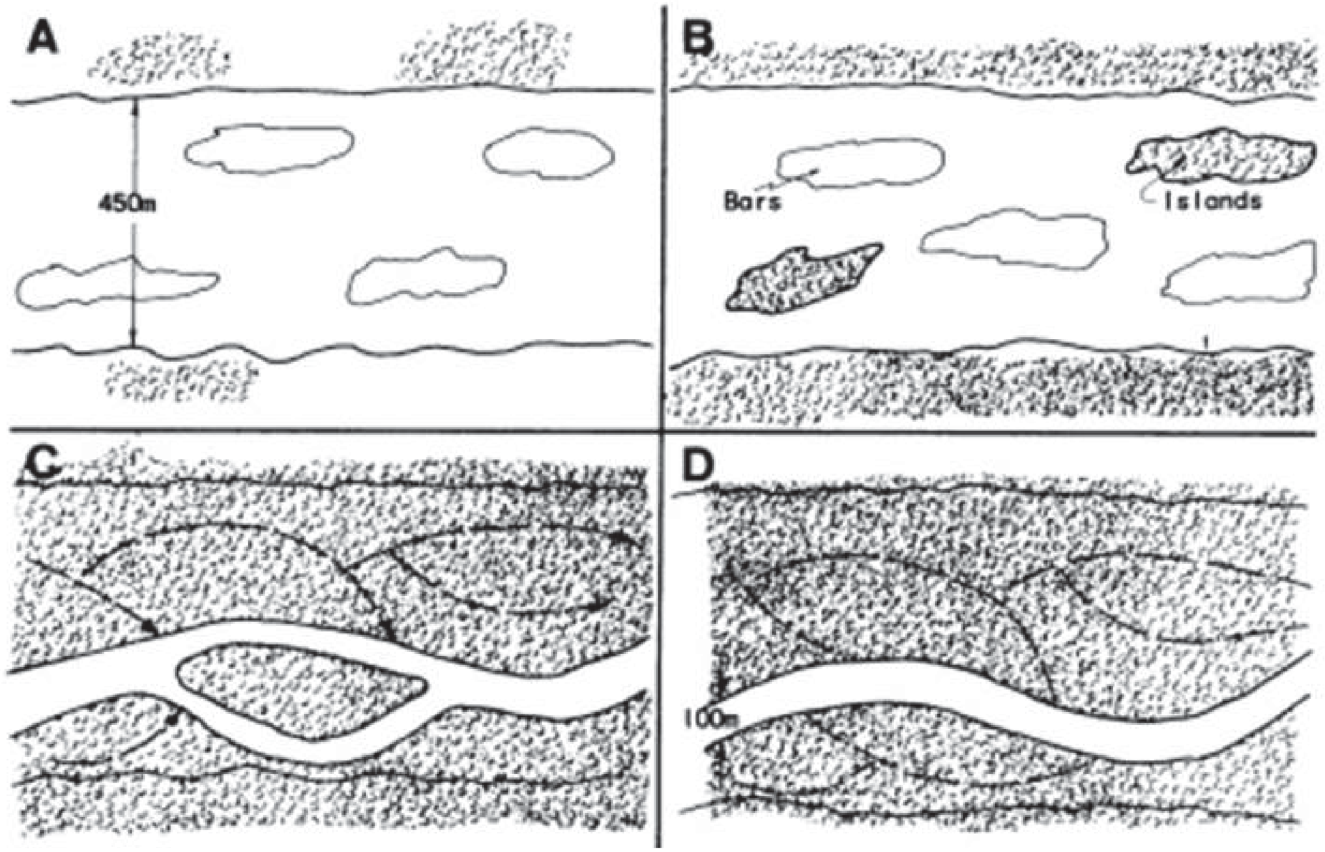

Figure 4-6. Model of South Platte River Metamorphosis. *A)* Early 1800s: discharge is intermittent, bars are transient. *B)* Late 1800s: discharge is perennial, vegetation is thicker on floodplain and islands. *C)* Early 1900s: droughts allow vegetation to establish itself below mean annual high water level, bars become islands, single thalweg is dominant. *D)* Modern channel: islands attached to floodplain, braided patterns on floodplain are vestiges of historic channels. (From Nadler & Schumm 1981.)

🟩 HEC-RAS Modeled Effective Discharge Floodplain

🟦 HEC-RAS Modeled 10 year Floodplain

🟦 HEC-RAS Modeled 50 year Floodplain

Service Layer Credits: Google Earth - imagery date 6/19/2014

South Platte River Restoration Master Plan

Figure 4-5: HEC-RAS Modeled Floodplains

COLORADO
Colorado Water
Conservation Board
Department of Natural Resources

CDM Smith

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4.6.1 Sediment Transport

In addition to carrying water, rivers may also transport sediment as small as sand and as large as boulders depending on the flow velocity. The September 2013 flood carried a tremendous volume of water and sediment, both of which contributed to significant deposition and minor lateral migration in unarmored banks. CDM Smith evaluated the sediment transport rate and effective discharge to assess the sediment characteristics of the river within the project area.

4.6.1.1 Transport Rate

Two locations were chosen to calculate the sediment transport rate through the project area: one location upstream of the Highway 85 Bridge and one location downstream of Riverside Park in the City of Evans. The Sediment Transport Capacity module in HEC-RAS was then used for calculating the sediment transport capacity using the Yang equation. The equation is presented in pages 12-44 and 12-45 of HEC-RAS Hydraulic Reference Manual (HEC 2010). Yang's equation was developed based on the assumption that the bed-material load is related to the rate of energy dissipation of the flow as an agent for sediment transport. This transport rate calculation method requires the user to enter particle size; however, as no site-specific particle size data was collected, the analysis was performed using gradations for medium sand and coarse sand as defined by the USACE in the manual for the HEC-6 program. This approach produces sediment characteristics that are reasonable in a sand bed channel such as the South Platte River.

The Sediment Transport Capacity module was set up to run for a variety of flows. Running the Sediment Transport Capacity module produced the sediment transport capacity at each cross-section location for different flow rates. **Figures 4-7 and 4-8** show the results at each location.

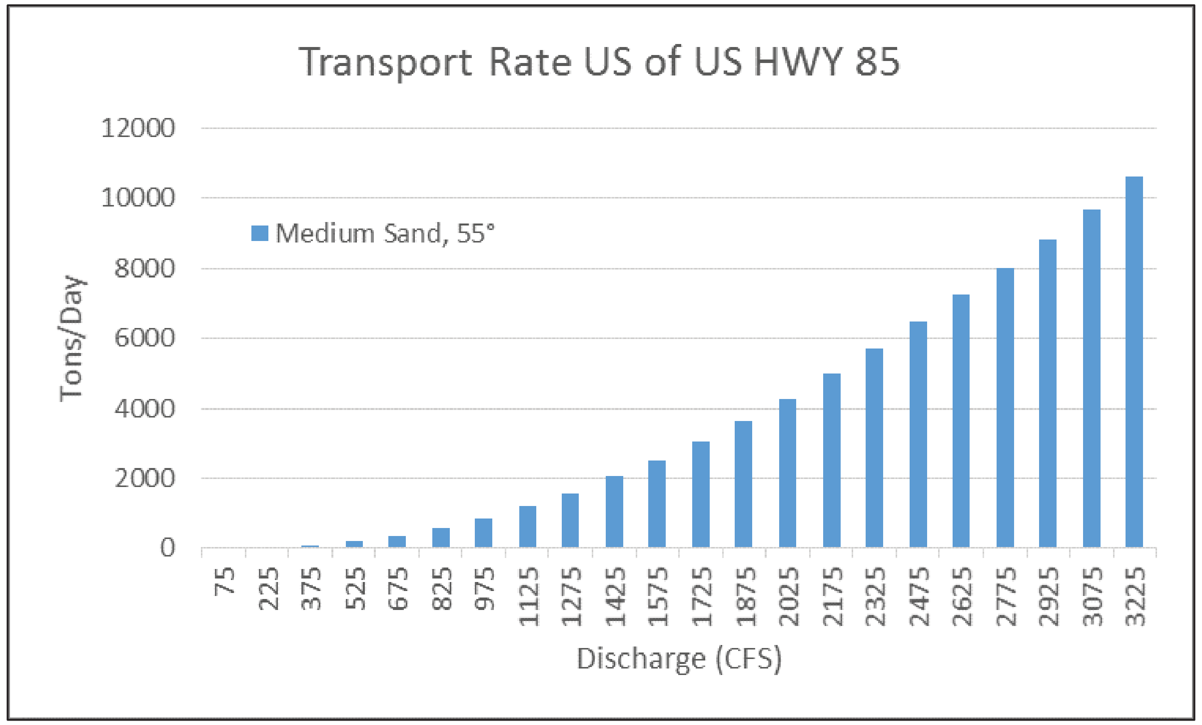

Figure 4-7. US Transport Rate

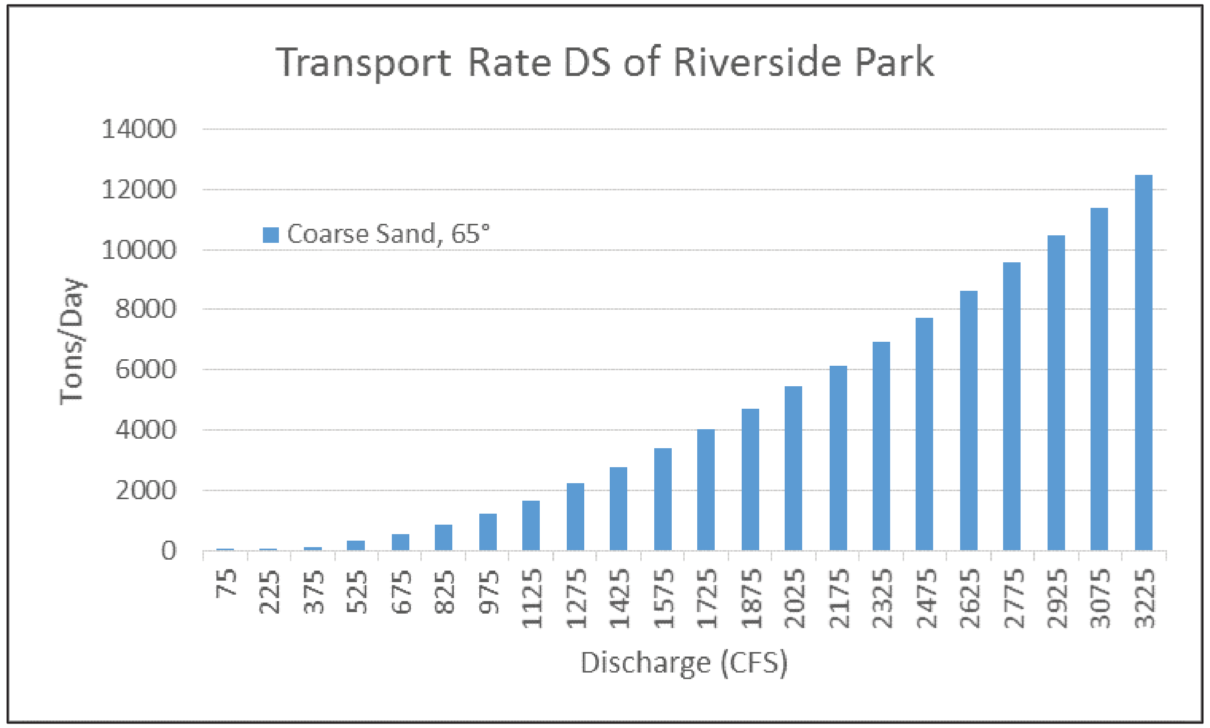

Figure 4-8. DS Transport Rate

The sediment transport capacity calculations along the study reach can be used as a surrogate for a detailed sediment transport modeling to predict the locations of streambed degradation (lowering of streambed) or aggradation (raising of streambed). **Figure 4-9** shows the sediment transport capacity distribution along the study reach calculated for 100-year peak discharge based on the assumption of medium sand streambed material. In the figure, the locations of abrupt increase in sediment transport capacity represent probable locations of streambed degradation, whereas the locations of abrupt decrease in sediment transport capacity represent probable locations of streambed aggradation. However, to predict the streambed profile changes correctly, sediment supply from the watershed also needs to be considered.

Note: a detailed sediment transport study will be performed in the future to better define the dominant sources of erosion and the degree to which each source (e.g., bank erosion, upstream bed load, etc.) contributes sediment to the project area. This study will build on the data collected as part of the Master Plan by identifying and quantifying discrete sources of sediment in upstream source areas, in the tributaries, and in the banks.

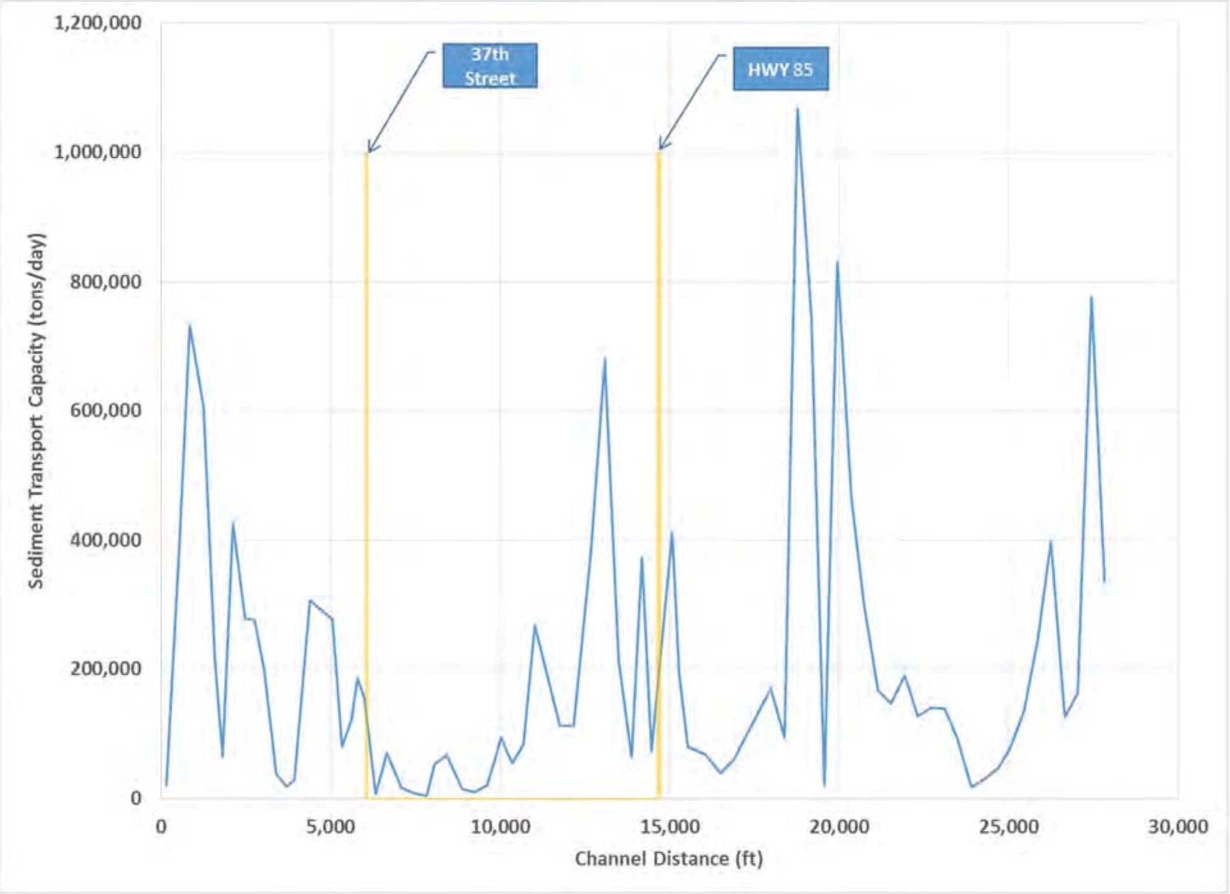

Figure 4-9. Sediment Transport Capacity Distribution along the Study Reach

4.6.1.2 Effective Discharge

Effective discharge is commonly defined as the discharge that transports the largest portion of the annual sediment yield over a period of years (Andrews 1980). CDM Smith performed an effective discharge calculation for the South Platte River near the City of Evans to predict the impact of alteration of watershed conditions with respect to sediment loads and hydrology on channel stability. The result of this analysis is an effective discharge between 600 cfs and 750 cfs. This range of flows are less than the annual flood predicted at the Kersey gage. Typical effective discharges are closer to the 2-year flood. The low to moderate flows indicate that recurrence intervals associated with effective discharges are on the low end of the 1- to 3-year recurrence intervals commonly reported in other studies. However, the high recurrence interval is probably representative of the large watershed, and recurrence intervals of effective discharges in smaller watersheds could be quite different. Note that the effective discharge is not typically a discharge associated with the most extreme flood events, which may carry large amounts of sediment load but occur infrequently.

An effective discharge associated with a more frequent flow means the river carries the most sediment over time at a flow rate less than the annual flood. In other words, the river transports most of its sediment load during low to moderate flow, and therefore, those flows do the most work in forming the channel. However, because the river transports sediment during a more frequent event it is an indicator of channel instability. Channel instability is the result of an imbalance in sediment supply and transport capacity. If the river were stable, excessive erosion or deposition would not occur. Since the river is unstable, more sediment is eroded from source areas (e.g., upstream watershed, steep-slope reaches, stream banks, etc.) and more sediment is deposited in depositional areas (e.g., mild-slope reaches, confluences, bridge crossings, etc.).

A stable stream is one where the channel is self-formed and where the characteristic dimensions and features of the channel do not change over engineering time scales (Thorne et al. 1996). This idea of a dynamically stable river allows for channel evolution over long-term time scales; as well as for short-term fluctuations, such as may be caused by a major flood or other events, that may interrupt channel stability and from which the channel has to recover. Due to the changes in and along the river – dams, bank armoring, diversion structures, and bridges – the river is no longer in equilibrium, which at least partially explains the significant deposition that occurs in the river.

The methodology for the effective discharge is described in **Appendix C**.

4.7 Channel and Stream Evolution Models

Channel Evolution Model (CEM) is a conceptual model that can be used to understand geomorphic responses of the study reaches to historic disturbances as well as future disturbances associated with proposed projects. Several adaptations of the CEM concept have been created based on progressions in research and a greater emphasis placed on habitat and ecosystem benefits. One of those adaptations was proposed by Cluer and Thorne (2013) and is referred to as a Stream Evolution Model (SEM), which is based on the CEMs originated by Schumm et al. (1984) and Simon and Hupp (1986). The following subsections describe the CEM and SEM concepts and use the SEM to help characterize and describe the Middle South Platte River.

4.7.1 Concept of CEM and SEM

Schumm et al. (1984) used field observations to generate a generalized five-stage channel evolution sequence for streams of the Yazoo Basin. In each reach of an idealized channel, Types I through V occur in series and, at a given location, will occur in the channel through time. The CEM describes the systematic response of a channel to base level lowering, and encompasses conditions that range from disequilibrium to a new dynamic equilibrium state. Simon and Hupp (1986) adapted the original five-stage CEM into a six-stage CEM, based on post-disturbance evolution of channelized streams in West Tennessee (**Figure 4-10**). The most obvious difference between the five-stage and six-stage CEMs is that Simon and Hupp include a "Constructed" stage between Stage I and II of the five-stage CEM, which considers the channelization, straightening, and re-sectioning of streams.

Cluer and Thorne’s (2013) proposed SEM builds on the Schumm et al. (1984) and Simon and Hupp (1986) CEMs. The SEM was developed by combining the stages featured in the original CEMs with a precursor stage to better represent pre-disturbance conditions and two successor stages to cover late-stage evolutionary changes missing from the original model (**Figure 4-11**). In addition, it replaces linear progression with an evolutionary cycle, and links habitat and ecosystem benefits to physical attributes and system responses to disturbance. Cluer and Thorne’s adaptation also recognizes that some streams do not experience all of the model stages and may experience “short-circuits” in the normal sequence or reach “dead-ends” where a stream gets stuck in one of the stages.

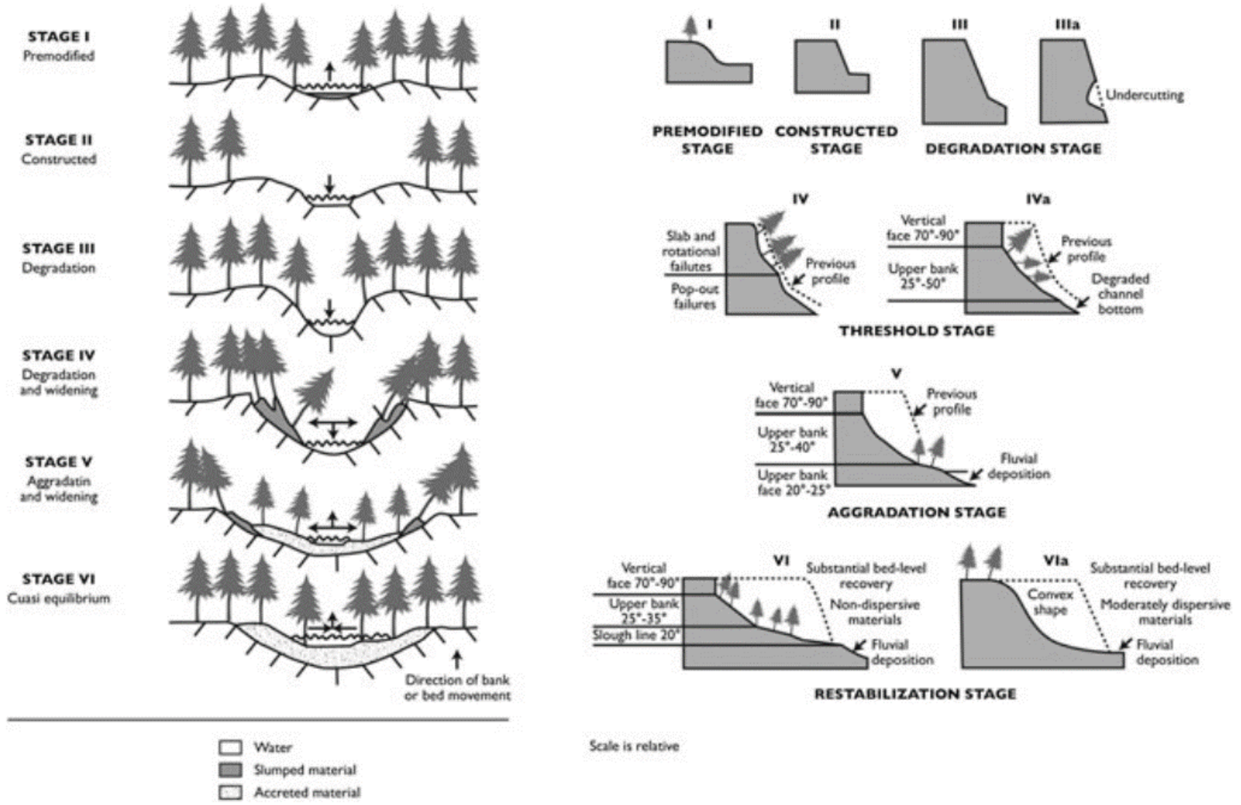

Figure 4-10. Channel Evolution Model (Simon and Hupp, 1986)

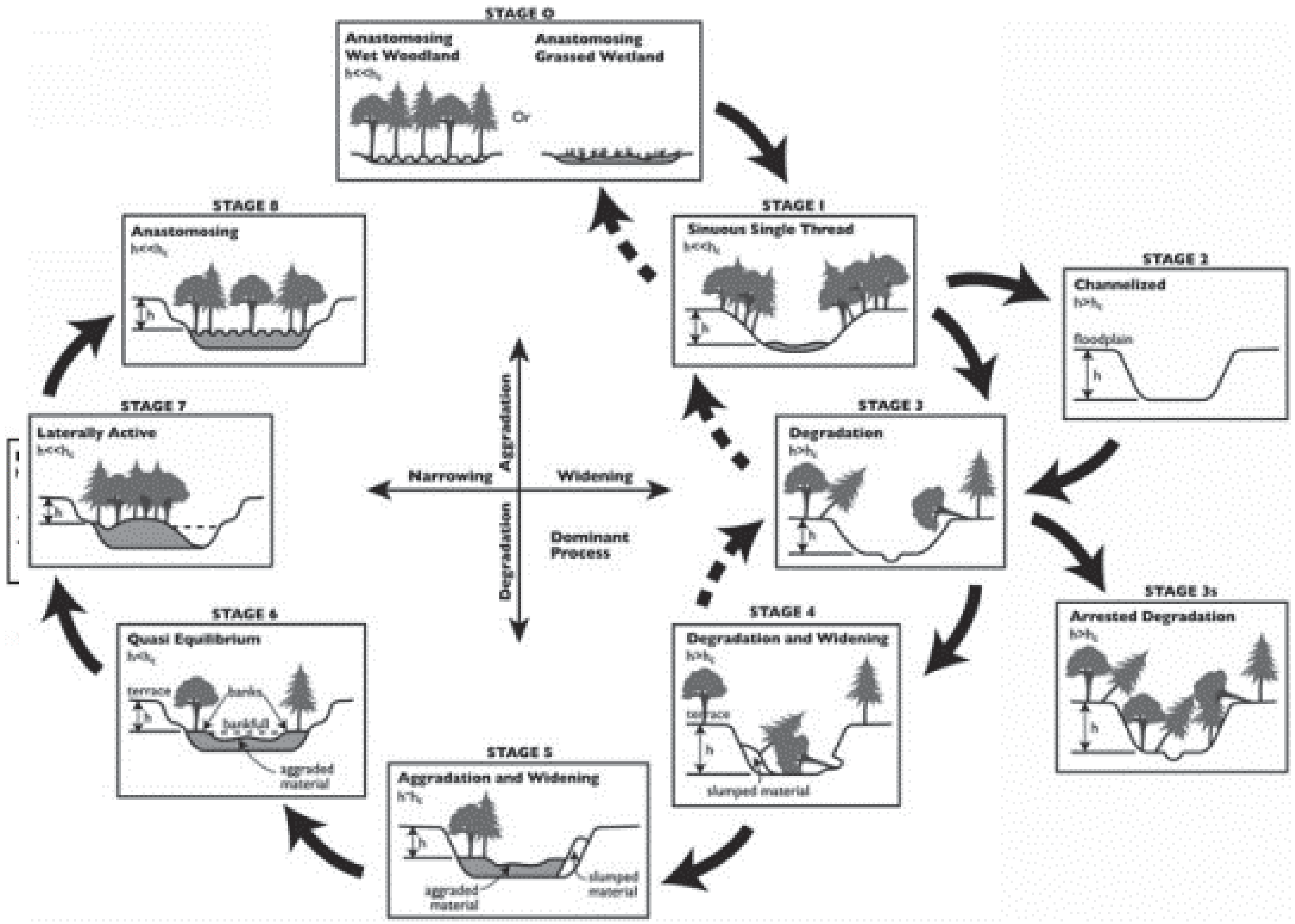

Figure 4-11. Stream Evolution Model (Cluer and Thorne 2013)

4.7.2 Application of SEM

Anthropogenic influences have had a profound effect on the Middle South Platte River as discussed in Section 4.4.4. Cluer and Thorne’s SEM provides more flexibility in characterization of river systems, even still, direct application to the Middle South Platte River system is difficult. Therefore, the SEM was used as a starting point to define the evolution of the river, but potential alternative evolutionary paths are suggested specific to the current conditions of the river. Additionally, the project area spans approximately 20 miles and the various reaches may be undergoing different processes and be in different evolutionary stages.

Aggradation is occurring throughout most of the project reaches which would suggest that the channel is in Stage 5 of Cluer and Thorne's SEM – Aggradation and Widening. Based on field observations the channel appears to be losing capacity because bank armoring prevents widening and the formation of medial bars within the current channel in effect reduces the channel width (note that some banks are not armored and there does appear to be some bank migration around channel bends). This suggests that the channel may be in a stage similar to Stage 3a – Arrested Degradation – where the channel is locked in place, but rather than degrading, it may be aggrading via mini-cycles of aggradation and degradation with formation of bars that are shifted and displaced during larger flow events. The loss of flow capacity associated with this cycle is problematic as significant flooding tends to occur on historic floodplains where agricultural development has occurred.

When designing the stream restoration projects, geomorphic responses of the study reaches to the proposed projects need to be investigated, based on a modified CEM or SEM to understand the potential evolutionary paths that the channel could take and ensure that it does not revert back to current trends. The projects should be designed to such that the trajectory of the river approaches an equilibrium stage, as much as possible.

The amount of data available to make these determinations is limited, therefore general concepts are presented to illustrate the evolutionary processes at work in the South Platte River. These concepts will be developed further in the follow-on sediment transport study.

Section 5

Flood, Fluvial Geomorphic, and Ecological Risk Assessment

As part of the Master Plan development process, CDM Smith, with the assistance of DHM, performed flood, fluvial geomorphic, and ecological risk assessments to better understand the areas of the watershed that are most vulnerable to future flood events. Each of the risk assessments were developed to identify the probability (potential) for damage from a flood event and possible magnitude of loss (severity) that may be caused by such an event. The risk assessments were completed on a reach-by-reach basis for the entire project area. The most vulnerable reaches were identified through the use of a scoring matrix developed to rate the potential for, and severity of, each type of impact for each reach. The following sections describe the methodology and results of each assessment. Additionally, **Tables 5-7 through 5-24** at the end of this section detail the overall observations and risk assessment results for each reach.

5.1 Flood Risk and Hazards Assessments

5.1.1 Methods

CDM Smith performed a flood risk assessment for the study area that incorporates parcel data from Weld County, FEMA preliminary flood maps (100-year floodplain), damage reported following the September 2013 flood, aerial photographs taken immediately following the September 2013 flood, CWCB post awareness flood maps, and the approximate 10-year flood map developed as part of this Master Plan.

5.1.2 Flood Risk Potential and Severity

5.1.2.1 Flood Risk Potential Scores

The potential for the river overtopping its inside banks and inundating the neighboring floodplain under various high flow conditions was classified for each reach within the project area. This determination was primarily based on review of the FEMA preliminary flood maps (100-year floodplain), aerial imagery taken in the aftermath of the September 2013 flood, and from the estimated floodplain for a 10-year event. Each reach was assigned a flood hazard potential classification and score of low (1), medium (2), or high (3) based on the area of highest potential risk of flooding hazards within a given reach. The following criteria were used to assign a flood hazard risk classification to each reach:

- **1 – Low Potential**
  - No buildings, roads, railroads, or other structures in the preliminary FEMA 100-year floodplain or inundated in the September 2013 flood.
- **2 – Medium Potential**
  - Structures including buildings, roads, and railroads in the preliminary FEMA 100-year floodplain or inundated in the September 2013 flood.
- **3 – High Potential**
  - Inundation experienced in September 2013 significantly exceeded preliminary FEMA 100-year floodplain; and/or
  - Additional constraints on the river (such as pinch points or undersize bridges) that increase the potential for flooding; and/or
  - The extent of the 10-year floodplain includes structures; hence higher potential for flooding impacts.

5.1.2.2 Flood Risk Severity Scores

The potential severity of damage or impact that may result from flooding was also classified for each reach within the project area. Each reach was assigned a flood risk severity classification and score of low (1), medium (2), or high (3) based on the area of highest risk of potential flood damage severity within a given reach. This determination was primarily based on the number of structures estimated to be within the preliminary FEMA 100-year floodplain and the estimated 10-year floodplain, as well as observations of the damage that resulted from the September 2013 flood. Parcel data provided by Weld County were utilized to estimate the number of structures in the FEMA regulatory 100-year floodplain and the estimated 10-year floodplain (for reaches 10-14 only due to available hydraulic model data); the results are shown in **Table 5-1**. The following criteria were used to assign a flood hazard severity classification to each reach:

- 1 – Low Severity
  - Floodplains consist of undeveloped riparian zones and/or agricultural lands, less than five insurable structures in the preliminary 100-year floodplain.
- 2 – Medium Severity
  - Roads and/or railroads in the 100-year floodplain.
  - Damages to roads reported as a result of the September 2013 flood.
  - Five to twenty insurable structures currently exist in the 100-year floodplain.
- 3 – High Severity
  - More than 20 insurable structures currently exist in the 100-year floodplain.
  - More than 10 insurable structures currently exist in the 10-year floodplain

Table 5-1. Insurable Structures within Floodplain

Reach	Approximate Number of Insurable Structures in 10-year Floodplain (data were not available for shaded reaches)	Approximate Number of Insurable Structures in Preliminary FEMA Floodplain
1		0
2		0
3		4-10
4		1-5
5		2-5
6		11-25
7		3-7
8		2-5
9		3-7
10	10-20	10-20
11	10-20	10-20
12	>10	>50
13	<10	10-20
14		0
15		5-10
16		10-20
17		0
18		0

5.1.3 Flood Risk Matrix and Results

Based on the flood risk potential and flood severity scores criteria discussed in Section 5.1.2, an overall rank of Low, Medium, or High risk was assigned to each reach according to the flood risk score matrix (**Table 5-2)**. The flood risk for each reach is shown in **Figure 5-1** on the following page.

Table 5-2. Flood Risk Score Matrix

Flood Potential	Flood Severity		
	1	2	3
1	Low	Low	Medium
2	Low	Medium	High
3	Medium	High	High

5.2 Fluvial Geomorphologic Assessments

5.2.1 Methods

CDM Smith performed a fluvial geomorphic assessment of the Middle South Platte River within the project area to quantify the potential for river channel movement and to evaluate locations and/or reaches that could experience erosion based on the history of river channel movement in this segment of the river. On November 18, 2014, CDM Smith conducted a reconnaissance survey along the Middle South Platte River from the confluence with St. Vrain Creek to the bridge at County Highway 54 (37th Street) in the City of Evans to document the geomorphic characteristics of the stream corridor. Each of the 18 reaches was characterized based on a number of geomorphic, hydrologic, and ecological factors and a semi-quantitative methodology was used to identify the most at-risk reaches and to prioritize reaches for project implementation (see Figure 3-1 for reach locations).

The fluvial geomorphic assessment incorporated aspects of several stream classification systems (e.g., Montgomery and Buffington [1998], and River Styles [Brierly and Fryirs 2005]) to determine the primary features of the river that may result in channel movement and damaging erosion. CDM Smith performed the assessment based on data collected during site visits, historical aerial imagery, and available GIS data. The analysis focused on identifying and mapping current and historical channel alignment, sinuosity, slope, and bank conditions. Assessment categories are defined below and the results are detailed by reach in Tables 5-7 through 5-24.

Each reach was assessed based upon the following attributes:

River Characteristics

- **Valley Setting:** Valley confinement serves as a primary control on the differentiation of geomorphic processes and describes the degree of freedom for channel meandering or migration. The three broad classifications include confined, partially confined, and laterally-unconfined, based on floodplain connection along the river.
- **Channel Planform:** Channel planform is defined as the configuration of the river in plan, or overhead, view. It was characterized using aerial photographs from June 2014. Changes in channel planform were evaluated using the available historical aerial photographs (1937, 1953, 1972, 1993, and 2014). Elements that define planform such as stream centerlines and bank lines were hand delineated from these aerial images. Refer to the historical aerial photograph comparison figures included on the CD attached to the Master Plan. The channel planform is also used to evaluate channel sinuosity. Sinuosity is defined as the ratio of the distance along the curved channel (channel length) to the straight-line distance along the valley (channel and valley length calculated using GIS). **Figure 5-2** shows graphical examples of various sinuosity.

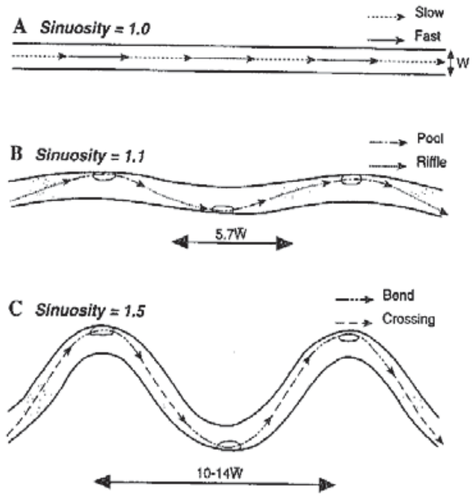

Figure 5-2. Graphical Depiction of Sinuosity (Thorne, Hey, and Newson 1997)

- **Cross Section Geometry:** Channel shape is determined by a combination of bed and bank features. Channel shape was determined from documentation collected during field visits. The entire project area exhibited asymmetrical cross-section geometry; i.e., at meander bends of the reaches, asymmetrical cross-sections formed by undercutting of the outside of the bends and formation of point bars inside of the bends.
- **Streambed Material:** The size and composition of the streambed material was determined based on observations recorded during field visits. The entire project area exhibited a fairly consistent sand bed channel.
- **Geomorphic Units:** Geomorphic units including: riffles, pools, point bars, and mid-channel bars were identified based on field observations and aerial photography. Additional observations such as floodplain connectivity and riparian condition were summarized when possible.
- **Bank Conditions:** Bank conditions were assessed based on site visits and aerial photographs. General observations included bank angles and type of bank protection; i.e., riprap, concrete rubble, car bodies, etc. Bank conditions are shown in **Figures C-1 to C-9** as well as in Tables 5-7 through 5-24**;** the symbology is described in **Figure 5-3.**

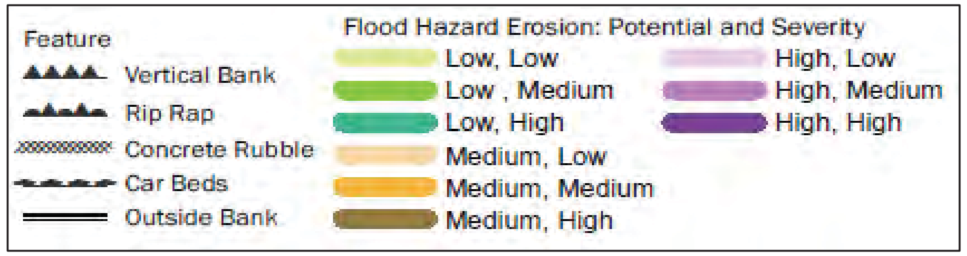

Figure 5-3. Symbology of Bank Conditions used for Figures C-1 through C-9.

Geomorphic Behavior

- **2013 Flood Response:** Using a series of aerial photographs produced in 2013 and 2014 showing pre-flood, flooded, and post flood conditions, CDM Smith assessed the direct impact of the large storm event on the channel, specifically in relation to migration or change in point and mid-channel bars. Location of bars post flood were hand delineated from aerial imagery and overlaid on pre-flood imagery to make general conclusions on bar migration. Flow rates for the 2014 imagery were higher compared to the 2013 imagery.
- **Geomorphic Behavior and Risks:** Based on site visits and historical aerials, CDM Smith assessed the geomorphic behavior over time and identified existing risks in the channel, including historic movement of sand bars and existing cut banks.
- **Sediment Transport Characteristics:** Based on site visits and historical aerials, CDM Smith assessed the primary sediment transport characteristics of each reach. Floodplain connectivity, sediment supply from upstream, and sediment transport capacity of the storm events affect the overall ability of the stream to transfer sediment.
- **Riparian Zone:** The conditions present in, and the connectivity of, the riparian zone were assessed based on aerial imagery, site visits, and existing wetland GIS coverages.

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Figure 5-1: Flood Risk

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CDM Smith

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5.2.2 Fluvial Geomorphic Risk Potential and Severity

5.2.2.1 Fluvial Geomorphic Risk Potential Scores

The potential for erosion of stream banks and for lateral migration on the outside of a river bend under future high flow conditions was investigated on a reach-by-reach basis using aerial photographs, topographic data, and field photographs collected during site visits. Each reach was assigned a risk potential rating and score of low (1), medium (2), or high (3) potential risk of damage caused by erosion and lateral migration based on the potential for planform change that would adversely affect infrastructure, insurable structures, or critical facilities. It should be noted that based on the extent of available observation data, there is some level of risk to all outside banks in the project area. The following criteria were used for each classification:

- **1 – Low Potential:**
  - Banks with armoring measures already in place (e.g., concrete rubble, car bodies, riprap).
  - Outside banks without current signs of erosion or outside banks where it was not possible to identify the current extent of bank erosion due to lack of site access and aerial imagery of insufficient quality to allow for bank assessment. Based on field observations, the majority of outside banks in the study area show some degree of erosion, as a result it was concluded that these banks are likely to have some potential risk for erosion and bank failure. It should be noted that while concrete rubble and car bodies do stabilize banks along these reaches, these techniques adversely impact the ecological functions of the river.
- **2 – Medium Potential:**
  - Areas where vertical banks less than 5 feet in height were identified in the field or from aerial imagery.
- **3 – High Potential:**
  - Areas with vertical banks greater than 5 feet in height were identified in the field.
  - Areas where lateral migration was identified using historic aerial imagery.

5.2.2.2 Fluvial Geomorphic Risk Severity Scores

The potential severity of impacts that may result from stream bank erosion or stream bed migration that could occur under future high flow conditions was reviewed independently of the risk of potential occurrence of damage in each reach. Each reach was assigned a risk severity classification and score of low (1), medium (2), or high (3) potential severity of damage based on the potential impact to infrastructure, insurable structures, or critical facilities. The following criteria were used for each classification:

- **1 – Low Severity**
  - Erosion and lateral migration will primarily encroach on riparian zones or vacant land only.
- **2 – Medium Severity**
  - Erosion and lateral migration will potentially encroach on agricultural lands. A minimal riparian buffer currently exists.
- **3 – High Severity**
  - Erosion and lateral migration will potentially encroach on roads, above ground facilities (e.g., oil/gas tanks, produced water vessels, etc.), homes, or other structures observed in the field or aerials.
  - Some riparian buffer may currently exist in areas in this classification, but if significant lateral migration occurred, impacts to developed lands would be substantial.

5.2.3 Fluvial Geomorphic Risk Matrix and Results

Based on the fluvial geomorphic risk potential and fluvial geomorphic risk severity scores criteria described in Section 5.2.2, an overall rank of Low, Medium, or High risk was assigned to each reach according to the fluvial geomorphic risk score matrix (**Table 5-3)**. The fluvial geomorphic risk for each reach is shown in **Figure 5-4** on the following page.

Table 5-3. Fluvial Geomorphic Risk Score Matrix

Fluvial Geomorphic Potential	Fluvial Geomorphic Severity		
	1	2	3
1	Low	Low	Medium
2	Low	Medium	High
3	Medium	High	High

5.3 South Platte River Ecological Evaluation

5.3.1 Methods

DHM conducted an ecological evaluation to assess the overall condition of the stream, riparian areas, and instream habitats within the project area. DHM used the Stream Visual Assessment Protocol Version 2 (SVAP2), developed by the NRCS (2009), to assess ecological conditions and generate ecological risk scores for each reach within the project area. This protocol is a qualitative assessment tool and is designed for visual assessments of ecological elements within the stream corridor (**Table 5-4**). However, due to the lack of public access along portions of the Middle South Platte River within the study area, the SVAP2 assessment also incorporated data from various state and federal agencies, aerial and site photographs, and personal correspondence with biologists. Each of the 18 reaches within the study area was evaluated individually based on the 13 elements shown in Table 5-4.

Table 5-4. SVAP2 Ecological Elements

Ecological Elements	Element Criteria
1. Channel Condition	Evaluates the channel relative to the floodplain
2. Hydrologic Alteration	Extent of change to streamflow versus a natural flow regime
3. Bank Condition	Stability of banks; bank failure versus protected banks
4. Riparian Area Quantity	Width of riparian area in relation to bankfull width
5. Riparian Area Quality	Riparian plant diversity; native versus non-native; age class
6. Canopy Cover	Percentage of overhanging vegetation over the stream
7. Water Appearance	Compares turbidity and color
8. Nutrient Enrichment	Evaluates presence of excessive algal and aquatic plant growth
9. Manure or Septic Sources	Identifies sources of manure and human waste
10. Pools	Number and depth of pools
11. Barriers to Movement	Identifies barriers to movement of aquatic species; seasonally or permanently
12. Fish Habitat Complexity	Identifies and quantifies different habitat types
13. Aquatic Invertebrate Habitat	Identifies and quantifies different habitat types

The ecological assessment of the South Platte River Corridor completed as a part of this investigation provides clear indication that the system has changed drastically throughout the decades of high intensity uses influenced by agriculture, industry, transportation, and other endeavors. The efforts to harness the river have modified the ecological context significantly and thoroughly. By studying the ecological conditions and providing a conditional analysis and description of the ecological resources of the multiple reaches of this system, some very apparent themes begin to develop about the current ecological conditions of the entire study area. Those themes are all centered around what the ideal future condition of the riparian zones and associated floodplain zones of this hard working river should be.

Note SVAP2 proposes that "excellent" areas are at lower risk to environmental degradation when in fact the opposite may be true, especially if located on private land subject to development. However, SVAP2 was deemed to be the most appropriate tool to meet the goals of the master plan.

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South Platte River Restoration Master Plan

Figure 5-4: Fluvial Geomorphic Risk

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The elements in Table 5-4 were evaluated separately for each bank of the river ("left" and "right," looking downstream) and were assigned a score between 1 and 10 based on the ecological conditions described in **Table 5-5**. Scores given independently for each side of the river were averaged together and recorded. Scores for riparian area quantity and riparian area quality were recorded separately for each bank and were not averaged. The final score for each reach was calculated by averaging all scores for a given reach (sum of ecological scores / number of ecological elements recorded).

Table 5-5. SVAP2 Ecological Condition Scores

Class	Ecological Condition Score	Description
Severely Degraded	**1 - 2.9**	Channel has little or no floodplain connection with steep and failing streambanks, or large portions of the bank are covered with riprap; riparian and floodplain rarely inundated, bankfull or higher flows rarely occur, with an altered flow regime; riparian corridor is narrow or not present with large gaps in vegetation and invasive species are widespread; water appears green and input from human activities present; lack of pools and habitat diversity for aquatic species; contains barriers to aquatic species movement.
Poor	**3 - 4.9**	Channel is actively incising with little floodplain connection, bank failures are evident, with some natural protection, fabricated structures cover more than half of the bank; riparian and floodplain inundated every 6-10 years with developments present; riparian area is slightly wider with smaller vegetation gaps and invasive plant species are common; lacks pools of significant depth and contains a small quantity of diverse habitat types for aquatic species; contains barriers that restrict aquatic species movement.
Fair	**5 - 6.9**	Channel and banks are moderately unstable with some natural protection, fabricated structures are less predominant, channel has some connectivity to the floodplain; riparian corridor with gaps of vegetation along the reach with invasive plant species present; water quality is fairly clear with less algal growth; limited habitat complexity and few pools of significant depth; contains barriers that restrict aquatic species movement.
Good	**7 - 8.9**	Channel and banks show signs of instability with some recovery taking place, the active channel and floodplain are connected in most areas and bankfull flows occur every 3-5 years, with little effect on flow regime from developments in the floodplain; riparian area is wide composed of predominantly native species with few vegetation gaps; clear water with limited algal growth; pools of significant depth, separated by riffles and numerous types of aquatic habitat present; barriers seasonally restrict aquatic species movement.
Excellent	**9 - 10**	Channel and banks are stable with continuous attachment to the floodplain, bankfull flows occur every 1-2 years; riparian area is wide with diverse vegetation and various age classes; water is clear or appropriate for the system; aquatic habitat types are diverse and numerous with numerous pools; no barriers to aquatic species movement are present.

5.3.2 Ecological Risk and Restoration Priority Scores

5.3.2.1 Ecological Risk Scores

Each reach was given an ecological risk value based on the score acquired during SVAP2 evaluation. The following criteria were used for each classification:

- **1 – Low ecological risk**
  - Ecological conditions score ranged from SVAP2: 6.7 to 10.0.
- **2 – Medium ecological risk**
  - Ecological conditions score ranged from SVAP2: 3.4 to 6.6.
- **3 – High ecological risk**
  - Ecological conditions score ranged from SVAP2: 0 to 3.3.

5.3.2.2 Ecological Restoration Priority Scores

A restoration priority level was assigned to each reach based on ecological condition scores, land ownership, and whether restoration projects would be effective in establishing a healthy, functioning ecosystem. The following criteria were used for each classification:

- **1 – Low restoration priority**
  - Areas located on private land that are degraded, have little potential for restoration, and would not benefit from restoration activities.
- **2 – Medium restoration priority**
  - Reaches located on private land and have good potential for restoration and would benefit greatly from restoration or preservation activities.
- **3 – High restoration priority**
  - Reaches located on public land and have good potential for restoration and would benefit greatly from restoration or preservation activities, or reaches on public land that would provide outstanding benefit ecologically.

It should be noted that the ecological restoration priority scores give greater weight to restoration projects on public lands. As such, private lands cannot be given a restoration priority score higher than 2. However, restoration and protection of private lands is as valuable as restoration of public lands but more difficult for the Alliance to manage.

5.3.3 Ecological Risk Matrix and Results

An overall rank of Low, Medium, or High risk was assigned to each reach according to the ecological potential and severity scores shown in the ecological risk score matrix (**Table 5-6)**. The ecological risk for each reach is shown in **Figure 5-5**.

Table 5-6. Ecological Risk Score Matrix

Ecological Risk	Ecological Restoration Potential		
	1	2	3
1	Low	Low	Medium
2	Low	Medium	High
3	Medium	High	High

5.4 Ecological, Fluvial Geomorphic, and Flood Risk Assessment Results

Tables 5-7 through 5-24 present the results of the fluvial geomorphic, flood risk, and ecological risk assessments for each reach within the project area. The tables summarize the data collected during site visits and from aerial imagery and GIS sources for each reach within the study area. The tables include site photos and planview maps describing streambank conditions. The overall risk score for each reach is the sum of the respective scores for flood risk and severity, fluvial geomorphic risk and severity, and ecological risk and restoration priority (see Sections 5.1, 5.2, and 5.3).

⊗ Diversion Structures
Stream
Canal/Ditch
Railroad
Highway

Ecological Risk
🟩 Low
🟨 Medium
🟥 High

0 1.25 2.5 5
Miles

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Figure 5-5: Ecological Risk

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Table 5-7. Reach 1: Confluence with St. Vrain Creek to 8,000 Feet Downstream

RIVER CHARACTERISTICS	
Valley Setting	Partially confined with partially connected floodplain.
Channel Planform	Channel has low sinuosity of 1.14. The channel is generally single thread, but braiding occurs at low flows. Historical aerials show that the channel sinuosity has varied from 1.22 in 1936 to 1.13 in 2013 (pre-flood). Historic aerials show that bank width has generally narrowed since 1937.
Cross Section Geometry	Asymmetrical. Typical channel width 220 feet.
Dominant Streambed Material	Sand
Geomorphic Units	Multiple riffles consisting of one large one and some smaller ones. Pools between 1 and 2 feet deep occur on the outside of bends and downstream of riffles. Point bars are typical on the inside of bends, and mid-channel bars form in straight sections. Partially connected floodplain with *Populus deltoides (*eastern cottonwood) galleries. Minimal large woody debris.
Bank Condition	Short section of riprap bank protecting railroad. Cut banks occur on the outside of bends and are typically around 6 feet high.
RIVER BEHAVIOR	
2013 Flood Response	Minor lateral migration. Sandbars shifted slightly downstream.
Geomorphic Behavior and Risks	Minor migration of mid-channel bars, point bars are relatively constant. Cut banks on outside of bends. Bank cutting appears to have started before the 2013 flood.
Sediment Transport Characteristics	Generally the reach is in stable condition (i.e., sediment transport capacity of the reach is balanced with sediment supply), but some fine sediment is introduced from cut banks. Low flows are generally confined to a single thread, concentrating on the outside of meander bends and in pools. Bankfull flows will generally inundate secondary channels and transfer sediment downstream, re-forming bars and banks. Flood flows will inundate all channel features and extensive areas of the floodplain, depositing fine sediments and debris in floodplain.
Riparian Zone	The left bank is heavily manipulated with a highly modified channel, and predominantly gravel substrate lacking cover of any kind. The right bank contains a more intact riparian corridor with a European pasture grass understory, with groupings of sparse and intermittent *P. deltoids* and some intact *Symphoricarpos* (snowberry) understory. The middle of the reach includes more complex vegetation island systems that have a more intact vegetation complex with a mixed age over story and moderate size class diversity. *Salix exigua* (sandbar willow)*, Salix amygdaloides* (peachleaf willow) identified as important back edge species, were found on numerous cut banks. Small off-channel wetland systems were observed in two locations.
Flood Risk	There are no insurable structures in floodplain. An abandoned railroad along the left bank is located in the FEMA Preliminary Flood Zone (AE). Review of post-flood aerials and CWCB post-flood awareness mapping, it does not appear that the railroad was impacted in the September 2013 event. Historically farmed agricultural lands are also located within the floodplain. ***Risk Score: 3 (Potential: Low Severity: Medium)***
Fluvial Geomorphic Risk	Risk of lateral migration and erosion along unprotected banks. An abandoned railroad runs along the left bank of the river, which is partially protected by riprap. ***Risk Score: 4 (Potential: Medium Severity: High)***
Ecological Risk	*SVAP2 Average Score: 3.6 (Poor)* Reach 1 contains the confluence with St. Vrain Creek, making it a high priority reach for restoration, particularly the confluence area. The north bank riparian area is thin and lacks vegetation in general and reconnecting the floodplain in the area between the two rivers would benefit wildlife greatly. The lower portion of Reach 1 also is a high priority location because of two pre-existing small off channel wetland systems along the south bank. ***Risk Score: 5 (Risk: Medium; Restoration Priority: High)***
Additional Field Notes	The reach ends at an old road crossing. Wooden piers are still visible.
Restoration Recommendations	There may be opportunities to increase riparian vegetation and riparian zone to improve habitat, stabilize banks, and increase flood attenuation. Wetland plantings, and reattachment of the floodplain could help to trap sediment in this area.
Overall Risk Score	**13-Medium**
	
	

Table 5-8. Reach 2: 8,000 Feet Downstream of the Confluence with St. Vrain Creek to 13,820 Feet Downstream

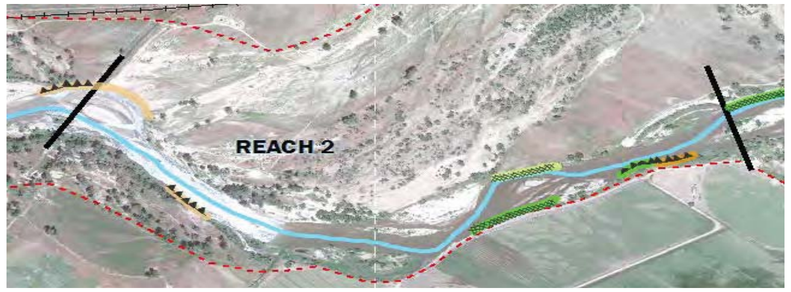
RIVER CHARACTERISTICS	
Valley Setting	Unconfined.
Channel Planform	Channel has low sinuosity of 1.19. The channel is generally single thread, but braiding occurs at low flows. Historical aerials show that the channel sinuosity has varied from 1.14 in 1937 to 1.27 in 2013 (pre-flood). Historic aerials show that bank width has generally narrowed since 1937.
Cross Section Geometry	Asymmetrical. Typical channel width 150 feet.
Dominant Streambed Material	Sand
Geomorphic Units	One small riffle. Small pools form on the outside of bends. Point bars are typical on the inside of bends, and mid-channel bars form in straight sections. Partially connected floodplain with eastern cottonwood galleries.
Bank Condition	Sections of concrete rubble revetment stabilizing banks along agricultural lands on either side of the river. Cut banks are occurring where floodplain is not connected. Cut banks are typically about 6 feet high.
RIVER BEHAVIOR	
2013 Flood Response	Channel did not migrate significantly. Sandbars shifted laterally near upstream end of the reach.
Geomorphic Behavior and Risks	Minor migration of mid-channel bars, point bars are relatively constant. Cut banks on outside of bends. Bank cutting appears to have started before the 2013 flood. This reach has a risk of lateral erosion where banks are unprotected. An access road for the adjacent agricultural land on the right bank is protected by riprap. The reach begins at an old bridge crossing. Wooden piers are still visible. The piers are causing sediment deposition to occur, and log jams to form.
Sediment Transport Characteristics	Generally the reach is in stable condition, but some fine sediment is introduced from cut banks. Low flows are generally confined to a single thread, accumulating on the outside of meander bends and in pools. Bankfull flows will generally inundate secondary channels and transfer sediment downstream, re-working bars and banks. Flood flows will inundate all channel features and extensive areas of the floodplain, depositing fine sediments in floodplain.
Riparian Zone	The riparian zone is composed of eastern cottonwood overstory with mostly declining individuals, lacking regeneration of juvenile eastern cottonwood. There is no significant understory (woody). Understory in right bank riparian corridor includes an intact *Bromus* grass understory from remnant agricultural applications, which creates good cover. The overstory layer consists of moderate age class eastern cottonwood forest with evidence of overall decline from live canopy indicators. Woody understory is 10% of overall actual cover. There are also significant quantities of noxious vegetation within this reach.
Flood Risk	There are no insurable structures in floodplain. ***Risk Score: 2 (Potential: Low Severity: Low)***
Fluvial Geomorphic Risk	Risk of lateral migration and erosion along unprotected outer banks. Small section of vertical bank adjacent to farmland. ***Risk Score: 4 (Potential: Medium Severity: Medium)***
Ecological Risk	*SVAP2 Average Score: 3.6 (Poor)* Reach located entirely on private property with riprap restoration potential. ***Risk Score: 3 (Risk: Medium Restoration Priority: Low)***
Additional Field Notes	Concrete rubble revetment is stabilizing banks along properties on both sides of the river.
Restoration Recommendations	Floodplain reconnection through floodplain benches and riparian plantings particularly along the south bank where the riparian corridor is intact but lacking regeneration of woody species. Reach lacks established riparian buffer. Cover and vegetate existing rip-rap. Remove bridge piers.
Overall Risk Score	**9-Low**
	
	

Table 5-9. Reach 3: 13,820 Feet Downstream of the Confluence with St. Vrain Creek to 18,490 Feet Downstream

RIVER CHARACTERISTICS	
Valley Setting	Unconfined.
Channel Planform	Channel has low sinuosity of 1.27. The channel is generally single thread, but braiding occurs at low flows. Historical aerials show that the channel sinuosity has varied from 1.14 in 1937 to 1.27 in 2013 (pre-flood). Historic aerials show that bank width has remained relatively constant since 1937.
Cross Section Geometry	Asymmetrical. Typical channel width 200 feet.
Dominant Streambed Material	Sand
Geomorphic Units	No apparent riffles. Small pools form on the outside of bends. Point bars are typical on the inside of bends, and mid-channel bars form in straight sections. Partially connected floodplain with eastern cottonwood galleries.
Bank Condition	Sections of concrete rubble revetment stabilizing banks along agricultural lands on either side of the river. Cut banks are occurring where floodplain is not connected. Vertical banks are typically about 4 feet high.
RIVER BEHAVIOR	
2013 Flood Response	Channel did not migrate significantly. Sandbars appear to have shifted downstream.
Geomorphic Behavior and Risks	Minor migration of mid-channel bars, point bars are relatively constant. Cut banks on outside of bends. Bank cutting appears to have started before the 2013 flood.
Sediment Transport Characteristics	Generally the reach is in stable condition, but some fine sediment is introduced from cut banks. Low flows are generally confined to a single thread, accumulating on the outside of meander bends and in pools. Bankfull flows will generally inundate secondary channels and transfer sediment downstream, re-working bars and banks. Flood flows will inundate all channel features and extensive areas of the floodplain, depositing fine sediments in floodplain.
Riparian Zone	The left bank has very thin, if any riparian corridor. The intermittent eastern cottonwood overstory consists of mostly declining individuals. There is a shrub sandbar willow component that is established on some of the sand bars. The right bank riparian is somewhat wider, and contains a side channel area mid-reach with some regeneration and a fair amount of a shrub understory, with intermittent connection to the flood plain.
Flood Risk	Estimated 4-10 insurable structures in the floodplain). Review of post-flood aerials and CWCB post-flood awareness mapping indicates that structures experienced flooding in September 2013. ***Risk Score: 4 (Potential: Medium Severity: Medium)***
Fluvial Geomorphic Risk	Risk of lateral migration and erosion along unprotected outer banks. Historical aerials show history of lateral migration along unprotected banks. ***Risk Score: 4 (Potential: High Severity: Low)***
Ecological Risk	*SVAP2 Average Score: 3.4 (Poor)* The southern bank provides good habitat and is a potential location to reestablish a regular floodplain connection. *Risk Score: 4 (Risk: Medium Restoration Priority: Medium)* Eastern cottonwood overstory is in overall decline. Noxious vegetation present on sand bars. ***Risk Score: 3.4 (Poor)***
Additional Field Notes	Concrete rubble revetment is stabilizing banks along properties on both sides of the river. Partial avulsion is occurring at the downstream end of the reach.
Restoration Recommendations	Right bank maintains a potential site for connection of the floodplain due to existing off channel wetland and side channel areas in place. Promoting the health of these areas and creating a wetland system that is regularly inundated would benefit aquatic and terrestrial wildlife.
Overall Risk Score	**12-Medium**
	
	

Table 5-10. Reach 4: 18,490 Feet Downstream of the Confluence with St. Vrain Creek to the Union Ditch Co. Diversion Structure

RIVER CHARACTERISTICS	
Valley Setting	Unconfined.
Channel Planform	Channel has sinuosity of 1.29. The channel is generally single thread, but braiding occurs at low flows. Historical aerials show that the channel sinuosity has increased over time, with a sinuosity of 1.15 in 1937 to 1.31 in 2013 (pre-flood). Historic aerials show that bank width has remained relatively constant on the left bank since 1937, but has become a more constricted on the right bank.
Cross Section Geometry	Asymmetrical. Typical channel width 200 feet.
Dominant Streambed Material	Sand
Geomorphic Units	No apparent riffles. Small pools form on the outside of bends. Point bars are typically on the inside of bends, and mid-channel bars form in straight sections. A large section of this reach has very good riparian vegetation with good floodplain connection. Otherwise partially connected floodplain with eastern cottonwood galleries.
Bank Condition	Sections of concrete rubble revetment stabilizing banks at oil tanks and along property on both sides of the river. A stretch of bank is protected by car bodies. Cut banks are occurring where floodplain is not connected. Cut banks are typically about 4 feet high.
RIVER BEHAVIOR	
2013 Flood Response	Channel did not migrate significantly. Sandbars appear to have shifted downstream.
Geomorphic Behavior and Risks	Minor migration of mid-channel bars, point bars are relatively constant. Cut banks on outside of bends. Bank cutting appears to have started before the 2013 flood.
Sediment Transport Characteristics	Generally the reach is in stable condition, but some fine sediment is introduced from cut banks. Low flows are generally confined to a single thread, accumulating on the outside of meander bends and in pools. Bankfull flows will generally inundate secondary channels and transfer sediment downstream, re-working bars and banks. Flood flows will inundate all channel features and extensive areas of the floodplain, depositing fine sediments in floodplain.
Riparian Zone	Left bank has a fairly wide riparian zone with an overstory canopy consisting mainly of eastern cottonwood with some parts of the reach exhibiting some regeneration. Herbaceous cover is growing between the car beds, which provides for more bank stability. There is also a back water channel that begins in Reach 5 and continues upstream into Reach 4. This back water channel provides excellent habitat opportunities for migratory birds and amphibians. The south bank also contains a wider riparian and consists of a moderate age class eastern cottonwood through most of the corridor however there are large gaps in the overstory.
Flood Risk	Estimated between one to five insurable structures in the floodplain. ***Risk Score: 3 (Potential: Medium Severity: low)***
Fluvial Geomorphic Risk	Risk of lateral migration and erosion along unprotected outer banks. ***Risk Score: 3 (Potential: Medium Severity: low)***
Ecological Risks	*SVAP2 Average Score: 3.4 (Poor)* Moderate potential for restoration activities. A fairly long backwater channel that attaches to the river in Reach 5 and runs upstream into Reach 4 is present. A waterfowl hunting outfitter is located along this reach and could be interested in restoration projects. *Risk Score: 4 (Risk: Medium Restoration Priority: Medium)* Eastern cottonwood overstory is in overall decline. Noxious vegetation (sandbar willow) present on sand bars. ***Risk Score: 3.4 (Poor)***
Additional Field Notes	There are riprap dikes on the right side of the river in one section. It is unclear what purpose they serve.
Restoration Recommendations	High concentration of armored banks that could benefit from floodplain benches and riparian plantings.
Overall Risk Score	**10-Low**

Table 5-11. Reach 5: Union Ditch Co. Diversion Structure to the County Road 27/State Highway 60 (CR 27/SH 60) Bridge

RIVER CHARACTERISTICS	
Valley Setting	Unconfined.
Channel Planform	Channel has high sinuosity of 1.31. The channel is generally single thread, but braiding occurs at low flows. Historical aerials show that the channel sinuosity has varied from 1.60 in 1937 to 1.33 in 2013 (pre-flood). Historic aerials show that bank width has generally narrowed since 1937.
Cross Section Geometry	Asymmetrical. Typical channel width 200 feet.
Dominant Streambed Material	Sand
Geomorphic Units	No apparent riffles. Large pools form on the outside of bends. Point bars are typical on the inside of bends, and mid-channel bars form in straight sections. Partially connected floodplain with eastern cottonwood galleries.
Bank Condition	Sections of concrete rubble revetment stabilizing banks at road crossing. Cut banks are occurring where floodplain is not connected. Cut banks are typically about 4 feet high.
RIVER BEHAVIOR	
2013 Flood Response	Channel did not migrate significantly. Sandbars appear to have shifted downstream.
Geomorphic Behavior and Risks	Minor migration of mid-channel bars, point bars are relatively constant. Cut banks on outside of bends. Bank cutting appears to have been in place before the 2013 flood.
Sediment Transport Characteristics	Generally the reach is in stable condition, but some fine sediment is introduced from cut banks. Low flows are generally confined to a single thread, concentrating on the outside of meander bends and in pools. Bankfull flows will generally inundate secondary channels and transfer sediment downstream, re-working bars and banks. Flood flows will inundate all channel features and extensive areas of the floodplain, depositing fine sediments and debris in floodplain.
Riparian Zone	Ecological conditions are generally observed to be in better condition in this reach. Both banks include an intact riparian corridor and riparian woodland forest zone with even aged and over mature eastern cottonwood making up the majority of the overstory. Riparian corridor observed is wide with an understory made up of various graminoids and herbaceous vegetation. Riparian corridor and flood plain are disconnected from the river.
Flood Risk	Estimated between one to five insurable structures in the floodplain. State Highway 60 (SH 60) bank is located in the FEMA Preliminary Flood Zone (AE). Review of post-flood aerials and CWCB post-flood awareness mapping, it does not appear that the road was impacted in the September 2013 event. ***Risk Score: 3 (Potential: Medium Severity: low)***
Fluvial Geomorphic Risk	Risk of lateral migration and erosion along unprotected outer banks. County Road 27/State Highway 60 Bridge crosses over the end of the reach, concrete rubble bank revetmentis in place. ***Risk Score: 4 (Potential: Low Severity: High)***
Ecological Risks	*SVAP2 Average Score: 3.4 (Poor)* This reach has significant habitat values. The channel is wide with braided channels and lacks connection to the floodplain, limiting forest regeneration. *Risk Score: 5 (Risk: High Restoration Priority: Medium)* Large gaps in overstory canopy and poor aquatic habitat quality ***Risk Score: 3.3 (Poor)***
Additional Field Notes	Union Ditch Co. Diversion Structure located in reach.
Restoration Recommendations	Diversion structure improvements and floodplain connection would promote regeneration of the riparian forest, and could help with sediment deposition issues downstream near the State Highway 60 Bridge. Conservation of existing intact riparian corridor.
Overall Risk Score	**12-Medium**
	
	

Table 5-12. Reach 6: CR 27/ SH 60 Bridge to the Railroad Crossing 12,000 Feet Downstream of Bridge
Overall Risk Score: 15-High

RIVER CHARACTERISTICS	
Valley Setting	Unconfined.
Channel Planform	Channel has low sinuosity of 1.27. The channel is generally single thread, but braiding occurs at low flows. Historical aerials show that the channel sinuosity has varied from 1.18 in 1937 to 1.28 in 2013 (pre-flood). Historic aerials show that bank width has generally narrowed since 1937.
Cross Section Geometry	Asymmetrical. Typical channel width 200 feet.
Dominant Streambed Material	Sand
Geomorphic Units	No apparent riffles. Small pools form on the outside of bends. Point bars are typical on the inside of bends, and mid-channel bars form in straight sections. Partially connected floodplain with eastern cottonwood galleries.
Bank Condition	Sections of concrete rubble revetment stabilizing banks along agricultural properties. Cut banks occurring where floodplain is not connected. Cut banks are typically 6-10 feet high. A berm is protecting a feed lot.
RIVER BEHAVIOR	
2013 Flood Response	Channel did not migrate significantly. Sandbars appear to have shifted downstream.
Geomorphic Behavior and Risks	Minor migration of mid-channel bars, point bars are relatively constant. Cut banks on outside of bends. Bank cutting appears to have started before the 2013 flood.
Sediment Transport Characteristics	Generally the reach is in stable condition, but there is deposition of sediment directly downstream of bridge as well as introduction of fine sediment from cut banks. Low flows are generally confined to a single thread, concentrating on the outside of meander bends and in pools. Bankfull flows will generally inundate secondary channels and transfer sediment downstream, re-working bars and banks. Flood flows will inundate all channel features and extensive areas of the floodplain, depositing fine sediments and debris in floodplain.
Riparian Zone	Eastern cottonwood overstory is intermittent on both banks, but significantly wide on north bank. All individuals are over mature and in general decline. There is a high incidence of state and county listed noxious vegetation within reach. The riparian corridor on right bank is fairly wide at the top of the reach but becomes very thin with developed agriculture directly adjacent to riparian zone.
Flood Risk	Estimated between 11-25 insurable structures in the floodplain. ***Risk Score: 3 (Potential: Medium; Severity: Medium)***
Fluvial Geomorphic Risk	Risk of lateral migration and erosion along unprotected banks. Vertical banks with history of lateral migration adjacent (less than two channel widths) to irrigation canal, farmland and structures. ***Risk Score: 6 (Potential: High; Severity: High)***
Ecological Risk	*SVAP2 Average Score: 2.9 (Severely Degraded)* This reach is especially affected by the upstream State Highway 60 Bridge, which is causing significant deposition of gravel and sediment, and extremely high bed loads. ***Risk Score: 4 (Risk: High; Restoration Priority: Medium)***

Additional Field Notes	Irrigation flow return at the beginning of the reach. Ditch return from feed lot. Lateral migration at downstream end of reach.
Restoration Recommendations	Potential along the north bank for floodplain reattachment to improve the ecological condition of this reach. Challenges in this reach include oil and gas development directly adjacent to the river channel. The south bank also presents opportunities for restoration by improving irrigation return channels and developing off channel wetlands.
Overall Risk Score	**15-High**

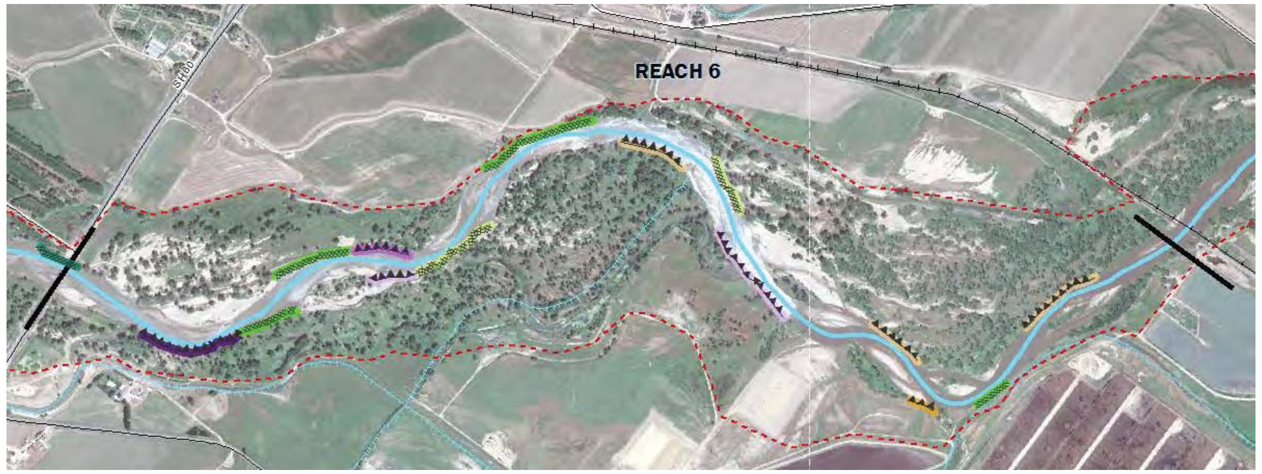


Table 5-13. Reach 7: Railroad Crossing to 6,900 Feet Downstream of the Railroad Crossing

RIVER CHARACTERISTICS	
Valley Setting	Unconfined.
Channel Planform	Channel has low sinuosity of 1.28. The channel is generally single thread, with secondary channels appearing in lower flows. Historical aerials show that the channel sinuosity has varied from 1.23 in 1937 to 1.37 in 2013 pre-flood. Historic aerials show that bank width has generally narrowed since 1937.
Cross Section Geometry	Asymmetrical. Typical channel width 200 feet.
Dominant Streambed Material	Sand
Geomorphic Units	No apparent riffles. Small pools form on the outside of bends. Point bars are typical on the inside of bends, and mid-channel bars form in straight sections. Partially connected floodplain with eastern cottonwood galleries.
Bank Condition	Sections of concrete rubble revetment stabilizing banks along agricultural properties. Cut banks are occurring on outside of bends and near the road crossing where there is no protection. Cut banks are typically 4-6 feet high.
RIVER BEHAVIOR	
2013 Flood Response	Channel did not migrate significantly. Sandbars appear to have shifted downstream.
Geomorphic Behavior and Risks	Minor migration of mid-channel bars, point bars are relatively constant. Cut banks are occurring where floodplain is not connected. Bank cutting appears to have started before the 2013 flood.
Sediment Transport Characteristics	Generally the reach is in stable condition, but some fine sediment is introduced from cut banks. Low flows are generally confined to a single thread, concentrating on the outside of meander bends and in pools. Bankfull flows will generally inundate secondary channels and transfer sediment downstream, re-working bars and banks. Flood flows will inundate all channel features and extensive areas of the floodplain, depositing fine sediments and debris in floodplain.
Riparian Zone	Left bank has little to no riparian corridor until the middle of the reach. Gravel deposition in this reach is almost 200 yards wide in many locations. The right bank has an intact riparian corridor in most locations consisting of an eastern cottonwood overstory with sandbar willow understory on the river banks and pasture complex grasses located farther back from the river as an understory. Proximity to high intensity agriculture and significant channel manipulation makes this a low quality habitat and riparian zone for species movement.
Flood Risk	Estimated between three to seven insurable structures and railroad tracks in the floodplain. Review of post-flood aerials and CWCB post-flood awareness mapping show the railroad and some structures may have been impacted in the September 2013 event. ***Risk Score: 4 (Potential: Medium; Severity: Medium)***
Fluvial Geomorphic Risk	Risk of lateral migration and erosion along unprotected banks. Unprotected vertical banks with a history of lateral migration near Highway 394; however, substantial riparian buffer is in place. ***Risk Score: 4 (Potential: High; Severity: Low)***
Ecological Risk	*SVAP2 Average Score: 2 (Severely Degraded)* Bank armoring, an extremely wide channel, and close proximity to agriculture make this a low priority ecologically for restoration efforts. ***Risk Score: 4 (Risk: High; Restoration Priority: Low)***
Additional Field Notes	Oil tank located along left bank. Godfrey Ditch diversion structure located in reach.
Restoration Recommendations	Diversion structure improvements and potential opportunity to develop riparian vegetation and wetlands with side channels created by irrigation water returns. Increase the vegetated buffer on the left bank.
Overall Risk Scores	**13-Medium**

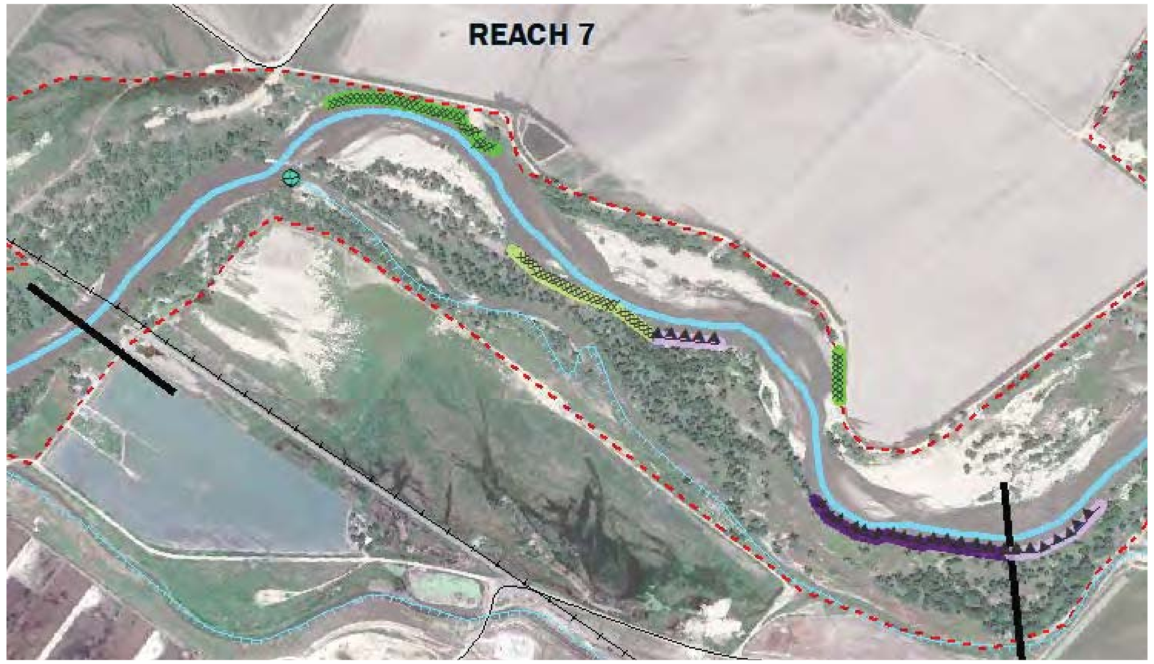


Table 5-14. Reach 8: 4,400 Feet Upstream of the Confluence with the Big Thompson River to the Confluence with the Big Thompson River

RIVER CHARACTERISTICS	
Valley Setting	Unconfined.
Channel Planform	Channel has low sinuosity of 1.03. The channel is generally single thread, with secondary channels appearing in lower flows. Historical aerials show that the channel sinuosity has varied from 1.03 in 1937 to 1.08 in 2013 (pre-flood). Historic aerials show that bank width has generally narrowed since 1937.
Cross Section Geometry	Asymmetrical. Typical channel width 200 feet.
Dominant Streambed Material	Sand
Geomorphic Units	No apparent riffles. Small pools form on the outside of bends. Point bars are typical on the inside of bends, and mid-channel bars form in straight sections. Partially connected floodplain with eastern cottonwood galleries.
Bank Condition	Sections of concrete rubble revetment stabilizing banks along agricultural properties and oil tanks. Cut banks are occurring on outside of bends and near the road crossing where there is no protection. Cut banks are typically 5-10 feet high.
RIVER BEHAVIOR	
2013 Flood Response	Channel did not migrate significantly. Sandbars appear to have shifted downstream.
Geomorphic Behavior and Risks	Minor migration of mid-channel bars, point bars are relatively constant. Cut banks are occurring where floodplain is not connected. Bank cutting appears to have started before the 2013 flood.
Sediment Transport Characteristics	Generally the reach is in stable condition, but some fine sediment is introduced from cut banks. Low flows are generally confined to a single thread, concentrating on the outside of meander bends and in pools. Bankfull flows will generally inundate secondary channels and transfer sediment downstream, re-working bars and banks. Flood flows will inundate all channel features and extensive areas of the floodplain, depositing fine sediments and debris in floodplain.
Riparian Zone	Towards the downstream section of reach, the riparian corridor is functioning at a high level with excellent width on the left bank and good buffering from low density residential uses beyond. The right bank area provides good quality habitat, with quality backwater and instream wetland complexes including ephemeral ponds and channels. The overstory and understory vegetation includes examples of native species, especially a number of native woody shrubs.
Flood Risk	Estimated between two to five insurable structures in the floodplain, additionally due to the pinch point near the confluence with the Big Thompson River the potential for flooding is increased. ***Risk Score: 4 (Potential: High; Severity: Low)***
Fluvial Geomorphic Risk	Risk of lateral migration and erosion along unprotected banks. Unprotected vertical banks with a history of lateral migration adjacent to riparian zone. ***Risk Score: 4 (Potential: High Severity: Low)***
Ecological Risk	*SVAP2 Average Score: 3.2 (Poor)* Reach consists of a wide river channel with multiple braids, sand bars, cobble bars, and islands, which is similar to what the historic South Platte may have looked like. This reach would be a high priority for preservation of existing ecological conditions and future restoration potential for many natural resource criteria. ***Risk Score: 6 (Risk: High; Restoration Priority: High)***
Additional Field Notes	Debris field near the beginning of the reach. Oil tanks adjacent to the river.
Restoration Recommendations	This reach would be a high priority for preservation of existing ecological conditions and future restoration potential for many natural resource criteria.
Overall Risk Score	**14-High**
	
	

Table 5-15. Reach 9: Confluence with the Big Thompson River to 7,450 Feet Downstream of the Confluence

RIVER CHARACTERISTICS	
Valley Setting	Unconfined.
Channel Planform	Channel has low sinuosity of 1.03. The channel is generally single thread, with secondary channels appearing in lower flows. Historical aerials show that the channel sinuosity has varied from 1.15 in 1937 to 1.06 in 2013 pre-flood. Historic aerials show that bank width has generally narrowed since 1937.
Cross Section Geometry	Asymmetrical: meander bend. Typical channel width 200 feet.
Dominant Streambed Material	Sand
Geomorphic Units	Two small riffles. Small pools form on the outside of bends and downstream of riffles. Point bars are typical on the inside of bends, and mid-channel bars form in straight sections. Partially connected floodplain with eastern cottonwood galleries. Downed trees are protecting the bank in a section near the center of the reach.
Bank Condition	A berm is protecting residential properties to the north of the river. Little to no bank protection. Cut banks are occurring where floodplain is not connected. Cut banks are typically 3-5 feet high.
RIVER BEHAVIOR	
2013 Flood Response	Channel did not migrate significantly. Sandbars appear to have shifted downstream.
Geomorphic Behavior and Risks	Minor migration of mid-channel bars, point bars are relatively constant. Cut banks on outside of bends. Bank cutting appears to have started before the 2013 flood.
Sediment Transport Characteristics	Generally the reach is in stable condition, but some fine sediment is introduced from cut banks. Low flows are generally confined to a single thread, concentrating on the outside of meander bends and in pools. Bankfull flows will generally inundate secondary channels and transfer sediment downstream, re-working bars and banks. Flood flows will inundate all channel features and extensive areas of the floodplain, depositing fine sediments and debris in floodplain.
Riparian Zone	The riparian corridor on both banks of the reach is currently utilized for agricultural uses including horse pasturing, which limits the height or function of grasses or herbaceous vegetation for wildlife use. The riparian forest in this area is mostly over-mature, however, the condition of individual trees is good.
Flood Risk	Estimated between three to seven insurable structures in the floodplain. ***Risk Score: 3 (Potential: Medium; Severity: Low)***
Fluvial Geomorphic Risk	Risk of lateral migration and erosion along unprotected outer banks. Vertical banks located along established riparian zones. ***Risk Score: 3 (Potential: Medium Severity: Low)***
Ecological Risk	*SVAP2 Average Score: 2.9 (Severely degraded)* The degree of degradation along this reach make it a low priority ecologically. ***Risk Score: 4 (Risk: High; Restoration Priority: Low)***
Additional Field Notes	A downed power line is in the river and is causing a riffle to form.
Restoration Recommendations	Floodplain benches along these vertical banks would promote redevelopment of riparian vegetation on the north bank where there is a very thin strip of riparian, and reduce sediment input along the right bank, where the majority of the reach has vertical failing banks.
Overall Risk Score	**10-Low**
	
	

Table 5-16. Reach 10: 7,450 Feet Downstream of the Confluence of the Big Thompson to the Lower Latham Diversion Structure

RIVER CHARACTERISTICS	
Valley Setting	Unconfined.
Channel Planform	Channel has low sinuosity of 1.18. The channel is generally single thread, with secondary channels appearing in lower flows. Historical aerials show that the channel sinuosity has varied from 1.27 in 1937 to 1.20 in 2013 (pre-flood). Historic aerials show that bank width has generally narrowed since 1937. Historical aerials also show a large bend that existed up until 1972 has been cut off.
Cross Section Geometry	Asymmetrical. Typical channel width 200 feet.
Dominant Streambed Material	Sand
Geomorphic Units	No apparent riffles. Small pools form on the outside of bends. A secondary channel is forming to cut off a bend. *Populus tremuloides* (quaking aspen) present in the riparian zone in one section. Point bars are typical on the inside of bends, and mid-channel bars form in straight sections. Partially connected floodplain with eastern cottonwood galleries.
Bank Condition	Sections of concrete revetment and car bodies stabilizing banks along agricultural properties. A berm is protecting residential properties to the north of the river. Cut banks are occurring where floodplain is not connected. Cut banks are typically 3-5 feet high.
RIVER BEHAVIOR	
2013 Flood Response	Channel did not migrate significantly. Sandbars appear to have shifted downstream.
Geomorphic Behavior and Risks	Minor migration of mid-channel bars, point bars are relatively constant. Cut banks on outside of bends. Bank cutting appears to have started before the 2013 flood.
Sediment Transport Characteristics	Generally the reach is in stable condition, but some fine sediment is introduced from cut banks. Low flows are generally confined to a single thread, concentrating on the outside of meander bends and in pools. Bankfull flows will generally inundate secondary channels and transfer sediment downstream, re-working bars and banks. Flood flows will inundate all channel features and extensive areas of the floodplain, depositing fine sediments and debris in floodplain.
Riparian Zone	This reach includes very high quality riparian areas and areas of good quality instream fish habitat (i.e., pools, backwater channel, refugia). There is significant terrestrial habitat for amphibians and reptiles within this reach, including observed wetlands, ephemeral wetlands, back channel stream threads, and off-channel open water.
Flood Risk	Estimated between 10-20 insurable structures in the preliminary FEMA floodplain and the approximate 10-year floodplain. However, flooding observed in September 2013 caused substantially more damage. The potential for flooding is increased due to backwater effects of the Highway 85 bridge. ***Risk Score: 6 (Potential: High; Severity: High)***
Fluvial Geomorphic Risk	Risk of lateral migration and erosion along unprotected banks. Unprotected vertical bank adjacent to farmland with minimal riparian buffer. ***Risk Score: 4 (Potential: Medium Severity: Medium)***
Ecological Risk	*SVAP2 Average Score: 4.4 (Poor)* This reach has high potential for restoration of in-channel and riparian corridor functions due to the presence of off-channel ephemeral wetlands, and back-channel stream threads. ***Risk Score: 3 (Risk: Medium; Restoration Priority: Low)***
Additional Field Notes	Substantial number of car bodies used for bank protection.
Restoration Recommendations	Increase riparian zone specifically along areas where farmland is directly adjacent to river and remove cars and replace with bioengineering. This reach has excellent potential for restoration and preservation of in-channel and riparian corridor functions.
Overall Risk Score	**13-Medium**

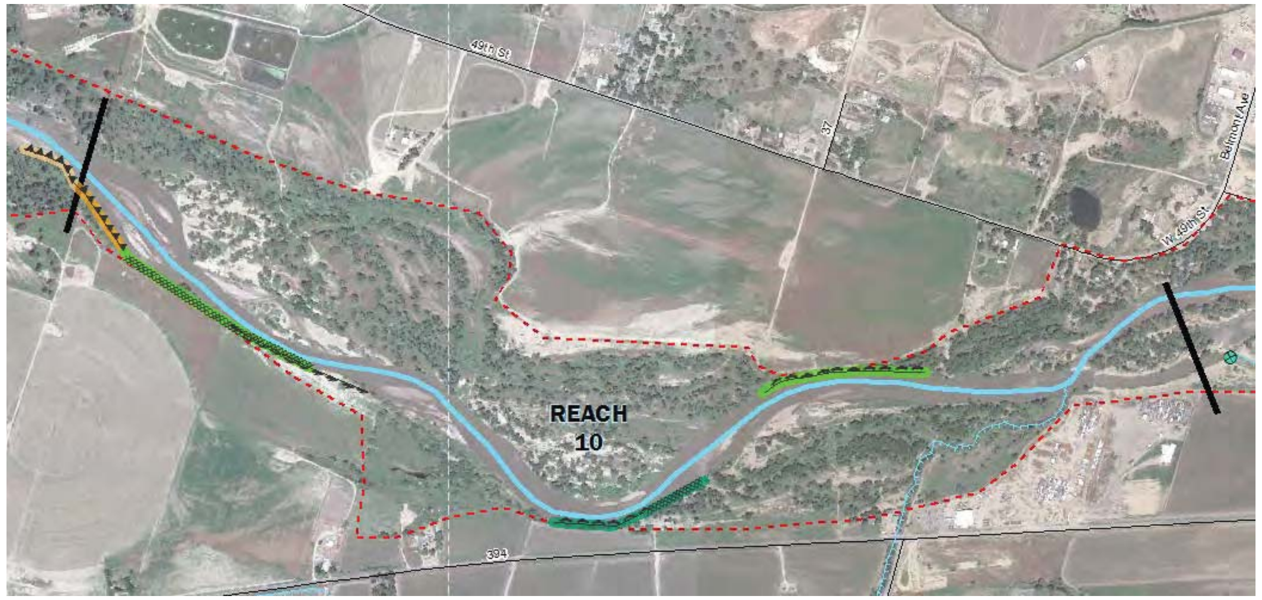


Table 5-17. Reach 11: Lower Latham Diversion Structure to US Highway 85

RIVER CHARACTERISTICS	
Valley Setting	Unconfined.
Channel Planform	Channel has low sinuosity of 1.18. The channel is generally single thread, with secondary channels appearing in lower flows. Historical aerials show that the channel sinuosity has varied from 1.27 in 1937 to 1.20 in 2013 pre-flood. Historic aerials show that bank width has generally narrowed since 1937.
Cross Section Geometry	Asymmetrical. Typical channel width 200 feet.
Dominant Streambed Material	Sand
Geomorphic Units	No apparent riffles. Small pools form on the outside of bends. Large areas of deposition upstream of bridge. Point bars are typical on the inside of bends, and mid-channel bars form in straight sections. Partially connected floodplain with eastern cottonwood galleries. Lower Latham diversion structure. Downed trees are protecting the bank in a section near the center of the reach.
Bank Condition	Sections of concrete rubble revetment stabilizing banks. Cut banks are occurring where floodplain is not connected. Properties are very close to the river on the right bank. Cut banks are typically 3-5 feet high.
RIVER BEHAVIOR	
2013 Flood Response	Channel did not migrate significantly.
Geomorphic Behavior and Risks	Minor migration of mid-channel bars, point bars are relatively constant. Cut banks on outside of bends. Bank cutting appears to have been in place before the 2013 flood. This reach has a risk of lateral erosion where banks are unprotected. Degradation and lateral erosions is likely. Continued aggradation is likely to occur at bridge, this will decrease the capacity of the bridge to pass flood waters.
Sediment Transport Characteristics	Generally a response reach, with areas of high aggradation. Some fine sediment is introduced from cut banks within this reach. Low flows are generally confined to a single thread, concentrating on the outside of meander bends and in pools. Bankfull flows will generally inundate secondary channels and transfer sediment downstream, re-working bars and banks. Flood flows will inundate all channel features and extensive areas of the floodplain, depositing fine sediments and debris in floodplain. Deposition occurring near the bridge will continue.
Riparian Zone	The right bank of this reach has very little to no riparian corridor in multiple locations, with industry directly adjacent to the channel. The left bank has a higher density of riparian forested zones and includes a high density of moderate aged eastern cottonwood individuals and stands.
Flood Risk	Estimated between 10-20 insurable structures in the preliminary FEMA floodplain and the approximate 10-year floodplain. However, flooding observed in September 2013 caused substantially more damage. The potential for flooding is increased due to backwater effects of the Highway 85 bridge. ***Risk Score: 6 (Potential: High; Severity: High)***
Fluvial Geomorphic Risk	Risk of lateral migration and erosion along unprotected banks. Unprotected vertical banks upstream of US Highway 85 bridge. ***Risk Score: 5 (Potential: Medium Severity: High)***
Ecological Risk	*SVAP2 Average Score: 2.5 (Severely degraded)* Degradation due to due to sediment deposition occurring within the channel. The degree of degradation along this reach make it a low priority ecologically. ***Risk Score: 4 (Risk: High; Restoration Priority: Low)***
Additional Field Notes	Large woody debris lodged beneath bridge deck, indicating that September 2013 flows nearly overtopped the bridge.
Restoration Recommendations	Bridge improvements. Diversion structure improvements. Creation of floodplain benches and riparian planting could promote trapping of the sediment further upstream of the bridges reducing the amount of in channel bars above and below the bridges.
Overall Risk Score	**15-High**
	
	

Table 5-18. Reach 12: US Highway 85 to 37th Street

RIVER CHARACTERISTICS	
Valley Setting	Unconfined.
Channel Planform	Channel has low sinuosity of 1.12. The channel is generally single thread, with secondary channels appearing in lower flows. Historical aerials show that the channel sinuosity has varied from 1.07 in 1937 to 1.14 in 2013(pre-flood). Historic aerials show that bank width has generally narrowed since 1937.
Cross Section Geometry	Asymmetrical. Typical channel width 200 feet.
Dominant Streambed Material	Sand
Geomorphic Units	Reach contains Riverside Park and berm. No apparent riffles. Pools form on the outside of bends. Point bars are typical on the inside of bends, and mid-channel bars form in straight sections. Partially connected floodplain with eastern cottonwood galleries. Heavy deposition at road and railroad crossing on the south side of the river.
Bank Condition	Sections of concrete rubble revetment stabilizing banks along agriculture properties. Cut banks where floodplain is not connected and near the road crossing where there is no protection. A berm is protecting Riverside Park.
RIVER BEHAVIOR	
2013 Flood Response	Channel did not migrate significantly. Sandbars did not appear to shift. Bike path along left bank collapsed due to erosion and flood waters, historic landfill exposed at Riverside Park.
Geomorphic Behavior and Risks	Minor migration of mid-channel bars, point bars are relatively constant. Cut banks on outside of bends. Bank cutting appears to have occurred before the 2013 flood.
Sediment Transport Characteristics	Generally the reach is in stable condition, but some fine sediment is introduced from cut banks. Low flows are generally confined to a single thread, concentrating on the outside of meander bends and in pools. Bankfull flows will generally inundate secondary channels and transfer sediment downstream, re-working bars and banks. Flood flows will inundate all channel features and extensive areas of the floodplain, depositing fine sediments and debris in floodplain.
Riparian Zone	The left bank is heavily modified with armoring and channelization. There is a significant element of non-native overstory within this reach *Ulmus parvifolia* (lace bark elm) and low habitat values. In channel habitat and conditions are low and degraded with very little aquatic or fishery habitat. The right bank portions of the reach have higher ecological values and a more intact riparian corridor associated with a multi-aged and multi-sized overstory dominated by eastern cottonwood.
Flood Risk	More than 50 insurable structures in the preliminary FEMA floodplain and more than 10 insurable structures in the approximate 10-year floodplain. Additionally, the La Salle Waste Water Treatment Plant is located within the floodplain in this reach. ***Risk Score: 6 (Potential: High; Severity: High)***
Fluvial Geomorphic Risk	Risk of lateral migration and erosion along unprotected banks. Lateral migration and bank failures visible as a result of September 2013 flood. Resulted in collapsed bike path along and river and exposure of historic landfill. ***Risk Score: 6 (Potential: High Severity: High)***
Ecological Risk	*SVAP2 Average Score: 2.9 (Severely degraded)* adjacent to Riverside Park, which make this reach a high priority for restoration. Public land ownership will facilitate access for restoration work along this reach. ***Risk Score: 6 (Risk: High; Restoration Priority: High)***
Additional Field Notes	Irrigation flow return near the end of the reach.
Restoration Recommendations	Riverside Park improvements and mitigation of exposed landfill along left bank.
Overall Risk Score	**18-High**
	
	

Table 5-19. Reach 13: 37th Street (County Highway 54) to the Patterson Ditch Diversion Structure

RIVER CHARACTERISTICS	
Valley Setting	Unconfined.
Channel Planform	Channel has low sinuosity of 1.10. The channel is generally single thread, with secondary channels appearing in lower flows. Historical aerials show that the channel had relatively constant sinuosity from 1.11 in 1937 to 1.10 in 2013 pre-flood. Historic aerials show that bank width has generally narrowed since 1937.
Cross Section Geometry	Asymmetrical. Typical channel width 200 feet.
Dominant Streambed Material	Sand
Geomorphic Units	Pools form on the outside of bends. Point bars are typical on the inside of bends, and mid-channel bars form in straight sections. Partially connected floodplain with eastern cottonwood galleries. Irrigation diversion structure present within reach.
Bank Condition	Substantial bank protection. Cut banks occurring where floodplains are not connected.
RIVER BEHAVIOR	
2013 Flood Response	Channel did not migrate significantly. Sandbars did not appear to shift. Properties in floodplain experienced significant flooding.
Geomorphic Behavior and Risks	Minor migration of mid channel bars, point bars are relatively constant. Cut banks on outside of bends. Bank cutting appear to have been in place before the 2013 flood.
Sediment Transport Characteristics	Generally the reach is in stable condition, but some fine sediment is introduced from cut banks. Low flows are generally confined to a single thread, concentrating on the outside of meander bends and in pools. Bankfull flows will generally inundate secondary channels and transfer sediment downstream, re-working bars and banks. Flood flows will inundate all channel features and extensive areas of the floodplain, depositing fine sediments and debris in floodplain.
Riparian Zone	Left bank is severely degraded with very low habitat value. Mid reach, the left bank condition improves with better age class diversity of eastern cottonwood and density of stands, as well as width of the riparian corridor. The heavily armored portions of the bank through this reach include areas where there is very little opportunity for connection to the floodplain.
Flood Risk	Estimated 10-20 insurable structures in the preliminary FEMA floodplain and less than two in the approximate 10-year floodplain. ***Risk Score: 5 (Potential: High; Severity: Medium)***
Fluvial Geomorphic Risk	Risk of lateral migration and erosion along unprotected banks. Vertical banks upstream of 37th Street Bridge and adjacent to industrial lot. ***Risk Score: 3 (Potential: Medium Severity: Low)***
Ecological Risk	*SVAP2 Average Score: 3.3 (Poor)* Adjacent to the Brower State Wildlife Area, public land ownership and existing back channel wetlands and newer scoured wetlands provide excellent opportunities to increase wetland habitat diversity for aquatic and avian wildlife. This could also increase recreational opportunities within the State Wildlife Area. ***Risk Score: 5 (Risk: Medium; Restoration Priority: High)***

Additional Field Notes	
Restoration Recommendations	Diversion structure modifications. Enhancements to existing wetlands utilizing public lands.
Overall Risk Score	**13-Medium**
	
	

Table 5-20. Reach 14: Patterson Ditch Diversion Structure to US Highway 34

RIVER CHARACTERISTICS	
Valley Setting	Unconfined.
Channel Planform	Channel has low sinuosity of 1.05. The channel is generally single thread, with secondary channels appearing in lower flows. Historical aerials show that the channel sinuosity has varied from 1.15 in 1937 to 1.09 in 2013 pre-flood. Historic aerials show that bank width has generally narrowed since 1937.
Cross Section Geometry	Asymmetrical: Typical channel width 200 feet.
Dominant Streambed Material	Sand
Geomorphic Units	Pools form on the outside of bends. Point bars are typical on the inside of bends, and mid-channel bars form in straight sections. Partially connected floodplain with eastern cottonwood galleries. Retention basin on left bank. Narrow river corridor.
Bank Condition	Bank protected in areas. Cut banks occurring where floodplain is not connected.
RIVER BEHAVIOR	
2013 Flood Response	Channel did not migrate significantly. Sandbars did not appear to shift. Properties in floodplain experienced significant flooding.
Geomorphic Behavior and Risks	Minor movement of mid-channel bars, point bars are relatively constant. Cut banks on outside of bends. Bank cutting appears to have started before the 2013 flood.
Sediment Transport Characteristics	Generally the reach is in stable condition but some fine sediment is introduced from cut banks. Low flows are generally confined to a single thread, concentrating on the outside of meander bends and in pools. Bankfull flows will generally inundate secondary channels and transfer sediment downstream, re-working bars and banks. Flood flows will inundate all channel features and extensive areas of the floodplain, depositing fine sediments and debris in floodplain.
Riparian Zone	The riparian corridor is intermittent and cover is varied in terms of species height, age class, and species diversity. There are some areas where the riparian width begins to connect to fairly appropriate widths, and other zones where the corridor is quite narrow. The general conditions of the corridor are predominantly better on the north bank with intact eastern cottonwood riparian forests, however, there is very little recruitment or regeneration occurring due to disconnect of the river channel.
Flood Risk	No insurable structures in the preliminary FEMA floodplain. US Highway 34 was damaged in the September 2013 flood. ***Risk Score: 4 (Potential: Medium; Severity: Medium)***
Fluvial Geomorphic Risk	Risk of lateral migration and erosion along outer banks. Concrete rubble revetment stabilizing banks at US Highway34 Bridge crossing. ***Risk Score: 4 (Potential: Low Severity: High)***
Ecological Risk	*SVAP2 Average Score: 3.3 (Poor)* Potential for wetland development along the south bank near the end of the reach. An existing historical stream channel could provide for wetland development with floodplain reattachment along the bank. ***Risk Score: 4 (Risk: Medium; Restoration Priority: Medium)***
Additional Field Notes	
Restoration Recommendations	US Highway 34 is currently being modified and repaired using FEMA Public Assistance funding. Diversion structure modifications may be beneficial to aquatic organisms. Potential for wetland development along the right bank near the end of the reach. An existing historical stream channel could provide for wetland development with floodplain reattachment along the bank. Ponds located in the floodplain may pose continued risk in the event of future floods breaching and "capturing" the river channel.
Overall Risk Score	**12-Medium**
	
	

Table 5-21. Reach 15: US Highway 34 to US Highway 34 Business Route

RIVER CHARACTERISTICS	
Valley Setting	Unconfined.
Channel Planform	Channel has low sinuosity of 1.05. The channel is generally single thread, with secondary channels appearing in lower flows. Historical aerials show that the channel sinuosity has varied from 1.03 in 1937 to 1.07 in 2013 (pre-flood). Historic aerials show that bank width has generally narrowed since 1937.
Cross Section Geometry	Asymmetrical. Typical channel width 200 feet.
Dominant Streambed Material	Sand
Geomorphic Units	Pools form on the outside of bends. Point bars are typical on the inside of bends, and mid-channel bars form in straight sections. Partially connected floodplain with eastern cottonwood galleries. Narrow river corridor.
Bank Condition	Bank protected in areas. Cut banks occurring where floodplain is not connected.
RIVER BEHAVIOR	
2013 Flood Response	Channel did not migrate significantly. Sandbars did not appear to shift. Properties in floodplain experienced significant flooding.
Geomorphic Behavior and Risks	Minor migration of mid-channel bars, point bars are relatively constant. Cut banks on outside of bends. Bank cutting started before 2013. Aggradation will occur upstream of the bridge, resulting in reduced flood capacity.
Sediment Transport Characteristics	Generally a response reach, with areas of high aggradation. Some fine sediment is introduced from cut banks within this reach. Low flows are generally confined to a single thread, concentrating on the outside of meander bends and in pools. Bankfull flows will generally inundate secondary channels and transfer sediment downstream, re-working bars and banks. Flood flows will inundate all channel features and extensive areas of the floodplain, depositing fine sediments and debris in floodplain. Deposition occurring near the bridge will continue.
Riparian Zone	Good connection and accessibility to the floodplain, excellent soil resources, and excellent age class diversity of the dominant overstory, which includes active recruitment and dynamic age class systems, good herbaceous cover, good woody shrub understory consisting of willow, *Fraxinus* (ash), *Acer* (maple), and others.
Flood Risk	Estimated between 5-10 insurable structures in the floodplain, US Highway 34 Business was overtopped and damaged during the September 2013 event. ***Risk Score: 3 (Potential: Medium; Severity: Medium)***
Fluvial Geomorphic Risk	Risk of lateral migration and erosion along unprotected banks. Concrete rubble revetment bank stabilization along outside banks of US Highway 34 and US Highway 34 Business bridges. History of lateral migration along outside bank at US Highway 34 Business Bridge. ***Risk Score: 5 (Potential: Medium Severity: High)***
Ecological Risk	*SVAP2 Average Score: 5 (Fair)* This reach of the river has had much less human intervention than the majority of the other reaches. Agricultural activities on the north bank are at an appropriate distance away, and CDOT managed lands make up the majority of the south channel corridor. Although this is one of the shorter reaches within the study area, it is one of the best examples of both in-channel, floodplain, and riparian health within the study zone. This reach would be a good anchor for restoration activities. ***Risk Score: 5(Risk: Medium; Restoration Priority: High)***

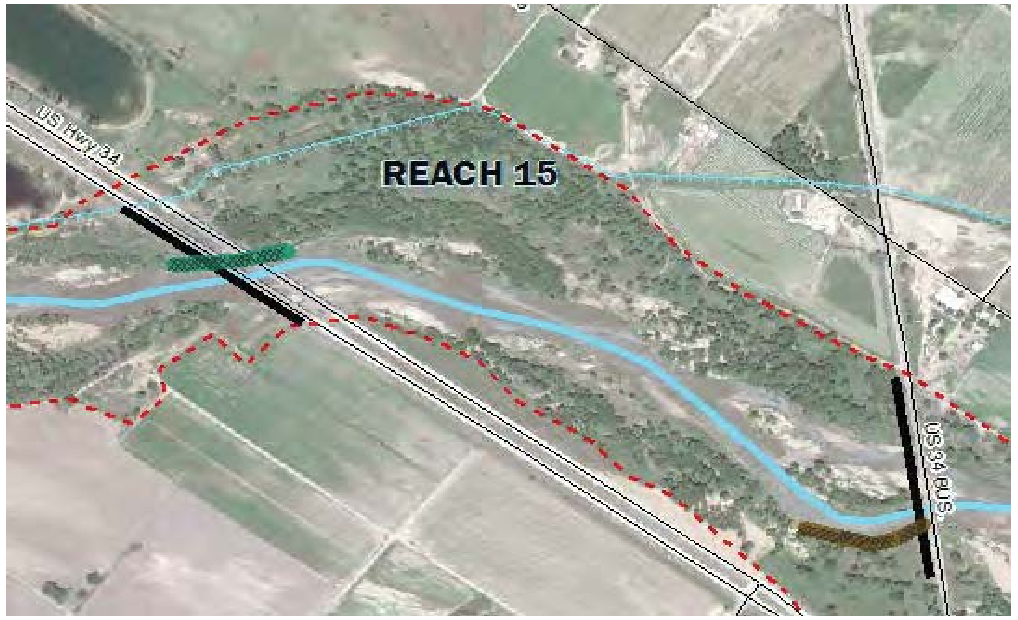
Additional Field Notes	
Restoration Recommendations	Bridge improvements and restoration/preservation of reach.
Overall Risk Score	**14-High**
	
	

Table 5-22. Reach 16: US Highway 34 Business Route to the Plumb Ditch Diversion Structure

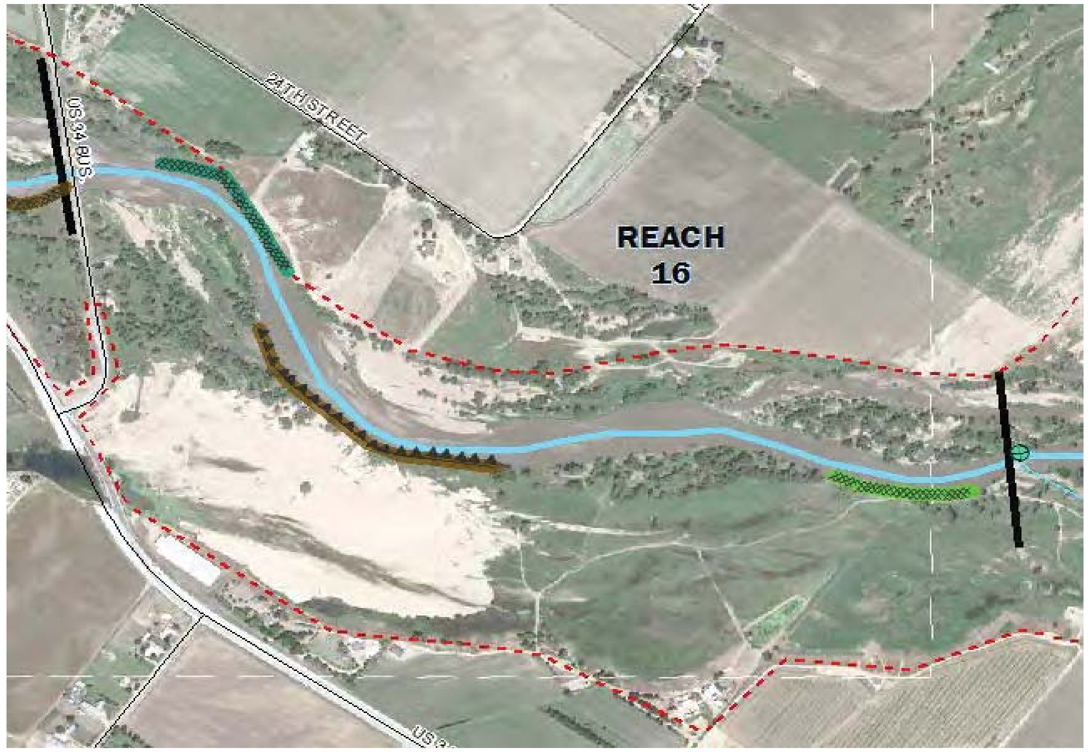
RIVER CHARACTERISTICS	
Valley Setting	Unconfined.
Cross Section Geometry	Asymmetrical: Typical channel width 200 feet.
Dominant Streambed Material	Sand
Geomorphic Units	Pools form on the outside of bends. Point bars are typical on the inside of bends, and mid-channel bars form in straight sections. Partially connected floodplain with eastern cottonwood galleries.
Bank Condition	Bank protected in areas. Cut banks occurring where floodplain is unconnected.
RIVER BEHAVIOR	
2013 Flood Response	Channel did not migrate significantly. Sandbars did not appear to shift. Properties in floodplain experienced significant flooding.
Geomorphic Behavior and Risks	Minor migration of mid-channel bars, point bars are relatively constant. Cut banks on outside of bends. Bank cutting appears to have started before the 2013 flood.
Sediment Transport Characteristics	Generally the reach is in stable condition, but some fine sediment is introduced from cut banks. Low flows are generally confined to a single thread, concentrating on the outside of meander bends and in pools. Bankfull flows will generally inundate secondary channels and transfer sediment downstream, re-working bars and banks. Flood flows will inundate all channel features and extensive areas of the floodplain, depositing fine sediments and debris in floodplain.
Riparian Zone	The left bank consists of a riparian corridor with a moderate aged overstory and a very poorly developed understory. Overall, the left bank of this reach extends from areas of fairly intact herbaceous cover to very little intact herbaceous cover and significant noxious vegetation with influences from residential and agricultural areas adjacent to the stream. The right bank has more diversity with a wide stretch of riparian corridor consisting mainly of an overstory of eastern cottonwood. No recruitment or regeneration within this reach was noted. In the middle portions of the reach, the south bank riparian zone transitions to a thin riparian area consisting of mostly bare ground.
Flood Risk	Estimated between 10-20 insurable structures in the floodplain, US Highway 34 Business was overtopped and damaged during the September 2013 event. ***Risk Score: 4 (Potential: Medium; Severity: Medium)***
Fluvial Geomorphic Risk	Risk of lateral migration and erosion along unprotected banks. History of lateral migration in area with scarce vegetation adjacent to US Highway 34. ***Risk Score: 5 (Potential: Medium Severity: High)***
Ecological Risk	*SVAP2 Average Score: 3.5 (Poor)* Residential and agricultural activities adjacent to the river channel will add to the difficulty of restoration activities. ***Risk Score: 3 (Risk Medium; Restoration Priority: Low)***
Additional Field Notes	
Restoration Recommendations	Diversion structure modifications and riparian plantings.
Overall Risk Score	**12-Medium**
	
	

Table 5-23. Reach 17: Plumb Ditch Diversion Structure to County Road 58 (18th St)

RIVER CHARACTERISTICS	
Valley Setting	Unconfined
Channel Planform	Channel has high sinuosity of 1.33. The channel is generally single thread, with secondary channels appearing in lower flows. Historical aerials show that the channel sinuosity has varied from 1.29 in 1937 to 1.37 in 2013 (pre-flood). Historic aerials show that bank width has generally narrowed since 1937.
Cross Section Geometry	Asymmetrical and compound. Typical channel width 200 feet.
Dominant Streambed Material	Sand
Geomorphic Units	Pools form on the outside of bends. Point bars are typical on the inside of bends, and mid-channel bars form in straight sections. Partially connected floodplain with eastern cottonwood galleries.
Bank Condition	Bank protected in areas. Cut banks occurring where floodplain is not connected.
RIVER BEHAVIOR	
2013 Flood Response	Channel did not migrate significantly. Sandbars did not appear to shift. Properties in floodplain experienced significant flooding.
Geomorphic Behavior and Risks	Minor migration on mid-channel bars, point bars are relatively constant. Cut banks on outside of bends. Bank cutting appears to have started before the 2013 flood. This reach has a risk of lateral erosion where banks are unprotected. Degradation and lateral erosion is likely. Aggradation will occur upstream of the bridge, resulting in reduced flood capacity.
Sediment Transport Characteristics	Generally the reach is in stable condition; however, there are areas of high aggradation. Some fine sediment is introduced from cut banks within this reach. Low flows are generally confined to a single thread, concentrating on the outside of meander bends and in pools. Bankfull flows will generally inundate secondary channels and transfer sediment downstream, re-working bars and banks. Flood flows will inundate all channel features and extensive areas of the floodplain, depositing fine sediments and debris in floodplain. Deposition occurring near the bridge will continue.
Riparian Zone	This is a highly modified reach with significant deposition within all areas of the reach that defines the lack of significant aquatic habitat. There is evidence of significant channel manipulation and heavy bank stabilization techniques. In addition, both sides of the channel include agricultural infrastructure adjacent to the channel and within the limited riparian corridors. There are some intact and intermittent stands and forest cover types within the reach that consist of primarily eastern cottonwood and peachleaf willow. Most of this coverage is broken or segmented.
Flood Risk	No insurable structures in the floodplain, 18th Street overtopped during September 2013 flooding. ***Risk Score: 4 (Potential: Medium; Severity: Medium)***
Fluvial Geomorphic Risk	Risk of lateral migration and erosion along unprotected banks. Outside bank at 18th Street has potential for lateral migration in the long term. ***Risk Score: 4 (Potential: Low Severity: High)***
Ecological Risk	*SVAP2 Average Score: 2.8 (Severely Degraded)* Agriculture and oil and gas activity are directly adjacent to the reach, which makes it a low priority for restoration or preservation. ***Risk Score 4 (Risk: High; Restoration Priority: Low)***

Additional Field Notes	
Restoration Recommendations	Reestablishing the riparian area along the north bank where the riparian corridor is wide but lacks regeneration and current vegetation is sparse would be the most beneficial.
Overall Risk Score	**12-Medium**

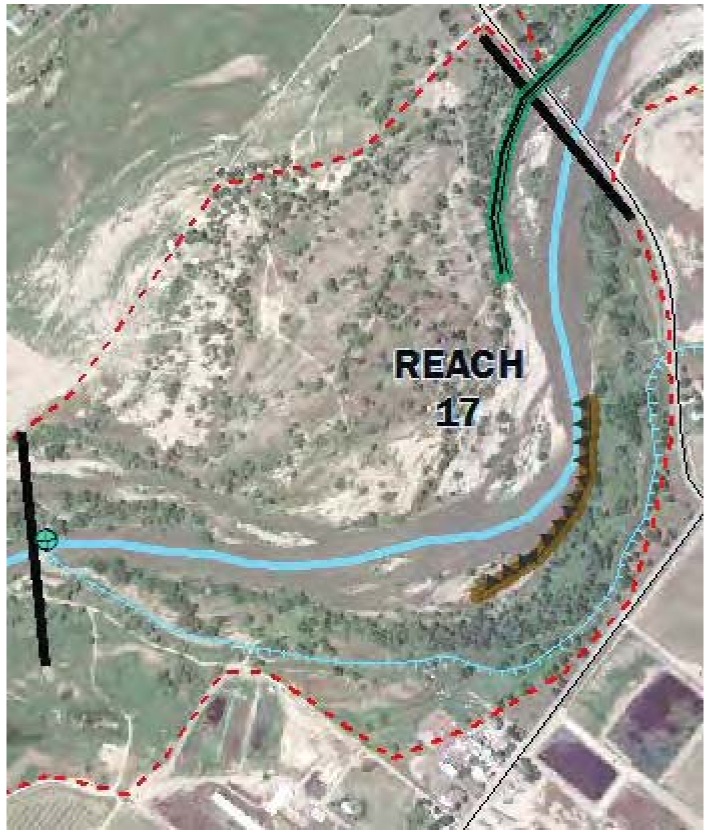


Table 5-24. Reach 18: County Road 58 to the Confluence with the Poudre River

RIVER CHARACTERISTICS	
Valley Setting	Unconfined.
Channel Planform	Channel has low sinuosity of 1.14 The channel is generally single thread, with secondary channels appearing in lower flows. Historical aerials show that the channel sinuosity has varied from 1.18 in 1937 to 1.20 in 2013 (pre-flood). Historic aerials show that bank width has generally narrowed since 1937.
Cross Section Geometry	Asymmetrical. Typical channel width 200 feet.
Dominant Streambed Material	Sand bed channel.
Geomorphic Units	Pools form on the outside of bends. Point bars are typical on the inside of bends, and mid-channel bars form in straight sections. Partially connected floodplain with eastern cottonwood galleries. Narrow river corridor for a portion of the reach.
Bank Condition	Bank protected in areas. Cut banks occurring where floodplain is disconnected.
RIVER BEHAVIOR	
2013 Flood Response	Channel did not migrate significantly. Sandbars did not appear to shift. Properties in floodplain experienced significant flooding.
Geomorphic Behavior and Risks	Minor migration of mid channel bars, point bars are relatively constant. Cut banks on outside of bends. Bank cutting appears to have started before the 2013 flood.
Sediment Transport Characteristics	Generally the reach is in stable condition, but some fine sediment is introduced from cut banks. Low flows are generally confined to a single thread, concentrating on the outside of meander bends and in pools. Bankfull flows will generally inundate secondary channels and transfer sediment downstream, re-working bars and banks. Flood flows will inundate all channel features and extensive areas of the floodplain, depositing fine sediments and debris in floodplain.
Riparian Zone	Eastern cottonwood galleries on both sides of the river. Good riparian zone on right bank of river. Very thin riparian corridors with large gaps in riparian vegetation. The instream components and channel qualities are low quality habitat with very little pooling, water quality inputs, significant amounts of algae, and very little structure for fish habitat.
Flood Risk	No insurable structures in the floodplain. ***Risk Score: 2 (Potential: Low; Severity: Low)***
Fluvial Geomorphic Risk	Risk of lateral migration and erosion along unprotected banks, all outside banks have a riparian buffer. ***Risk Score: 2 (Potential: Low Severity: Low)***
Ecological Risk	*SVAP2 Average Score: 2.8 (Severely Degraded)* The confluence with the Cache La Poudre River provide an excellent opportunity for ecological restoration and management. ***Risk Score 6 (Risk: High; Restoration Priority: High)***

Additional Field Notes	
Restoration Recommendations	Adjacent to a State Wildlife Area along the north bank, which will allow for more flexibility with management, stewardship, and restoration.
Overall Risk Score	**10-Low**

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Section 6

Risk Scores and Prioritization Ranking

6.1 Overall Risk Scores

The overall risk score for each reach was calculated by summing the flood, fluvial geomorphic, and ecological risk scores assigned to each reach. The total scores were used to assign the reach an overall risk designation as follows:

- 6-10 -- low overall risk
- 11-13 -- medium overall risk
- 14-18 -- high overall risk

Table 6-1 summarizes each reach's fluvial geomorphic hazard, flood hazard, and ecological risk designation and **Figure 6-1** illustrates the findings for the overall project area.

Table 6-1. Overall Risk and Prioritization Rankings

Reach	Flood risk			Fluvial Geomorphic Risk			Ecological Risk			Overall Risk	Priority
	Potential	Severity	Score	Potential	Severity	Score	Risk	Priority	Score	Score	
12	3-High	3-High	**6-High**	3-High	3-High	**6-High**	3-High	3-High	**6-High**	**18-High**	1
6	2-Medium	2-Medium	**4-Medium**	3-High	3-High	**6-High**	3-High	2-Medium	**5-High**	**15-High**	2
11	3-High	3-High	**6-High**	2-Medium	3-High	**5-High**	3-High	1-Low	**4-Medium**	**15-High**	2
8	3-High	1-Low	**4-Medium**	3-High	1-Low	**4-Medium**	3-High	3-High	**6-High**	**14-High**	4
15	2-Medium	2-Medium	**4-Medium**	2-Medium	3-High	**5-High**	2-Medium	3-High	**5-High**	**14-High**	4
1	1-Low	2-Medium	**3-Low**	2-Medium	3-High	**5-High**	2-Medium	3-High	**5-High**	**13-Medium**	6
10	3-High	3-High	**6-High**	2-Medium	2-Medium	**4-Medium**	2-Medium	1-Low	**3-Low**	**13-Medium**	6
13	3-High	2-Medium	**5-High**	2-Medium	1-Low	**3-Low**	2-Medium	1-Low	**3-Low**	**13-Medium**	6
3	2-Medium	2-Medium	**4-Medium**	3-High	1-Low	**4-Medium**	2-Medium	2-Medium	**4-Medium**	**12-Medium**	9
5	2-Medium	1-Low	**3-Low**	1-Low	3-High	**4-Medium**	3-High	2-Medium	**5-High**	**12-Medium**	9
7	2-Medium	2-Medium	**4-Medium**	3-High	1-Low	**4-Medium**	3-High	1-Low	**4-Medium**	**12-Medium**	9
14	2-Medium	2-Medium	**4-Medium**	1-Low	3-High	**4-Medium**	2-Medium	2-Medium	**4-Medium**	**12-Medium**	9
16	2-Medium	2-Medium	**4-Medium**	2-Medium	3-High	**5-High**	2-Medium	1-Low	**3-Low**	**12-Medium**	9
17	2-Medium	2-Medium	**4-Medium**	1-Low	3-High	**4-Medium**	3-High	1-Low	**4-Medium**	**12-Medium**	9
4	2-Medium	1-Low	**3-Low**	2-Medium	1-Low	**3-Low**	2-Medium	2-Medium	**4-Medium**	**10-Low**	15
9	2-Medium	1-Low	**3-Low**	2-Medium	1-Low	**3-Low**	3-High	1-Low	**4-Medium**	**10-Low**	15
18	1-Low	1-Low	**2-Low**	1-Low	1-Low	**2-Low**	3-High	3-High	**6-High**	**10-Low**	15
2	1-Low	1-Low	**2-Low**	2-Medium	2-Medium	**4-Medium**	2-Medium	1-Low	**3-Low**	**9-Low**	18

6.2 Overall Prioritization Rankings

A discrete numerical prioritization rank was given to each reach based on the overall risk designation. The resulting reach prioritization ranking (Table 6-1) serves as a roadmap for maximizing the returns on investment during development and selection of specific projects, which may be implemented as part of the overall risk reduction strategy put forth in the Master Plan. The following section briefly summarizes the key risks in each reach (starting with the highest priority).

6.2.1 High Priority Reaches

- ***Reach 12:*** This reach is adjacent to Riverside Park, which makes the reach a high priority for restoration. Over 50 insurable structures in the preliminary FEMA 100-year floodplain and more than 10 insurable structures in the approximate 10-year floodplain. Lateral migration and bank failures are visible as a result of the September 2013 flood, which resulted in a collapsed bike path along the river and the exposure of a historical landfill.

- ***Reach 6:*** A high concentration of vertical banks and a history of lateral migration exist in this reach, which also includes vertical banks adjacent (less than two channel widths) to irrigation canal, farmland, and structures. An estimated 10 to 25 insurable structures exist in the floodplain. This reach is especially affected by the Highway 60 Bridge immediately upstream of the reach, which is causing significant deposition of gravel and sediment as well as high bed loads.

- ***Reach 11:*** This reach is directly upstream of the US Highway 85 Bridge. An estimated 10 to 20 insurable structures exist within the preliminary FEMA 100-year floodplain and the approximate 10-year floodplain. However, the flooding observed in September 2013 caused substantially more damage due to backwater effects of the Highway 85 Bridge. Significant aggradation is occurring due to sediment deposition occurring within the channel, primarily along the south side. In addition, the reach is at risk for lateral migration and erosion along unprotected vertical banks upstream of the US Highway 85 Bridge.

- ***Reach 8:*** A constriction, or pinch point, caused by a sharp bend and floodplain encroachment directly upstream of the confluence with the Big Thompson River constrains the river and increases the potential for flooding, primarily of farm lands. Reach 8 consists of a wide river channel with multiple braids, sand bars, cobble bars, and islands, which is similar to what the historical South Platte River may have resembled.

- ***Reach 15:*** US Highway 34 Business was overtopped and damaged during the September 2013 event and there is a history of lateral migration along the outside bank at the US Highway 34 Business Bridge. This reach of the river has had much less human intervention than the majority of the other reaches and it is one of the best examples of both in-channel, floodplain, and riparian health within the study area.

6.2.2 Medium Priority Reaches

- ***Reach 10:*** An estimated 10 to 20 insurable structures exist in the preliminary FEMA 100-year floodplain and the approximate 10-year floodplain. However, flooding observed in September 2013 caused substantially more damage in the area. Similar to Reach 11, the potential for flooding is increased due to backwater effects of the Highway 85 Bridge. This reach also contains unprotected vertical banks adjacent to farmland with minimal riparian buffer.

- ***Reach 13:*** An estimated 10 to 20 insurable structures are in the preliminary FEMA 100-year floodplain, although less than 10 insurable structures are in the approximate 10-year floodplain. This reach is adjacent to the Brower State Wildlife Area and the existing back channel wetlands and newer scoured wetlands provide excellent opportunities to increase wetland habitat diversity for aquatic and avian wildlife.

- ***Reach 1:*** This reach is at risk for lateral migration and erosion along unprotected banks. Railroad tracks exist along the left bank of the river, which are partially protected by riprap. This reach includes the confluence with St. Vrain Creek, making it a high priority reach for restoration, particularly in the confluence area.

- ***Reach 3:*** An estimated 4 to10 insurable structures exist in the floodplain and these structures experienced flooding in September 2013. A history of lateral migration exists along this reach. The right bank provides good habitat and is a potential location to reestablish a regular floodplain connection.

- ***Reach 5:*** Reach 5 has an intact riparian corridor and riparian woodland forest zone; however, the channel lacks connection to the floodplain, limiting forest regeneration. This reach includes the Union Ditch Co. diversion structure.

- ***Reach 7:*** Approximately 3 to 7 insurable structures and railroad tracks exist in the floodplain along Reach 7. Some of the structures may have been impacted in the September 2013 event. The left bank has little to no riparian corridor throughout the upper portion of this reach.

- ***Reach 14:*** US Highway 34 within this reach was damaged in the September 2013 flood. There is very little recruitment or regeneration of vegetation occurring in the area due to the disconnected floodplain and river channel. An existing historical stream channel exists in the area along the right bank of the river, which could provide for wetland development with floodplain reattachment.

- ***Reach 16:*** An estimated 10 to 20 insurable structures exist in the floodplain and US Highway 34 Business was overtopped and damaged during the September 2013 event. There is a history of lateral migration in the area and scarce vegetation exists in the riparian area adjacent to US Highway 34 Business.

- ***Reach 17:*** 18th Street overtopped along this reach during the September 2013 flooding. Reach 17 is a highly modified reach and significant sediment deposition occurs throughout the reach, which results in a lack of aquatic habitat. There is evidence of significant channel manipulation and heavy bank stabilization techniques in use along this reach. In addition, both sides of the channel include agricultural infrastructure adjacent to the channel and within the limited riparian corridors.

6.2.3 Low Priority Reaches

- ***Reach 4:*** This reach is characterized by a high concentration of armored banks and a wide riparian zone on both banks.

- ***Reach 9:*** The riparian corridor on both banks of this reach is currently utilized for agricultural uses including horse pasturing, which limits the height or function of grasses or herbaceous vegetation for wildlife use. The riparian forest in this area is mostly over-mature; however, the condition of individual trees appears to be good. Overhead utilities are within the reach (a downed power line was observed in the channel during a site visit) but do not constrain the floodplain.

- ***Reach 18:*** Cottonwood galleries exist on both sides of the river within this reach and a high quality riparian zone exists along portions of the right overbank of river. Otherwise a very thin riparian corridor with large gaps in riparian vegetation is prevalent in this reach. However, the confluence with the Cache La Poudre River provides an excellent opportunity for ecological restoration and management.

- ***Reach 2:*** Vertical banks directly adjacent to farmland occur throughout this reach. The riparian zone is composed of an eastern cottonwood overstory with mostly declining individuals and lacking regeneration of juvenile cottonwood trees. There is no significant woody understory and significant quantities of noxious vegetation occur within this reach.

Service Layer Credits: Google Earth - imagery date 6/19/2014

South Platte River Restoration Master Plan

Figure 6-1: Overall Risk Designation

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

CDM Smith

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Section 7

Recommendations and Conclusions

7.1 Recommendations and Conceptual Design Strategies

This Master Plan includes a number of recommended actions designed to help reduce risk and restore the Middle South Platte River to a healthier, more stable condition that supports both human and wildlife activities. The recommendations are broken into two categories:

1. General Restoration Strategies
2. Specific Projects

The recommendations discussed in the following sections are based on the goals and objectives of the Master Plan, analysis of existing conditions, sound planning principles, and input from the Alliance and the public.

7.1.1 Restoration and Risk Reduction Objectives

The majority of the 18 reaches within the project area were severely degraded and given a "poor" overall rating, with the exception of Reach 15, which was rated as "fair." In general, the river channel is highly modified and there are very few locations where the river is connected to the floodplain. The riparian area is fairly wide but there are many locations with large gaps in the riparian vegetation. Additionally, the lack of regeneration of cottonwoods and willow species, along with the presence of invasive plant species, degrades the overall riparian quality. Water quality within the project area is negatively affected by runoff from adjacent agricultural and industrial operations, which promotes excessive algal and plant growth. Lastly, habitat for aquatic species was limited and lacked diversity due to the homogeneity of the river channel.

The following are general restoration objectives intended to rehabilitate and support ecologic services and functions of the Middle South Platte River.

- Reconnect the Middle South Platte River with its floodplain with floodplain benches and reestablish a healthy riparian corridor along its banks. Reconnecting the floodplain is possible by regrading existing banks (i.e., laying back the slope) and re-stablishing a new bankfull bench to create lower floodplains within river corridor. A healthy riparian zone that is inundated at frequent intervals promotes regeneration of riparian plant species and acts as a sediment trap and pollutant filter. As the riparian zones begin to rejuvenate, the active river channel will begin to narrow and stream velocities will increase, which will help to improve the river's sediment transport efficiency.

- Retrofit, replace, or remove irrigation diversion structures to reduce or eliminate sediment deposition upstream of the diversion, and to support aquatic species movement and migration. The five diversion structures within the project area are significant obstacles to the migration and movement of aquatic species. Feasibility studies should be conducted to determine the potential for making improvements to existing diversion structures to enhance fish passage (e.g., fish ladders).

- Protect and promote areas with high-quality and high-functioning riparian zones. The three major confluences within the project area (St. Vrain Creek, Big Thompson River, and Poudre River) currently provide the best habitat and ecological services along the Middle South Platte River. The reaches of the river that exhibit a natural morphology and riverine habitat should be preserved. Parts of the river that have been adversely affected by urbanization and encroachment should be rehabilitated in a manner that simulates the natural condition to the extent possible. Where possible, an attempt should be made to reconnect the river channel with the floodplain, either by creating flood storage areas at a lower elevation or by utilizing open space adjacent to the channel for flood storage.

- Develop an integrated noxious vegetation management plan along the Middle South Platte River to remove and mitigate noxious vegetation. Non-native and noxious plant species are abundant throughout the project area. These species suppress native species that provide important ecological services within the riparian zone and support overall watershed health.

7.1.2 Risk Reduction and Restoration Strategies

Risk reduction strategies are generally defined as an overarching management or policy technique to address risks. Restoration strategies include approaches that bring the river to more natural and stable condition long term. These strategies include methods for dealing with system-wide risks such as sediment and debris at crossings and diversion structures and approaches for restoring riparian vegetation. They include both structural and non-structural options such as floodplain reconnection, vegetation management, water quality management practices, or debris reduction.

General strategies for the overall study reach include:

1. Preserve low risk reaches to maintain reaches that have a relatively high functioning ecosystem, geomorphic stability, and minimal, if any, flood hazards.

2. Modify the channel, especially at constrictions (i.e., pinch points), to alter the channel planform, bedform, and profile as a means to stabilize the channel, eliminate constrictions, restore floodplain connection, and establish natural ecosystem functions. The channel modifications would improve sediment transport by creating an active low flow channel and prevent future flooding due to aggradation. In addition, channel modifications would provide space for the stream to adjust to changes in sediment load and discharge as the river establishes new equilibriums in the wake of the September 2013 floods.

3. Reconnect the channel to the floodplain to manage floods by storing and conveying flood flows on floodplains, either through setting back berms and/or regrading the existing banks. Floodplain reconnection also allows floods to pass more slowly, reducing damage to bridges, berms and other infrastructure. Other benefits associated with floodplain reconnection include improving water supply through increased groundwater recharge, enhancing water quality, and increasing ecological complexity.

4. Remove debris from bridges, infrastructure, and diversion structures. Removing debris will improve channel hydraulic conveyance, and reduce or eliminate back water as well as improve sediment transport during high flows.

5. Identify locations that can be used to capture debris and sediment before they impact infrastructure. Ideal locations would be in overbank areas with established vegetation that become inundated as flows rise. The overland flow can then spread out and drop much of its sediment load and debris before connecting back to the channel.

6. Re-vegetate bare stream banks and enhance native vegetation in floodplain areas. Vegetation serves a number of functions including energy dissipation, bank stability, runoff capture and filtration, and ecosystem enhancement. Guidelines specific to the South Platte River system include:

   a. Plantings should utilize seed mixtures with an appropriate diverse species of grasses and forbs suitable for the soil type and elevation, as well as perennial shrubs and trees.

   b. Leaving woody material, woody debris etc. on riparian and upland sites will enhance the diversity of habitat types and the plant species supported by the site, which will benefit a larger variety of wildlife.

7. Restore a riparian buffer where feasible to allow for channel migration, flood attenuation and sediment deposition, as well as, provide wildlife habitat and improved water quality. The riparian buffer should be comprised of native tree species and/or pervious surfaces such as vegetation or pervious paving that should extend laterally from the top of the bank. Buffer widths should be determined based on specific goals for each reach and should be estimated using the sediment transport model which will be developed as an extension of the master plan. A recommended baseline is two channel widths.

8. Identify new stormwater facilities such as detention basins and wetlands to improve water quality, enhance wildlife habitat, and provide recreational amenities. In addition, stormwater best management practices (detention basins, bio-filters, hydrodynamic devices, media filters, retention ponds, wetland basins, wetland channels, grass swales, grass buffers, rain gardens, and pervious materials) should be encouraged in order to protect and improve water quality. Water quality improvements to the South Platte River can be accomplished through several methods. Daylighting of existing storm sewers and stormwater detention ponds should incorporate wetlands to filter out pollutants, as well as providing aesthetic recreation and wildlife benefits. To complement and increase the effectiveness of the wetland filtration areas, the facilities should be located so stormwater outfalls will spill out upstream of the wetland features. Connecting adjacent lands to the river to create a buffer along the river should be pursued in order to increase pervious land to reduce stormwater run-off and groundwater recharge.

9. Create and maintain a public river edge throughout the South Platte River Corridor, where possible, to encourage public access and single point connection locations to the river and prevent access to sensitive areas.

10. Educate the public and land owners to encourage stewardship and best management practices along the river.

Examples of project types and policies that may apply to the South Platte River study area for implementing the overall goals of the project include:

- Development/enhancement of guidelines for establishing and maintaining flood defensible space
- Voluntary Property buyouts to establish and/or preserve riparian buffers
- Land use planning updates to include riparian buffers and dike construction.
- Establish new riparian zones through setbacks and conservation easements
- Determine need for FEMA floodplain re-mapping (new hydrology)
- Development of FEMA non-regulatory products: Flood Risk Dataset (changes since last FIRM, risk assessment, areas of mitigation interest, depth and analysis grids), Flood Risk Map, Flood Risk Report
- Enhance and preserve existing habitat and recreation areas

Not all of the project types or policies will be practical or reasonably implementable in all study reaches. For example, although property buyout is technically feasible to address various risks, this strategy can be both economically and politically challenging. Although not directly considered in the scope of this project, the Alliance should explore identifying land owners through public outreach activities who may be willing to voluntarily consider property transfers to state or non-governmental organizations (Ducks Unlimited, Great Outdoors Colorado, and CPW) for riparian corridor enhancements.

7.1.3 Project Types

Project types can generally be categorized as those designed to improve or enhance channel conveyance and geomorphic stability, bridge modifications/replacement, riparian corridor planting, habitat improvements, water quality enhancement, or recreational amenity. Specific project types are classified under the following categories.

Sediment Management

Removal of sediment deposits upstream of structures such as diversion structures and bridges to increase conveyance, and reduce or eliminate back water. It should be noted that management of sediment within the channel is a maintenance application intended to be used in combination with other projects that address causal issues and prevent future sediment deposits from forming in these areas. In other words, it is a short-term solution to a long-term problem.

Bridge Modifications

Upgrading or replacing existing bridge structures that do not have the hydraulic capacity to convey flood flows. **Figure 7-1** shows a conceptual design of a new bridge while **Figure 7-2** shows a conceptual design for a retrofit project. Note several bridge modifications/replacement projects are already underway by CDOT at Highway 60 and Highway 34 Business.

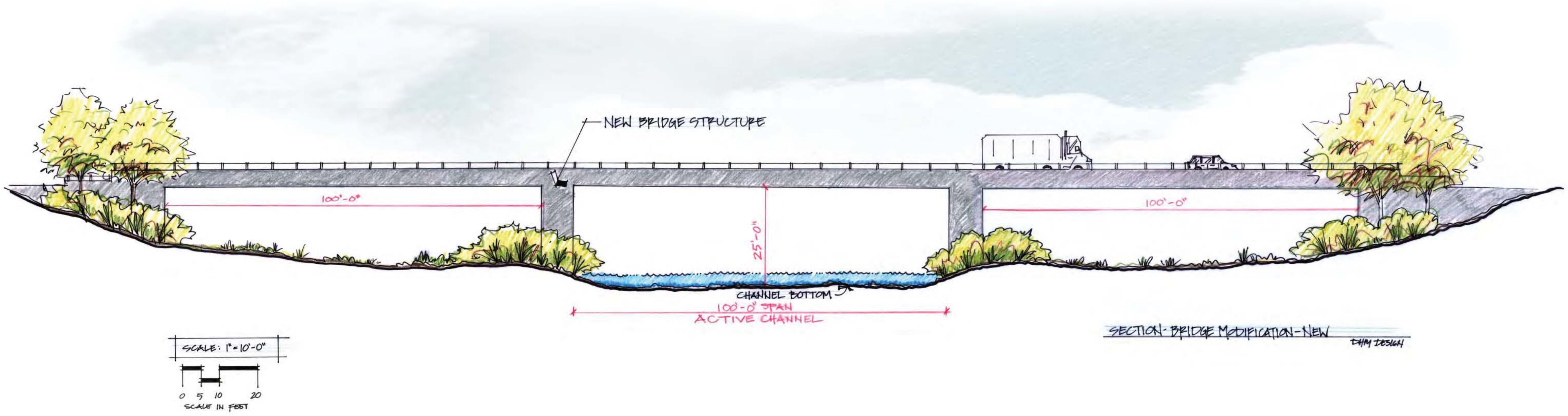


Figure 7-1. New Bridge Project

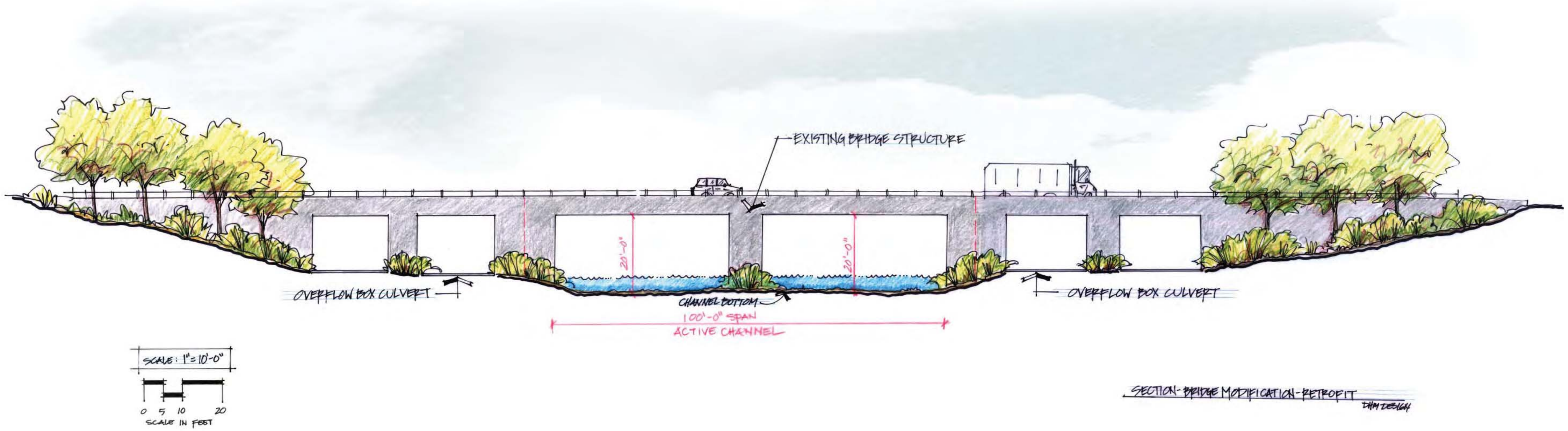


Figure 7-2. Bridge Retrofit Project

Channel Modifications/Realignment

Proposed channel modifications are intended to alter the channel planform, bedform, and profile as a means to improve sediment transport, reconnect the channel to its floodplain, and establish natural ecosystem functions.

Channel morphology is a term used to describe a stream's planform, cross-sectional, and longitudinal geometries. Channel morphology is a function of physical processes and environmental conditions, including flow rates, recurrences, and characteristics; the composition and erodibility of the bed and banks; vegetation types and densities in both the channel and along its banks; and the availability and characteristics of suspended sediment and other mobilized material. In a natural system, each of these functional characteristics interact to establish a stable channel that typically maintains relatively constant average geometries system-wide while experiencing localized changes over time.

The proposed channel modifications are intended to improve channel morphology by realigning the planform and regrading the bed profile.

Planform

Channel planform refers to the horizontal spatial pattern and alignment of a channel, as if one were looking down on it from above (see **Figure 7-3**). Maintaining a natural meandering low flow channel planform within the "active channel" of the South Platte River is an important component to restoring the river due to the river's inclination to migrate laterally and aggrade and degrade. Providing a natural, stable channel morphology will improve the sediment transport capacity, as well as aquatic habitat and riparian vegetation.

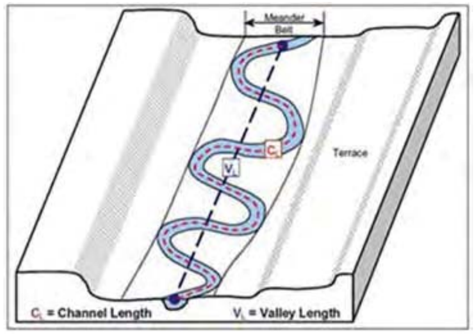


Figure 7-3. Planform view

Bedform

Bedform refers to the depositional features on the bed of a river that are formed by the movement of the bed material, primarily sands, gravels, and cobbles, in response to flow. Typical bedforms in a cobble, gravel, and sand bed channel, like the South Platte River, are riffle-pool sequences, runs, glides, and bars. The location, spacing, and shaping of these channel bedform features is a characteristic of the flow parameters, in particular flow depth and velocity and channel constraints.

Riffles and Pools

Riffles and pools are often associated and comprise the dominant bedforms in coarse-grained channels. Riffles are depositional features associated with straighter, often higher-gradient channel sections and are characterized by shallow, faster turbulent flow (see **Figure 7-4**). Pools are erosional features that are usually located along the outside bank of channel bends. These two bedform features often alternate in response to channel sinuosity, with the riffle occurring in the straight reach. Riffles are also spawning beds for native fish species.

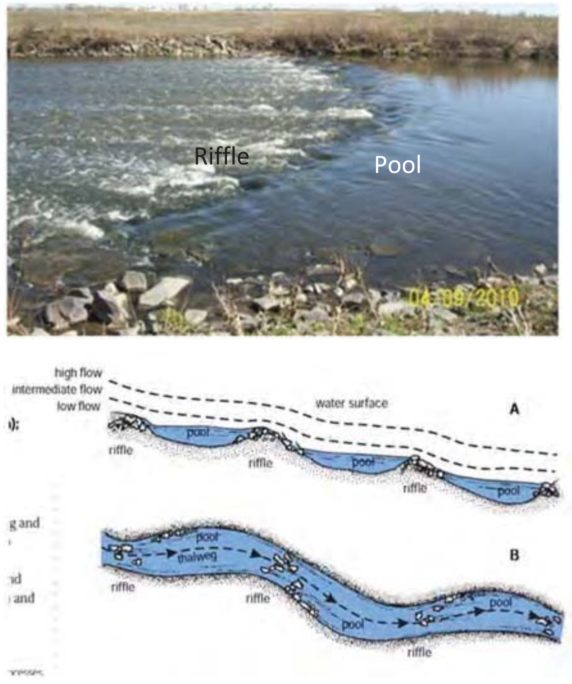


Figure 7-4. Typical riffle-pool

Bioengineered Bank Protection

Revetments are typically used to stabilize banks by providing resistivity to flow that reduces the erosivity of the bank. Revetments are often composed of rock (e.g., riprap) and covered with soil and vegetated to create a natural looking bank. Vegetation can include woody species such as willows and cottonwoods to provide near bank shading of the low flow channel. Bank stabilization projects could include enhancement of existing stabilized banks (i.e., removing of concrete rubble or car bodies) or protection of eroding banks in critical areas.

In addition to revetments, rootwads and willow waddles can also be used to protect banks with additional benefits. Rootwoods and willow waddles reduce boundary shear stress by creating greater roughness and redirecting flow away from the bank, providing bank protection, refugia for aquatic species, and organic substrate for macro-invertebrates and vegetation. In the case of rootwads, the tree trunk is keyed into the bank leaving the exposed root mass along the channel bank to prevent erosion.

Figures 7-5 and 7-6 show a conceptual design of the elements involved with bank stabilization projects.

Regrading and Revegetation

Regrading and revegetation riparian areas are critical elements of creating a healthy, resilient river corridor. In addition, these improvements will help establish a riparian buffer for the channel. It includes three main elements; 1) creating floodplain benches, 2) riparian zone plantings, and 3) creating secondary channels and backwater ponds.

Floodplain Benches

Floodplain or emergent benches are developed by laying back and redesigning the bank to form multiple flood zones. These zones enhance the river ecosystem by providing bank stabilization, redirection of stream flow, removal of pollutants, and other varied environmental properties to support different native vegetation. An important ecological function of the floodplain bench is that it creates a connection between the low flow channel and riparian corridor. Floodplain benches are often associated with point bars but can also occur continuously through straight reaches of the river. **Figure 7-7** shows a conceptual design of a floodplain bench project. These benches should range in width between 20 feet (minimum) and 60 feet or greater (desirable).

Riparian Zone Plantings

Riparian zones protect stream banks from erosion and can attenuate flood peaks. They also provide habitat for fish and wildlife and help stabilize stream channels. Modifying the channel banks to create a multi-tiered cross section with floodplain benches will support plants similar to those in emergent benches; however, the floodplain benches can also contain woody plant materials such as willows that thrive in these areas. Emergent vegetation exists within the toe and bank zone, while riparian vegetation is found in the overbank zone. These plants are less tolerant of frequent flooding. Plants that are submerged are frequently referred to as submerged aquatics (toe zone). These plants typically grow in the wettest areas of the emergent bench. Plants located in riparian benches seek out the water table and rely on this water source to sustain their growth and the eventual dispersion of rhizomes to produce further growth.

Secondary Channels and Backwater Ponds

The creation and enhancement of secondary channels and backwater ponds will provide refugia for aquatic species as well as wetland habitat for birds and small mammals. Secondary channels exist around point and mid-channel bars and create slack water areas outside of the main current of the primary channel. In addition, due to low-flow velocities, secondary channels often sustain aquatic vegetative growth that is used for foraging and cover by aquatic species. Off-channel backwater pools provide habitat refuge and can polish the stormwater and flood flows.

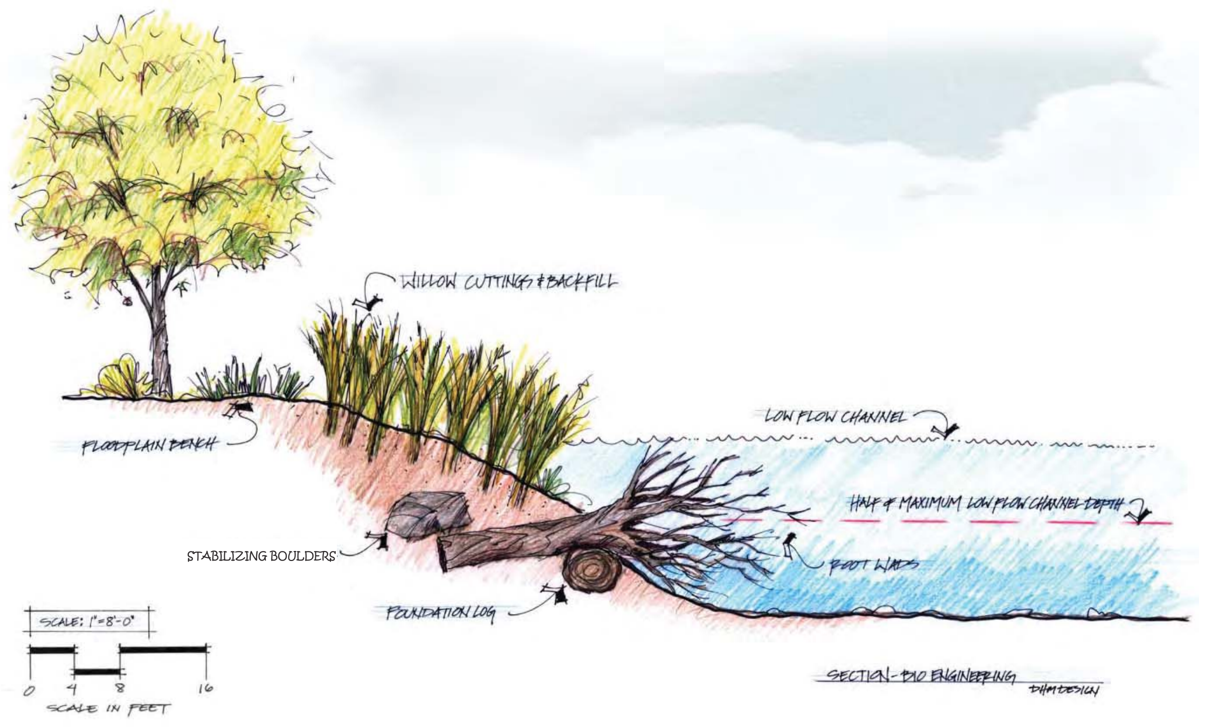


Figure 7-5. Bank Stabilization Project Example

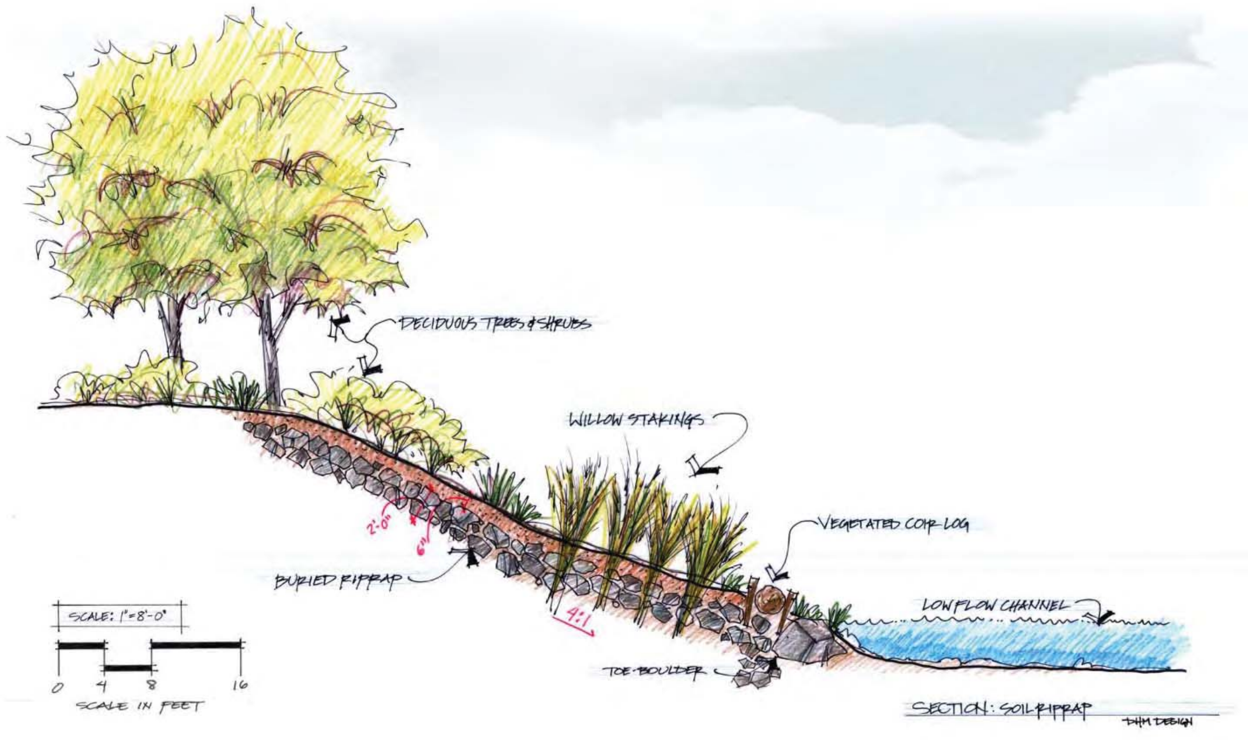


Figure 7-6. Bank Stabilization Project Example

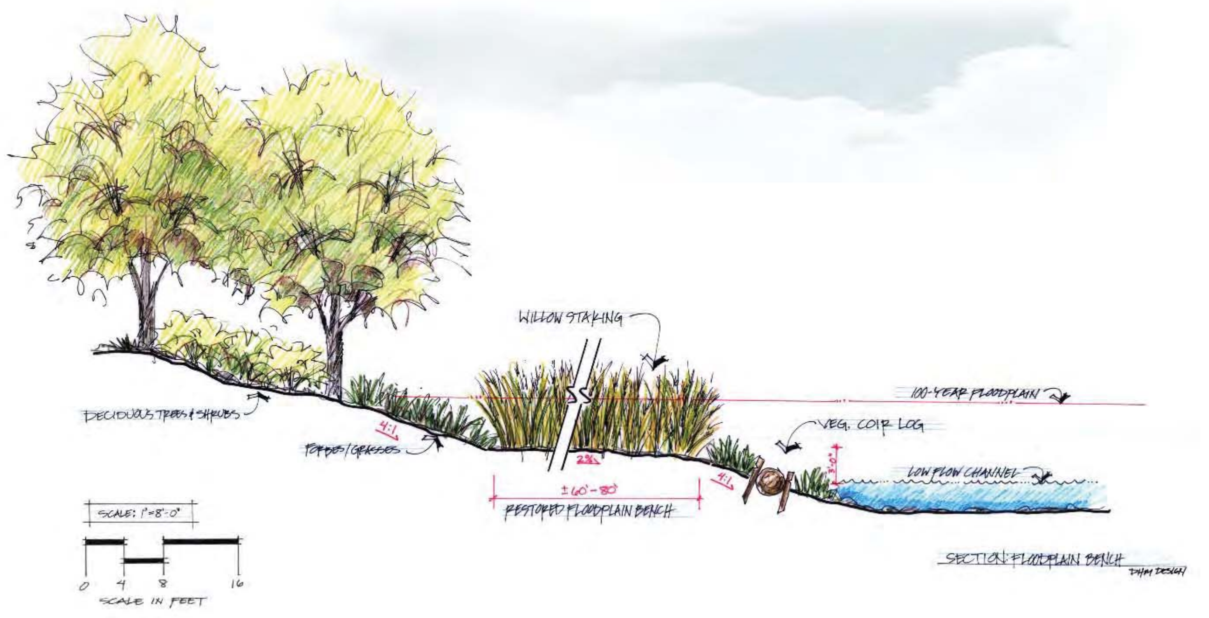


Figure 7-7. Floodplain Bench Project Example

A general materials plant list is provided below for floodplain benches and upland zones.

1. Floodplain Bench Zone

   Woody:
   - Birch
   - Dogwood
   - Plains Cottonwood
   - Peach Leaf Willow
   - Willow (*S. planifolia, S. exigua*)
   - Alder
   - Chokecherry
   - Red Hawthorne

   Grasses and Forbs:
   - Bulrush (Hardstem Bulrush)
   - Rush (Baltic Rush)
   - Sedge (Wooly Sedge, Beaked Sedge, Clustered Sedge)
   - Typha
   - Spike-Rush
   - Streambank Wheat Grass
   - Switch Grass
   - Prairie Slough Grass
   - Prairie Cord Grass
   - Meadow Bromes
   - Fescues

2. Upland Zone
    - Plains Cottonwood
    - Snowberry
    - Sumac
    - Potentilla
    - Sand Cherry
    - Eastern Juniper
    - Rabbitbrush/Sage

Elevation of plantings on the floodplain bench above the low flow channel (wetland plants) should be approximately 0.5 feet above the low flow water surface elevation. Woody plants should be 2 to 5 feet above low flow water surface elevation (depending on size and rootmass of the plants as well as the local hydrology and soils). Figure 7-7 depicts the locations of the planting zones and their relation to each other.

Construction of Recreational Trails and Parks

Recreational trails are used for a variety of recreational activities and supplement efforts to promote connection and access to the Middle South Platte River. A regional trail along the Middle South Platte River and/or nature trails could be considered. Trail creation should consider potential geomorphic and ecological impacts.

Develop Public River Access

Develop river access points on public property for recreation activities including infrastructure for fishing, boating, and canoeing.

Diversion Structure Modifications

The existing diversion structures prevent fish migration and may hinder recreational uses of the river as well. Modifying diversion structures to be more multi-objective would allow fish passage for native fish and improve in-channel habitat. Modifications could be designed to divert the same amount of flow previously diverted to avoid water rights conflicts. **Figure 7-8** shows a conceptual design for a diversion retrofit project.

Dike Removal, Setbacks, and Berms

Earth embankments have been constructed adjacent to the river channel to prevent flooding of agricultural fields. Repairing, replacing, or removing existing dikes could improve the flood conveyance capacity and flood attenuation as well as reduce costly maintenance. **Figure 7-9** shows a conceptual design for a dike removal project.

In some cases it may be necessary to create new earthen berms to protect property. The new berms will be utilized where space is limited along the river corridor, and property is threatened.

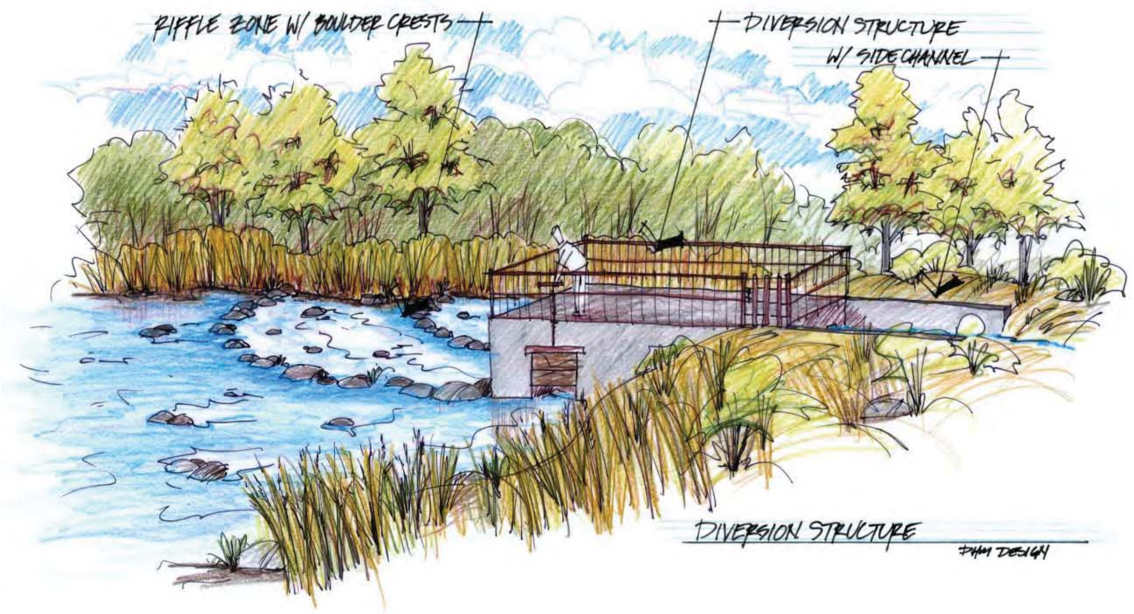


Figure 7-8. Diversion Retrofit Project Example

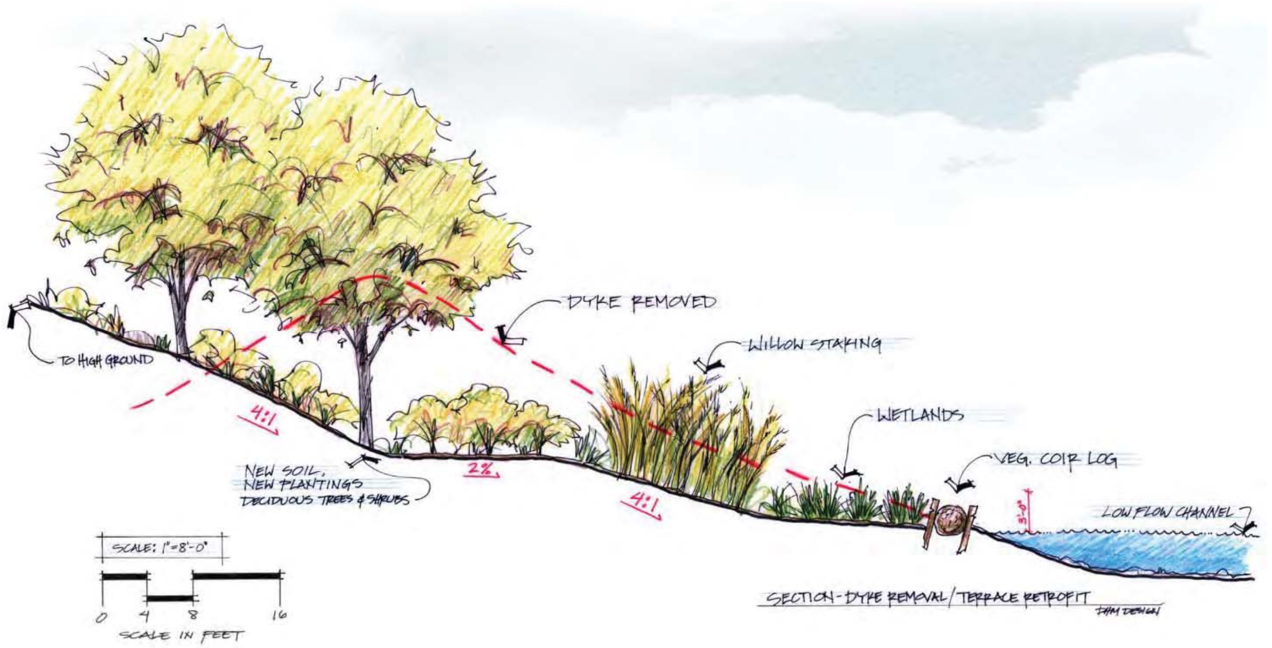


Figure 7-9. Dike Removal Project Example

7.2 Specific Projects

Implementation of any restoration and/or risk reduction strategies identified will be site-specific and take advantage of local conditions in and near the river. Some reaches are likely better suited for specific improvements than others. For this reason, risk reduction strategies and their associated project options are best evaluated through the grouping of risk reduction options on a river reach basis. **Figures 7-10 through 7-17** show specific projects through reaches 6 to 14. Projects were specifically identified for the reaches where the landowner meetings were held (see Section 2.2).

Projects were grouped by reach and extent of the improvements. Some improvements span multiple reaches, so adjacent projects were also grouped in within these improvements.

7.2.1 Reach 6 Improvements

Figures 7-10 through 7-11 show proposed improvements to Reach 6. Projects within this reach include channel modifications, riffles and pools, regrading and revegetation, and bioengineered bank protection.

Individual improvements in this section include the following:

- RA1, RA2, RA3 – Channel realignment within this section will reconnect the channel to the floodplain (river left), shift the channel away from a feed lot, and facilitate the creation of a riparian buffer. The channel realignment will also create a low flow channel that will improve sediment transport through the reach.
- RF1, RF2, RF3, RF4 – Riffles will stabilize the proposed channel realignment and provide spawning and feeding habitat for native fish species.
- RG1, RG2 – Regrading and revegetation areas will create a riparian buffer, wetlands, and secondary channels, all of which improve the resiliency of the river. The banks will be replanted with native vegetation noted above.
- BE1 – Bioengineered bank protection will protect a narrow section of the riparian buffer on the outside of a newly created bend.

7.2.2 Reach 7, 8, and 9 Improvements

Figures 7-11 through 7-13 show proposed improvements to Reaches 7, 8, and 9. Projects within this reach include channel modifications, riffles and pools, regrading and revegetation, and bioengineered bank protection. Specific projects in this section are removing debris from a railroad bridge, improving the wetlands on the Sorin property, improving the Godfrey ditch diversion structure and flood gates, and widening the pinch point adjacent to the confluence with the Big Thompson River.

Individual improvements in this section include the following:

- RA4, RA5, RA6 – Channel realignment within this section will reconnect the channel to the floodplain (river left), shift the channel away from a feed lot, and facilitate the creation of a riparian buffer. The channel realignment will also create a low flow channel that will improve sediment transport through the reach. This realignment will also help to relieve the pinch point at the confluence with the Big Thompson River.
- RF5, RF6 – Riffles will stabilize the proposed channel realignment and provide spawning and feeding habitat for native fish species.
- RG3, RG4, RG5, RG6 – Regrading and revegetation areas will create a riparian buffer, wetlands, and secondary channels, all of which improve the resiliency of the river. The banks will be replanted with native vegetation noted above.
- BE2, BE3, BE4 – Bioengineered bank protection (rootwads, willow waddle, or void filled riprap) will protect a narrow section of the riparian buffer on the outside of a bend.
- BM1 – Earthen berm will protect agricultural property at the confluence with the Big Thompson River from low to moderate flows that overtop the river's banks. The berm is not indented to protect the property during an extreme flood (i.e., 100-year event).
- Railroad Bridge – Clean debris and removing sediment that has accumulated because of the railroad crossing.
- Godfrey Ditch Diversion Structure – Remove and replace the existing diversion structure to improve sediment transport as well as fish passage.
- Godfrey Ditch Flood Control Gate – Replace the existing flood control gate to improve conveyance in the river during low and high flows as well as sediment transport.
- Sorin Wetlands – Improving existing wetlands and creating new wetlands will improve the overall ecological function of the river and provide floodplain storage during high flows.

7.2.3 Reach 10, 11, and 12 Improvements

Figures 7-13 through 7-16 show proposed improvements to reaches 10, 11, and 12. Projects within this reach include channel modifications, riffles and pools, regrading and revegetation, and bioengineered bank protection. Specific projects in this section are removing car bodies that are protecting some banks within this reach and replacing them with bioengineered bank protection, constructing an earthen berm to protect private property, improving the Latham ditch diversion structure, and removing debris and sediment from the Highway 85 and railroad bridges.

Individual improvements in this section include the following:

- RA7, RA8, RA9, RA10 – Channel realignment within this section will shift the channel to account for reconstructing the diversion structure of the Latham Ditch as well improve sediment transport upstream and downstream of Highway 85 and the railroad bridge. The realignment will also reconnect the channel to the floodplain (river left and right) and create a low flow channel.
- RF7, RF8, RF9, RF10 – Riffles will stabilize the proposed channel realignment and provide spawning and feeding habitat for native fish species.

- RG7, RG8, RG9, RG10, RG11, RG12– Regrading and revegetation areas will create a riparian buffer, wetlands, and secondary channels, all of which improve the resiliency of the river. The banks will be replanted with native vegetation noted above.
- BE5, BE6, BE7, BE8, BE9 – Bioengineered bank protection (rootwads, willow waddle, or void filled riprap) will protect a narrow section of the riparian buffer on the outside of a bend.
- BM2 – Earthen berm to protect a property adjacent to the channel realignment, RA8.
- Highway 85 and Railroad Bridge – Clean debris and removing sediment that has accumulated because of the railroad crossing.
- Lower Latham Ditch Diversion Structure – Remove and replace the existing diversion structure to improve sediment transport as well as fish passage.
- Remove car bodies from the banks and replace with bioengineering.

7.2.4 Reach 13 and 14 Improvements

Figures 7-16 through 7-17 show proposed improvements to reaches 13 and 14. Projects within this reach include regrading and revegetation, and bioengineered bank protection. Specific projects in this section are removing car bodies that are protecting some banks within this reach and replacing them with bioengineered bank protection, constructing an earthen berm to protect the private property, improving the Patterson ditch diversion structure, and removing debris and sediment from the 37th Street Bridge.

Individual improvements in this section include the following:

- RG13, RG14– Regrading and revegetation areas will create a riparian buffer, wetlands, and secondary channels, all of which improve the resiliency of the river. The banks will be replanted with native vegetation noted above.
- BE10, BE11 – Bioengineered bank protection (rootwads, willow waddle, or void filled riprap) will protect a narrow section of the riparian buffer on the outside of a bend.
- BM3 – Earthen berm to protect private properties during low to moderate flows that overtop the river's banks. The berm is not indented to protect the property during an extreme flood (i.e., 100-year event).
- 37th Street Bridge – Clean debris and removing sediment that has accumulated because of the railroad crossing.
- Patterson Ditch Diversion Structure – Remove and replace the existing diversion structure to improve sediment transport as well as fish passage.
- Remove car bodies from the banks and replace with bioengineering.

7.3 Planning Level Opinion of Probable Construction Cost

CDM Smith prepared an opinion of probable construction cost (OPCC) for the projects listed in the previous section. The construction costs of these projects are based off of conceptual level design, and should only be used for planning purposes. Pricing for individual items is based on CDM Smith's experience with similar project along the South Platte River and around Colorado. Design and engineering fees have not been included in the OPCC for these projects. Detailed breakdowns of the OPCC have been included in **Appendix G**.

Table 7-1. Summary of Total Project Cost Estimate

Section	Cost ($)
Reach 6	19,300,000
Reach 7, 8, & 9	27,800,000
Reach 10,11, & 12	27,100,000
Reach 13 & 14	12,500,000

The concept level construction cost opinion for all the improvements included in this Master Plan is $87.4 million; an additional 10 to 15 percent should be added for design, engineering and on the ground construction management the projects.

7.3.1 Takeoff of Quantities and Assumptions

The opinion of probable cost was developed based on quantity takeoffs from the conceptual design shown in Figures 10-17. The key assumptions for the OPC are as follows:

- Unit costs were estimated using similar project CDM Smith has implemented along the South Platter River and around Colorado's Front Range.
- Mobilizations costs were assumed to be 5% of the unit costs.
- Water control was assumed to be 30% of the unit costs.
- Erosion control was assumed to be 10% of the unit costs.
- A contingency of 25% was applied to the total project cost.

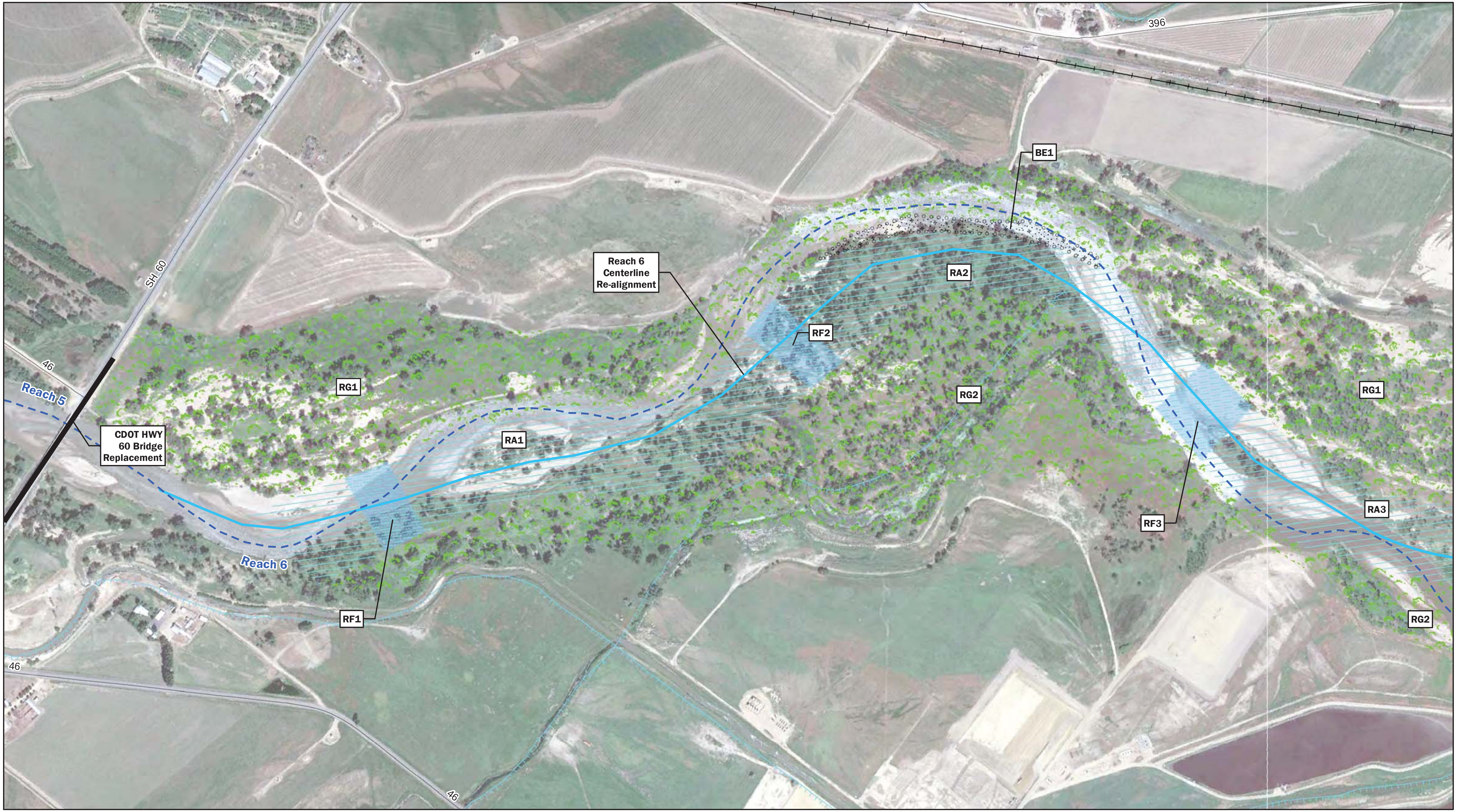
The costs included in Table 7.3 above and the unit costs provided below are for planning purposes only.

Channel Realignment

The channel centerline realignment unit cost is based on forming a low-flow channel that is sized for the two-year flood. **$340/LF**.

Regrade and Revegetate

The unit cost of regrading and revegetation was calculated by separating the two components. The regrading unit cost was based on a 5-foot depth uniform excavation over the entire regrading area, **$46,800/acre**. The revegetation unit cost was estimated on a per acre basis for clearing and grubbing, wetland, upland, and riparian seeding, **$8,500/acre**.



Notes:
Service Layer Credits: Google Earth - imagery date 6/19/2014
Contours shown at 2 ft intervals

▬	Study Reach Division
▬	Proposed River Realignment
⌒	Berm
▨	Riffle
⁘	Wetlands
○	Bio-Engineer Bank
⁘	Regrade and Vegetate
▨	River Realignment

0 250 500 1,000
Feet

Drawn KEH	*Date* 11/06/2015	*Title:* **Proposed Projects**	
Scale **1 inch = 500 feet**	*Checked* JH	*Figure* **7-10**	*Site:* **Middle South Platte River Restoration Master Plan**

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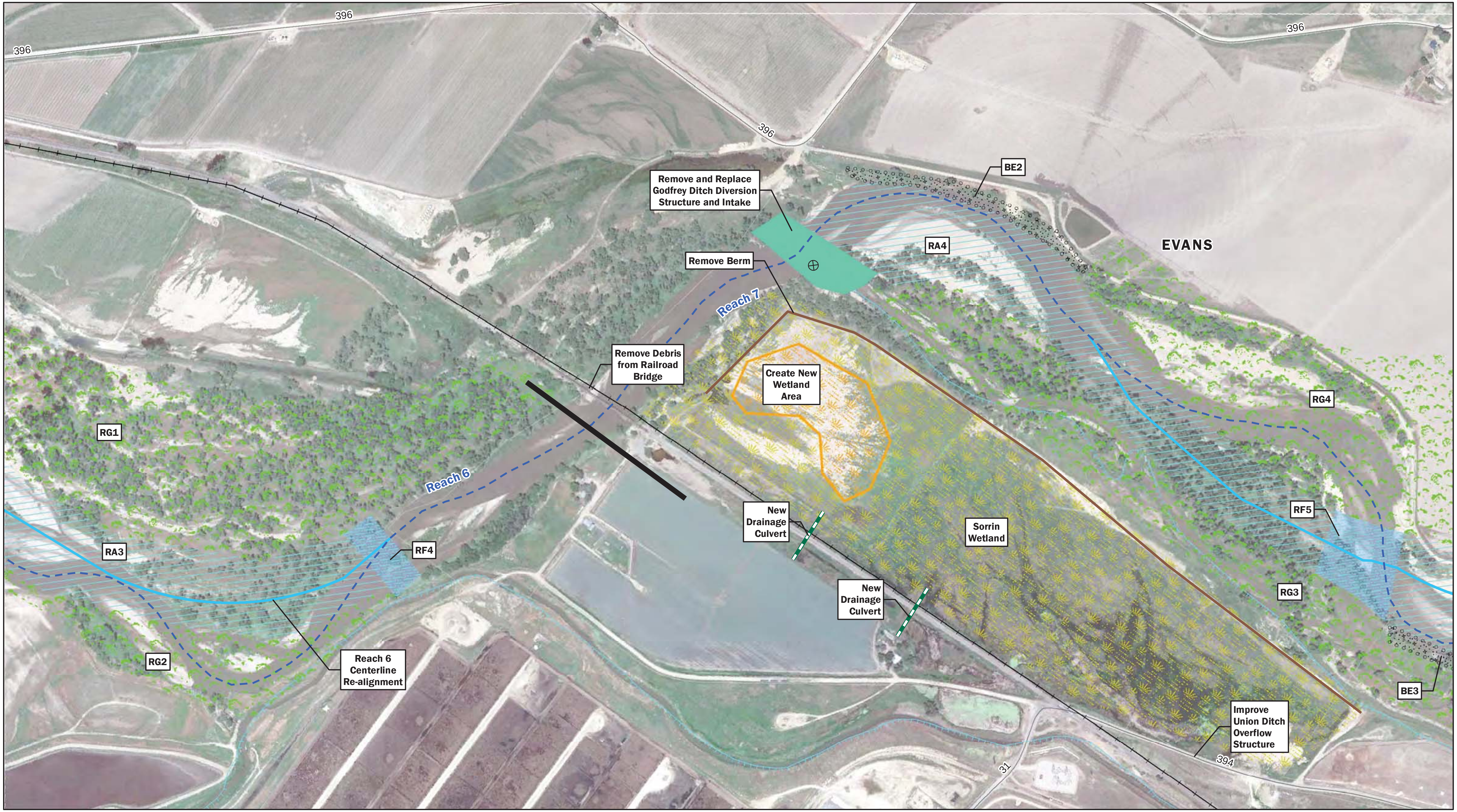

Notes:
Service Layer Credits: Google Earth - imagery date 6/19/2014
Contours shown at 2 ft intervals

▬ Study Reach Division	Berm	Wetlands	Regrade and Vegetate
▬ Proposed River Realignment	▨ Riffle	Bio-Engineer Bank	▨ River Realignment

0 250 500 1,000
Feet

Scale **1 inch = 500 feet**

Drawn **KEH**

Checked **JH**

Date **11/06/2015**

Figure **7-11**

Title: **Proposed Projects**

Site: **Middle South Platte River Restoration Master Plan**

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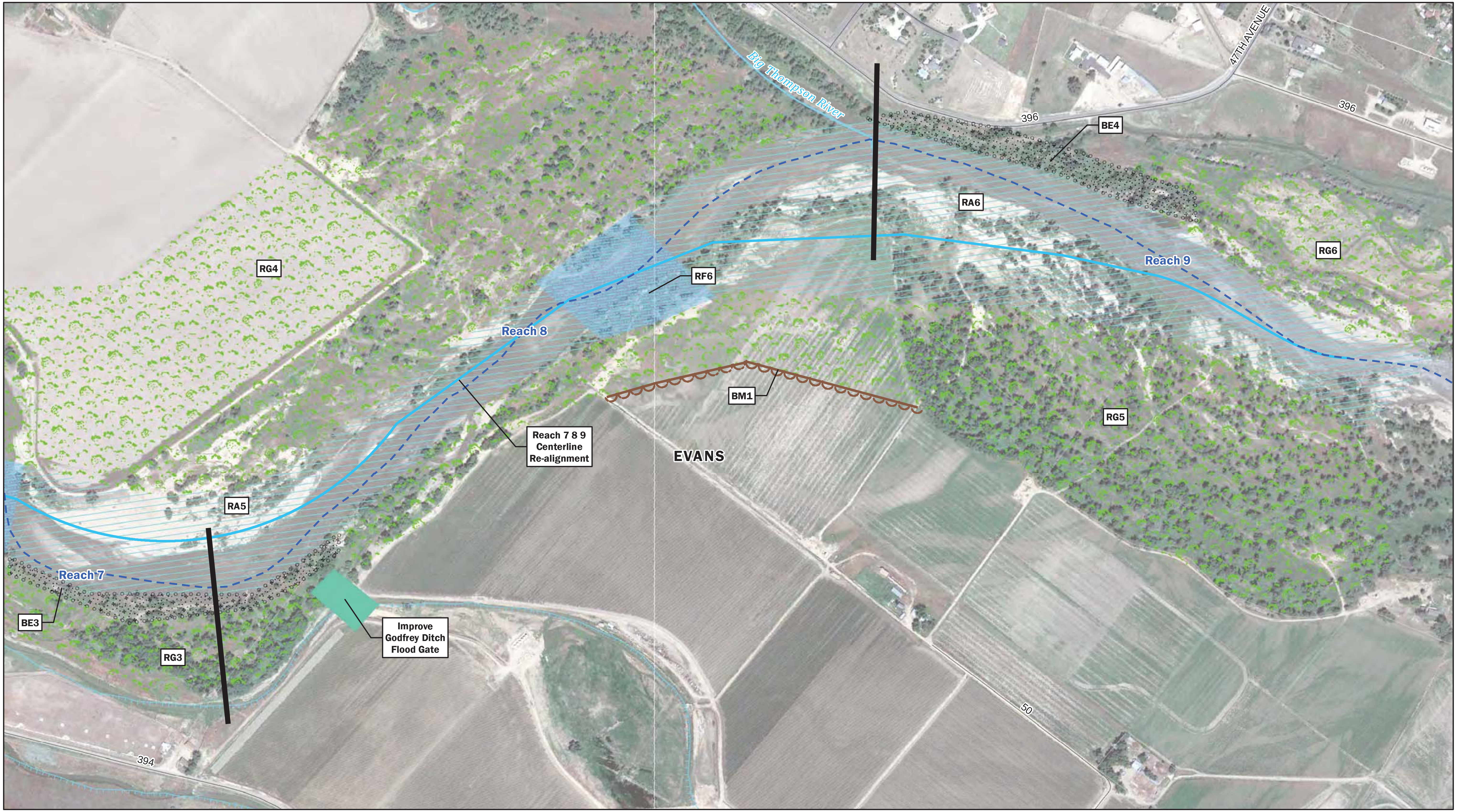

Notes:
Service Layer Credits: Google Earth - imagery date 6/19/2014
Contours shown at 2 ft intervals

▬ Study Reach Division	Berm	Wetlands	Regrade and Vegetate
▬ Proposed River Realignment	▨ Riffle	Bio-Engineer Bank	▨ River Realignment

0 250 500 1,000
Feet

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Figure **7-12**

Site: **Middle South Platte River Restoration Master Plan**

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Contours shown at 2 ft intervals

▬ Study Reach Division	Berm	Wetlands	Regrade and Vegetate
▬ Proposed River Realignment	▨ Riffle	Bio-Engineer Bank	▨ River Realignment

0 250 500 1,000
Feet

Drawn KEH

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Figure **7-13**

Site: **Middle South Platte River Restoration Master Plan**

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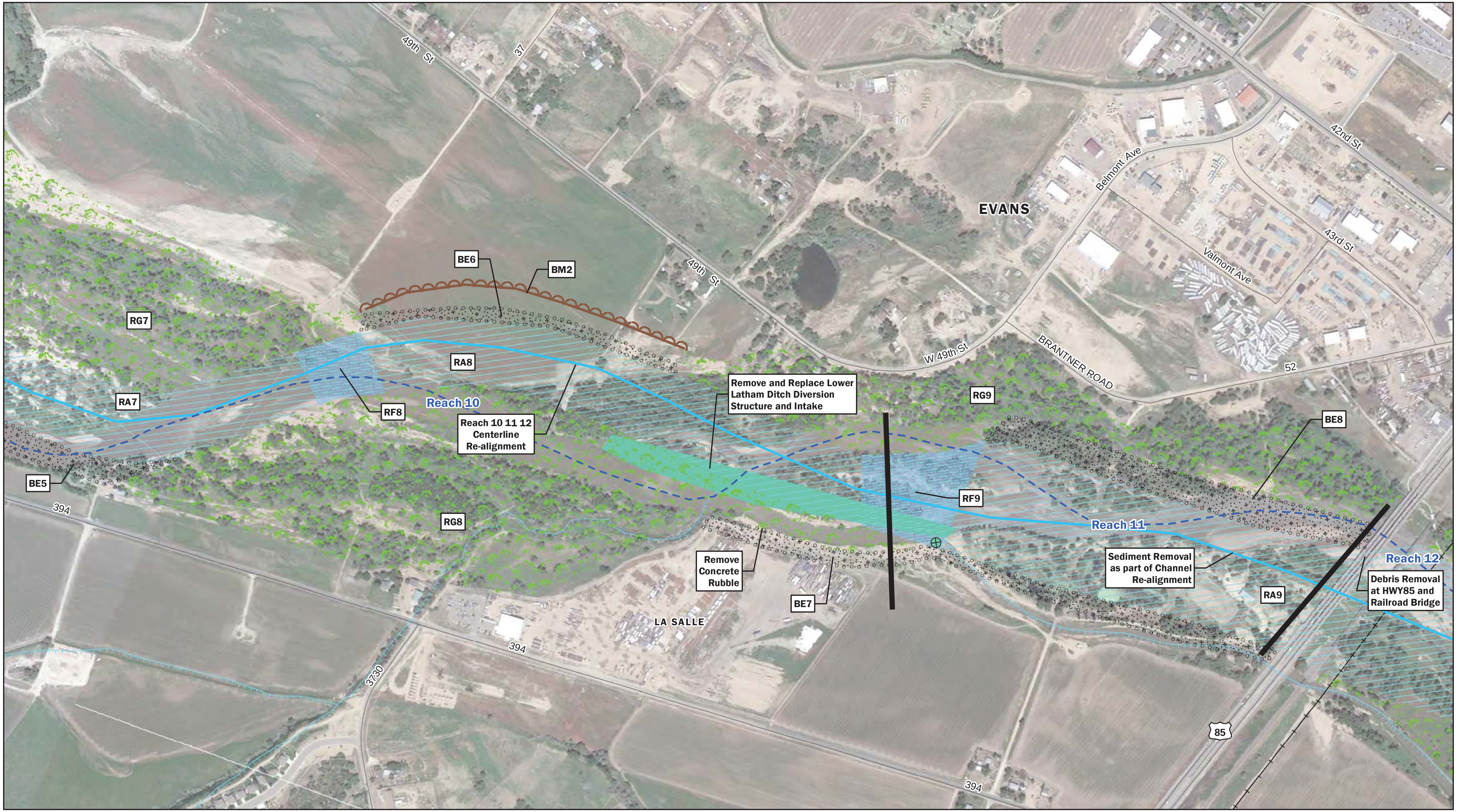

Notes:
Service Layer Credits: Google Earth - imagery date 6/19/2014
Contours shown at 2 ft intervals

▬	Study Reach Division
▬	Proposed River Realignment
⌒⌒	Berm
▨	Riffle
⁚	Wetlands
○	Bio-Engineer Bank
⁚	Regrade and Vegetate
▨	River Realignment

0 250 500 1,000
Feet

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Date 11/06/2015

Title: **Proposed Projects**

Scale **1 inch = 500 feet**

Checked JH

Figure **7-14**

Site: **Middle South Platte River Restoration Master Plan**

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Notes:
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Contours shown at 2 ft intervals

▬	Study Reach Division
▬	Proposed River Realignment
⌒	Berm
▨	Riffle
⁘	Wetlands
⁘	Bio-Engineer Bank
⁘	Regrade and Vegetate
▨	River Realignment

0 250 500 1,000
Feet

Drawn KEH
Date 11/06/2015
Title: **Proposed Projects**

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Scale **1 inch = 500 feet**
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Figure **7-15**
Site: **Middle South Platte River Restoration Master Plan**

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▬	Study Reach Division
▬	Proposed River Realignment
⌒⌒	Berm
▨	Riffle
⁘	Wetlands
○	Bio-Engineer Bank
⁘	Regrade and Vegetate
▨	River Realignment

0 250 500 1,000
Feet

Scale 1 inch = 500 feet

Drawn KEH

Checked JH

Date 11/06/2015

Figure 7-16

Title: **Proposed Projects**

Site: **Middle South Platte River Restoration Master Plan**

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Notes:
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▬	Study Reach Division
▬	Proposed River Realignment
	Berm
▨	Riffle
	Wetlands
	Bio-Engineer Bank
	Regrade and Vegetate
▨	River Realignment

0 250 500 1,000
Feet

Drawn KEH

Date 11/06/2015

Title: **Proposed Projects**

Scale 1 inch = 500 feet

Checked JH

Figure 7-18

Site: **Middle South Platte River Restoration Master Plan**

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Bioengineered Bank Protection

Bioengineered bank protection refers to rootwad bank protection, willow wattle bundles, or void filled riprap bank protection. The unit cost for rootwad/willow waddle bank protection was determined from similar projects, **$310/Linear Foot.** The unit cost for void filled riprap was determined by assuming a 10 foot maximum bank height, 3:1 side slope, and 9” D_{50} riprap, **$200/Linear Foot**.

Riffles

Riffle unit pricing was based on similar projects along the South Platte River, **$145,000/each**.

Diversion Structures

Diversion structure unit pricing was based on similar projects along the South Platte River, **$725,000/each**.

Berms

Unit costs for earthen berms is based on the assumptions that the berm will be four feet higher than existing grade, 3:1 side slopes, and a three foot wide top width. The river side of the berm will also be lined with 9” D50 riprap, and the entire berm will be seeded with upland seed mix, **$130/Linear Foot**.

Specialty Projects

Various specialty projects across all reaches were estimated using best available data and engineering judgment.

7.4 Regulatory Recommendations and Requirements

7.4.1 Recommendations

To accomplish the goals of this plan, the Alliance should implement regulatory measures to improve the health and vitality of the South Platte River. The following best practices were identified that would benefit the South Platte River:

- **Create a Technical Advisory Committee:** Create a South Platte River Technical Advisory Committee, comprised of one or more members of the Alliance and representatives from universities, local utilities, State agencies (CWCB, DOLA, CDPHE etc.), and Federal agencies (NRCS, USACE, U.S. Environmental Protection Agency [EPA], etc.). The committee would meet on a semi-annual basis to review and advise on implementation plan progress. The committee would also develop new implementation steps as needed. By creating a Technical Advisory Committee, the Alliance could leverage the Committee’s expertise to improve its ability to successfully implement specific plan elements and facilitate any necessary permits or other regulatory approvals. For example, once preliminary design of a project is complete, the Technical Advisory Committee could meet to review and provide comments to improve the design, ensure the design is consistent with other nearby projects, and provide insight on specific issues to consider in completion of final design. Once a plan element has been implemented and its performance has been studied for a reasonable period, the Technical Advisory Committee could review the project, help identify lessons learned, and suggest ways to incorporate those lessons learned in future projects. Members of the Technical Advisory Committee may also have access to additional grant funds and could assist the Alliance with grant applications or letters of support.
- **Riparian Buffer Conservation Easements:** This is a voluntary approach to riparian setbacks where the Alliance can work with willing landowners and non-profit conservation organizations to acquire the development rights to key riparian buffer areas and restore them as needed to improve water quality within the South Platte River corridor. The Alliance should seek a minimum setback of two channel widths for each easement and encourage the reestablishment of riparian habitat where appropriate.
- **Zoning Setback Standard:** In order to establish a viable public edge, a minimum setback requirement from the top of the bank of at least 50 feet is recommended. This will ensure adequate space for trail connections and public access amenities. All surfaces within this setback should be pervious. Permits from the applicable regulatory agencies, i.e. Weld County, FEMA, Evans, etc., will need to be obtained prior to any development in the 100-year regulatory floodplain.

Finally, the Alliance should explore the use of a river restoration development fee to assist with the acquisition and construction of river and open space projects.

7.4.2 Requirements

Several permits will be required prior to construction of the proposed projects that address environmental, floodplain, and water quality issues. Jurisdictional authorities that will require coordination include the federal government, State of Colorado, and Weld County. Permits required will include a Clean Water Act Section 404 Dredge and Fill Permit, administered by the USACE; Section 401 Water Quality Certification and stormwater discharge permit for construction activity administered by the CDPHE; and, a Weld County Floodplain Use permit.

Clean Water Act Section 404 Permit/401 Water Quality Certification

Section 404 of the Clean Water Act, Section 10 of the Rivers and Harbor Act of 1899, and Section 103 of the Marine Protection, Research and Sanctuaries Act requires USACE to regulate activities that involve the dredging or filling of waters of the United States, which includes all navigable waters, interstate lakes, rivers, streams (including intermittent streams), tributaries of such waters, and wetlands adjacent to such waters. The South Platte River falls within this definition, and therefore is subject to permitting under these three acts. The USACE jurisdiction over these waters, in the absence of wetlands, lies below the OHWM. The USACE defines the OHWM as:

> "*...that line on the shore established by the fluctuations of water and indicated by physical characteristics such as a clear, natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas.*" (33 CFR 328.3[e])

Section 404 permits issued by the USACE can be either nationwide general permits (NWPs) or individual permits. An NWP is issued to the general public and covers a spectrum of particular activities that typically occur in jurisdictional waters. If a proposed project does not fit within the activities covered by an NWP or may result in more than a minimal impact to jurisdictional wetlands or areas below the OHWM, an individual permit may be required. Individual permits require a project alternatives analysis and a public review period.

Section 401 of the Clean Water Act ensures that federal permits comply with applicable state water quality requirements and standards. The CDPHE has the authority to administer and enforce the state's water quality control program, including the 401 certification process. The purpose of this program is to reduce the amount of pollutants entering streams, rivers, lakes, and wetlands as a result of runoff from urban areas and construction sites. State regulation 5 CCR 1002-61 covers discharges from construction sites. In Colorado, the 401 certification is obtained as part of the 404 permit process. When an application for a Section 404 permit is filed, the USACE will contact CDPHE who will review the permit application for water quality issues and may attach conditions to the Section 404 permit based on this consultation. Under the Colorado 401 Certification Regulation, all nationwide permits are certified by statute and do not require a certification by the CDPHE Water Quality Control Division (WQCD). Applicants for NWPs do not need to submit any information or documents to the WQCD.

Weld County Floodplain Use Permit

Because the proposed improvements involve work within the Special Flood Hazard Area (SFHA) of the South Platte River, a floodplain use permit must be obtained from Weld County. Requirements for issuance of a Floodplain Use

Permit are contained in Article XI of Chapter 23 of the Weld County Charter and County Code titled, "Floodplain Management Ordinances."

The application procedure is managed by the Weld County floodplain administrator, within the Weld County Planning and Building Department. See the Weld County Floodplain Development Permit for all requirements of the permit. The Weld County floodplain administrator will refer application materials to affected federal, state, or local government agencies for review and comment, as necessary.

Floodplain permits may be required and issued by the governing city outside of Weld County's jurisdiction and the local jurisdiction's planning and/or building departments should be consulted.

Colorado Pollution Discharge System Stormwater Permitting for Construction Activities

Colorado is an EPA-delegated state, meaning that the state administers federally-mandated water quality programs such as the National Pollutant Discharge Elimination System (NPDES) under the Clean Water Act and the Federal Water Pollution Control Act (33 U.S.C. 1251, et seq.). Stormwater discharges associated with construction activity are regulated by CDPHE through the Colorado Pollution Discharge System (CPDS) General Permit COR-030000 as specified within the Colorado Water Quality Control Act.

Since the proposed improvements will disturb more than 1 acre, authorization to discharge under the CPDS General Permit will be required. Authorization includes applying for and obtaining certification that a Stormwater Management Plan (SWMP) has been completed and implemented. The responsibility for obtaining a water quality certification is usually given to the "construction site operator" and certification is required within 10 days of the start of construction.

CDPHE defines the construction site operator as the person who has day-to-day control over the project. At various times during the construction project, different parties may satisfy the definition of "operator" and the certification may be transferred as roles change. For the purposes of this project, the operator can be defined as the prime contractor during construction, and the application and certification should be submitted by this person prior to onsite mobilization. This requirement will be specified in the Project Manual.

Prior to commencement of construction, a SWMP must be developed and implemented for each facility covered by the permit. The SWMP identifies potential sources of pollution (including sediment generated onsite, fuels, oils, and hydraulic fluids, etc.) that may reasonably be expected to affect the quality of the stormwater discharges associated with the construction activity. In addition, the SWMP must describe the best management practices (BMPs) that will be used to eliminate the release of contaminated stormwater discharge from the site. The contractor must implement all provisions of the SWMP as a permit condition.

7.5 Property Access

Temporary and permanent access easements will be required to allow access to the proposed project areas for construction, monitoring, and maintenance purposes. Property owners will have to be engaged from project stakeholders, the Alliance, and permitting agencies to ensure that these project can be implemented. Appendix A contains a map that shows property ownership along the river. Only minimal impacts to existing infrastructure are expected as a result of the proposed projects. Impacts are primarily due to regrading and will not adversely affect structural stability or operational plans of any of the adjoining properties. Improvements are intended to improve structural stability of the channel and therefore, should be amenable to property owners.

7.6 Conclusions

The Middle South Platte River plays an important role in the communities and economies of Weld County. The South Platte River Restoration Master Plan provides guidance to the Alliance, the City of Evans, and local communities on identifying and prioritizing stream restoration and rehabilitation projects to reduce impacts from future flooding events. The Master Plan provides a comprehensive, integrated watershed approach to mitigating geomorphic and flood hazards, as well as ecosystem degradation impacts. The recommendations, especially the specific projects, presented in this plan should be further refined to implement projects that address and reverse the adverse impacts on the river discussed in the Risk Assessment section. The Alliance can utilize this plan to identify projects for risk reduction and restoration along the Middle South Platte River, by forming partnerships with local and national organizations such as the Ducks Unlimited, NRCS, and the City of Evans the Alliance can gain support and identify funding opportunities to move these projects forward.

Section 8

References

Andrews, E.D., 1980. Effective and bankfull discharges in the Yampa River basin, Colorado and Wyoming. Journal of Hydrology., 46: 311--330.

Brierley, G.J. and K.A. Fryirs, 2005.Geomorphology and River Management: Applications of the River Styles Framework. Blackwell Publications, Oxford, UK.

CSCB (Colorado State Conservation Board). 2011. Lower South Platte Watershed Plan.

FEMA (Federal Emergency Management Agency). 1999. Flood Insurance Study, Weld County, Colorado, Unincorporated Areas and Town of Eaton, Colorado, Weld County. Community Number 080266. FEMA, Washington, D.C. Revised September 22, 1999.

Montgomery, D. and J. Buffington, 1998. Channel Processes, Classification, and Response. River Ecology and Management.

NRCS (Natural Resources Conservation Service). United States Department of Agriculture. Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/. Accessed March 24, 2015.

Thorne, Hey, and Newson. 1997. Applied Fluvial Geomorphology for River Engineering and Management. John Wiley & Sons Ltd.

USACE (United States Army Corps of Engineers). 1977. Special Flood Hazard Information Report, South Platte River, Volume I, Weld County Colorado, prepared for Weld County and Colorado Water Conservation Board, Omaha, Nebraska, April 1977.

USFWS (United States Fish & Wildlife Service). 2015. IPaC Trust Resource Report for Weld County, Colorado. https://ecos.fws.gov/ipac/project/NGHWQMYVKVCW5G6LY4IIZWEKHI/resources, accessed on May 4, 2015.