Lower South Platte River Master Plan

Prepared for:

Morgan County

Prepared by:

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April 9, 2018

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Morgan, Washington, Logan, and Sedgwick Counties

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

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Department of Local Affairs

Table of Contents

List of Figures

List of Tables

Appendices

Acronyms

AOI	Areas of Influence
BMP	Best Management Practices
CDOT	Colorado Department of Transportation
CDPHE	Colorado Department of Public Health and Environment
CEM	Channel Evolution Model
cfs	Cubic Feet per Second
CHAMP	Colorado Hazard Mapping Program
COGCC	Colorado Oil and Gas Conservation Commission
Counties	Morgan, Washington, Logan, and Sedgwick Counties
CPDS	Colorado Pollution Discharge System
CPW	Colorado Parks and Wildlife
CWCB	Colorado Water Conservation Board
DNR	Colorado Department of Natural Resources
DOLA	Colorado Department of Local Affairs
DWR	Colorado Department of Water Resources
EHA	Erosion Hazard Area
FEMA	Federal Emergency Management Agency
FFA	Flood Frequency Analysis
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Studies
FWS	U.S. Fish and Wildlife
GIS	Geographic Information System
HIFLD	Homeland Infrastructure Foundation-Level Data
HRC	Historic River Channel
LiDAR	Light Detection and Ranging
LOMR	Letter of Map Revision
Master Plan	The Lower South Platte River Master Plan
MSPRA	Middle South Platte River Alliance
NFIP	National Flood Insurance Program
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
OHWM	Ordinary High-Water Mark
OIT	Colorado Office of Information Technology
OPCC	Opinion of Probable Construction Cost
SEM	Stream Evolution Model
SFHA	Special Flood Hazard Area
STL	State Trust Lands
SVAP2	Stream Visual Assessment Protocol Version 2
SWA	State Wildlife Area
SWMP	Stormwater Management Plan
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WSEL	Water Surface Elevation
WWTP	Wastewater Treatment Plant

Glossary of 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 material, woody shrubs and trees, or a combination

Bankfull Discharge: The OHWM discharge, with a recurrence interval of approximately 1.5 years for most streams

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 material and woody shrubs and trees; relies mostly on the long-term integrity of the live plants sand their rooting systems for its streambank stabilization function

Channel Stability: A relative measure of the resistance of a stream to aggradation or degradation

Cubic Feet per Second (cfs): A unit of stream discharge representing 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 the floodplain

Deposition: The settlement or accumulation of material out of the water column and onto the streambed or floodplain

Effective Discharge: The discharge responsible for the largest volume of sediment transport over a long period of time

Entrenchment: The vertical containment of the river and the degree to which it is incised in the valley floor

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 cliate and overflows upon during events greater than bankfull discharge

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

HEC-RAS: One-dimensional finite difference hydraulic model developed by the USACE

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

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

Point Bar: The depositional feature that facilitates the movement of bedload from one meander to the next

Reach: Any specified length of stream

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

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

Sediment Transport: The rate of sediment movement through a given reach of stream[1]

Sinuosity: The ratio of the stream channel length to the down-valley distance

Stage: Elevation of the water surface above any chosen reference plane

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[1] Adapted from Yochum 2015

Section 1

Introduction

1.1 Project Background

In September 2013, the lower South Platte River that flows from the western-most edge of Morgan County to the Nebraska state line experienced a record flood event that resulted in significant damage to the river corridor and surrounding communities. Peak flow rates during the event reached 60,000 cubic feet per second (cfs) in Fort Morgan, Colorado (USGS 06759500 South Platte River at Fort Morgan, CO). The record high peak flow, in combination with the extended duration of the event (approximately seven days), caused considerable damage to local infrastructure, and significantly altered the river corridor.

This area suffered another flood in 2015, and while peak flows only reached approximately 15,000 cfs in Fort Morgan, CO, the river remained at flood stage, flowing at greater than 1,500 cfs, for nearly 90 days, from April 28th through July 26th. This event, based on conversations with Morgan County residents, caused substantially more damage in the study area than the 2013 event. In numerous locations the floodwaters scoured away waterlines, septic systems, roads, and flood-control structures, resulting in more than twenty million dollars of federal assistance, throughout Colorado, from FEMA alone (FEMA 2015). These large, extended flood events caused noticeable and quantifiable changes to the South Platte River. For example, the river channel experienced significant transport of sediment, causing erosion and sediment deposition, which expanded, and in some cases, created, new point and mid-channel bars. This erosion and sedimentation has had adverse impacts to communities and landowners along the lower South Platte River, including erosion of private land and loss of channel conveyance capacity, resulting in an increased flood risk in other areas.

The lower South Platte River plays an important role in the communities and economies of Morgan, Washington, Logan, and Sedgwick Counties (the Counties). The Lower South Platte River Master Plan (Master Plan) was initiated by Morgan County, through funding provided by the Colorado Department of Local Affairs (DOLA), to provide guidance to the Counties and local communities to identify and prioritize stream restoration and rehabilitation projects that will reduce the impacts of future flood events. CDM Smith was hired by the Counties to develop the Master Plan for the lower South Platte River.

The project area includes the main stem of the South Platte River corridor, from the Weld-Morgan county line to the Nebraska state line, a distance of approximately 125 miles, or 143 river miles (**Figure 1-1**); and it includes 20 HUC10 subbasins (**Figure 1-2**), according to data compiled from the USGS National Hydrography Dataset (USGS 2016).

1.2 Project Scope

The Master Plan provides a comprehensive, integrated watershed approach to determine methods to mitigate the impacts of flooding, erosion/sedimentation, and environmental degradation on infrastructure and property (public and private). The master planning for a flood damaged river and adjacent communities is a process that must address multiple challenges. The goal of this project is to address the challenges by:

- Identifying and prioritizing projects, considering economic, social, and environmental issues, by developing a combination of proven and innovative technologies and methodologies to improve channel stability, flood management, and water quality.
- Developing a master plan for the lower South Platte River that quantifies risks and identifies solutions to address those risks in a geomorphologically stable manner that also protects water supply diversions and infrastructure.

In addition, the Master Plan is intended to support the Counties and stakeholders in the prioritization and implementation of projects to reduce the impact of future floods and increase the resiliency and health of the lower South Platte River system.

This Master Plan included collaboration and cooperation with the Counties, as well as other stakeholders. With help from stakeholders, the plan identifies effective solutions to those multiple challenges to provide technically, financially, and regulatorily feasible projects and strategies that encourage a healthy, functioning river and floodplain. Information on the planning and stakeholder outreach process is provided in Section 2.

1.3 Master Plan Overview

The Master Plan presented here represents months of extended collaboration and effort between CDM Smith and its subconsultants, the Counties, major stakeholders (including Colorado Division of Water Resources, irrigation/ditch companies, and Colorado Parks and Wildlife), and the general public. This document will serve as a roadmap for the communities of the lower South Platte River to identify and prioritize restoration and rehabilitation projects in the coming years.

The Master Plan is divided into the following sections:

1.0 Introduction: Master Plan background and scope

2.0 Planning Process: Master Plan objectives and public outreach efforts

3.0 Project Area Description: Project area boundaries and description, background of 2013 and 2015 flooding events, and description of river reaches

4.0 Data Collection and Analysis: Description of the data collection process

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

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: Stakeholder Meeting Materials

Appendix B: Reaches and Property Data

Appendix C: Site Visit Field Notes and Photos

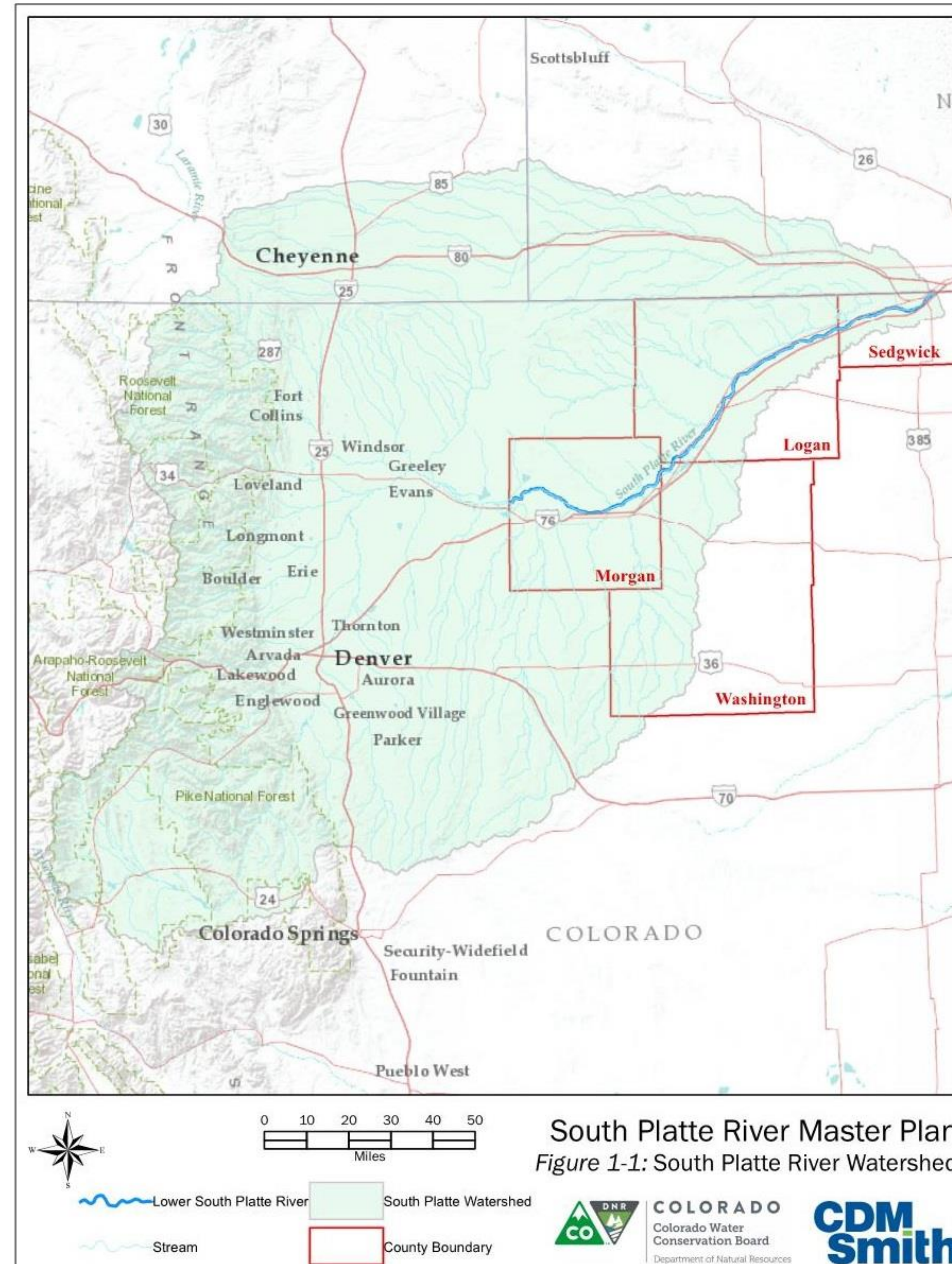
Appendix D: Hydrologic Data

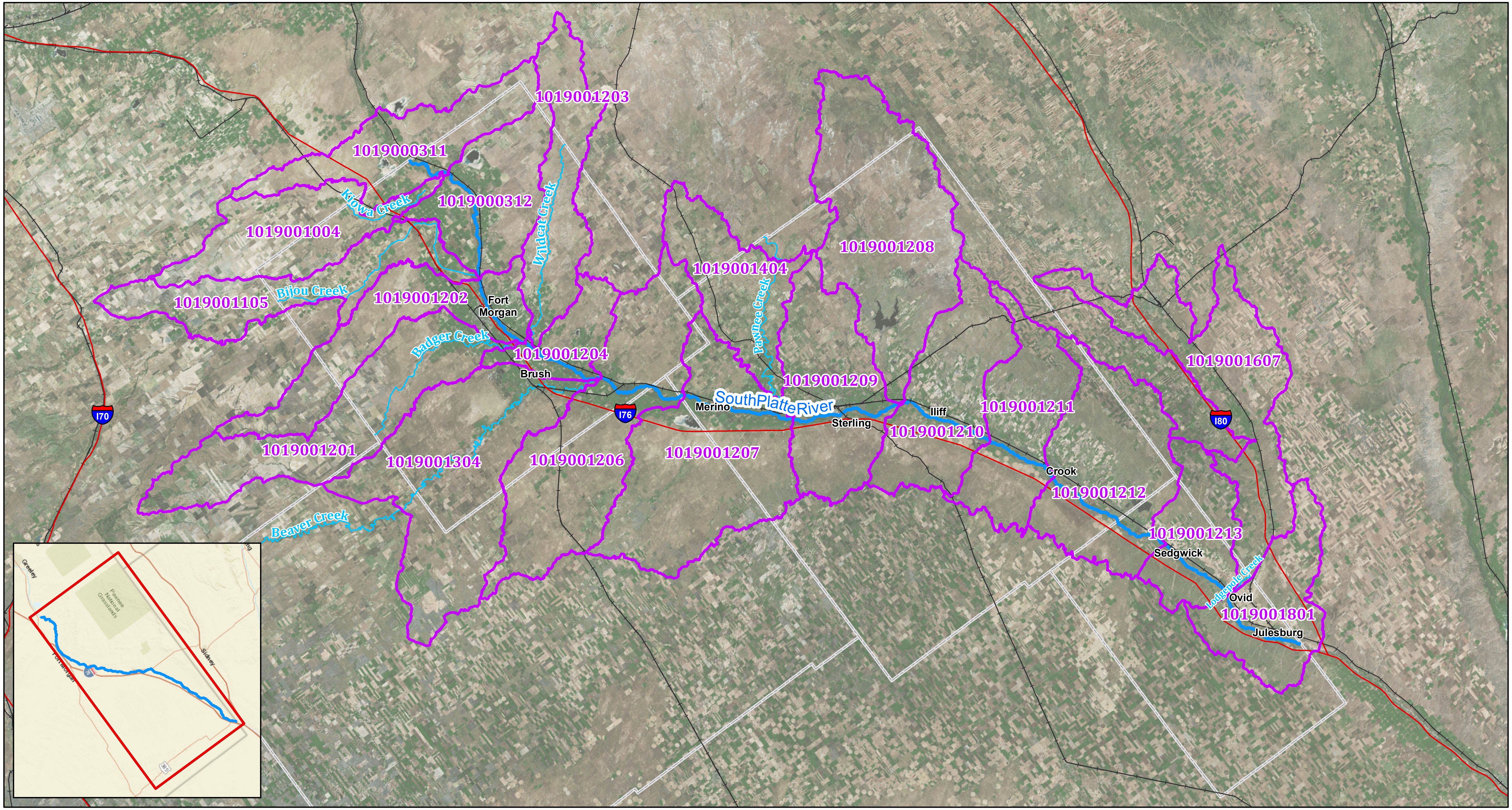
Appendix E: Effective Discharge and Stream Power

Appendix F: Flood Hazard Risk Analysis

Appendix G: Fluvial Geomorphic Risk Analysis

Appendix H: Ecological Risk Analysis





South Platte River — Interstate — County Boundary — Tributary — Railroad — HUC 10 Subbasin Boundary

0 5 10 15 20 25
Miles

South Platte River Master Plan

Figure 1-2-: Project Area Subwatershed

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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 lower South Platte River following the flood events of 2013 and 2015. The development of the Master Plan involved regular communication and coordination between local agencies, various stakeholders, and the community through public meetings and outreach events that occurred throughout the planning cycle.

The following objectives were identified for this project:

- Acquisition and review of existing data (flood, geomorphology, ecology, etc.), and any applicable studies along the lower South Platte River
- Assessment of risks within the project area, including flood risks, geomorphological risks, and ecological risks
- Identification and prioritization of potential projects (structural and non-structural), as well as evaluation of the effectiveness of those projects
- Conceptual designs of priority projects
- Cost estimation for priority projects

These objectives were executed in tandem with a public/stakeholder engagement process, which will ideally be used to build a coalition or an alliance for short- and long-term project implementation.

2.2 Public Engagement Process

The development of the Master Plan incorporated feedback from the community at public outreach 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, are included in **Appendix A**.

Five public outreach events were held during the development of the Master Plan in 2017 (February 6, April 19 and 20, May 12, July 17, and October 18).

These meetings served as opportunities for the public to provide information and feedback that was used to develop the Master Plan, and included representatives of the following counties, agencies, etc.:

- Private Landowners
- Colorado Water Conservation Board
- Colorado Parks and Wildlife
- Morgan County
- Logan County
- Sedgwick County
- Washington County
- City of Fort Morgan
- Jackson Lake Reservoir and Fort Morgan Irrigation
- Division of Water Resources
- Lower South Platter Water Conservation District
- Senator Cory Gardner's Office
- Julesburg Irrigation District
- City of Sterling

The meeting on February 6, 2017 served as the kickoff meeting and initial introduction of the master planning process to the Counties and stakeholders.

Attendees at the April 19th and 20th roundtable meetings were invited to discuss their views on which issues were the most important for mitigating risks along the lower South Platte River. Guiding questions presented to the attendees during these meetings included the following:

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

Approximately 25 local landowners and community officials participated in these April meetings, and discussions indicated that property protection, infrastructure protection and improvements, and irrigation were among the most important issues to residents along the lower South Platte River.

Below is a summary of key discussion items and comments:

- River management has changed over the course of the past 25 to 50 years. Many farming and ranching properties have been turned over to private hunting clubs and Colorado Parks and Wildlife (CPW). The land is managed differently such that vegetation (trees, willows, etc.) is no longer removed (via cattle grazing) so there is significantly more debris loading into the river. Also, increased sedimentation and the formation of additional vegetated islands have reduced the river channel's capacity to convey flood flows. The river is shifting and has formed new channels within the last few years, which affects adjacent infrastructure. There are also issues of water quality due to increased eutrophication resulting from increased nutrient loads to the river from a variety of sources.
- The Master Plan will leverage and capture data from previous studies. It will identify problem and risk areas and include potential projects and project prioritization, as well as an operational plan, with steps moving forward. In addition, the Master Plan will help identify mitigation projects that can reduce flooding.
- While consideration will be given to the impact that significant tributaries (e.g. Beaver, Bijou, Pawnee, Kiowa, etc.) have on the mainstem, funding for the Master Plan is intended to address the main stem of the South Platte River. While the Master Plan can be used to document issues with tributaries, it will not

provide specific recommendations or projects on tributaries that don't have a direct impact on the South Platte River. The Master Plan may, however, act as a spring board to drive focus towards tributaries for future planning efforts. It can also identify funding for future studies of tributaries.

- The Platte River Recovery Program in Nebraska can serve as a model for stakeholders coming together to improve river management.
- Land being purchased by public agencies and private entities, such as CPW and hunting clubs, was raised as a possible concern because there is a sentiment among some stakeholders that these organizations do not engage in proper land or river management activities.

In addition to these broad comments, the landowners and irrigators provided input on problem areas along the river and on private property. Problem areas were identified on maps by stakeholders, and a site visit was planned to tour the problem areas. Specific focus areas provided by stakeholders for Morgan and Washington Counties included:

- There is concern about roads and bridges in Morgan County that were highly impacted in the 2013 and 2015 floods.
- When the river floods near Washington County and eastern Morgan County (and the North Sterling Canal fills), water is trapped on the north side of the railroad tracks, creating a health issue for those on septic.
- There is concern regarding uncontrolled water coming into ditches, such as the North Sterling Canal. There is a need to create avenues for water to return to the river. The Town of Messex had no way to evacuate water in 2013 and 2015.
- Colorado State Highway 144 bridge, near Orchard, creates a bottleneck, constricting flows along the river.

Specific focus areas provided by stakeholders for Logan and Sedgwick Counties included:

- There is immense erosion on the south side of the river near Julesburg, causing exposure of fiber optic lines and other infrastructure.
- There is a large sedimentation problem near the Henderson-Smith Ditch.
- Logan County Road 93 bridge needs to be replaced (wooden structure); the overflow bridge is supposed to function when the main bridge is closed, but it ends up being closed during flooding anyway.
- Railroad trestles (near Pawnee) block the passage of debris and limit sediment transport.
- There are problems with return flow when water gets trapped north of the railroad.
- The cooling pond near the ethanol plant in Sterling flooded in 2013.
- There is a lack of river management at State Wildlife Areas (SWAs), such as Tamarack and Dune Ridge.

Many of the project areas were similar in nature and will require a system-wide remedy, rather than project-specific solutions. The Master Plan seeks to provide short- and long-term solutions to these issues.

There was also discussion about forming a Watershed Coalition, which included:

- Discussion of how watershed coalitions become the day-to-day drivers of the Master Plan and represent a wide variety of stakeholders. They are generally formed at the watershed level, which may not make sense for the South Platte River, given its size.
- What might an Alliance do and how might a coalition help?
  - An Alliance can identify funding
    - Multi-tiered funding collaboration
    - Funding from many sources, including federal, state, county, and city funds
  - An Alliance can facilitate the implementation of projects
  - Coalitions add credibility and help in obtaining funding from grants
  - Coalitions facilitate networking with stakeholders to understand different perspectives
- Who might drive a coalition in the lower South Platte?
  - Multiple irrigation districts
  - Private landowners

Chloe Lewis from the Middle South Platte River Alliance (MSPRA) was identified as an available resource to share lessons learned.

May 12, 2017

The meeting on May 12, 2017 was convened on by Dave Donaldson, Logan County Commissioner. The meeting included representatives from federal and state agencies with jurisdiction over the South Platte River. The meeting facilitated a discussion and listening session to educate the project stakeholders on issues and constraints of regulations on implementation of the Master Plan priority projects.

Attendees included elected officials from Morgan, Logan, Sedgwick and Washington County, CDM Smith staff, Kevin Houck of the Colorado Water Conservation Board (CWCB), representatives from the U.S Army Corp of Engineers (USACE), U.S. Fish and Wildlife (FWS), Federal Emergency Management Agency (FEMA), and CPW, as well as stakeholders.

July 17, 2017

At the July 17, 2017 meeting, CDM Smith provided an update on the data collection and risk assessments to County representatives and stakeholders. In addition, Jerry Kenny with the Platte River Recovery Implementation Program gave a presentation on the Program and their approach to regulatory coordination and permitting. The Program brings together the states, federal government, water users, and environmental groups to work collaboratively to improve and maintain the associated habitats for designated species.

October 18, 2017

At the October 18, 2017 meeting, CDM Smith, Anderson Consulting Engineers, and Otak presented their approaches to each of the three risk assessments, including flood, fluvial geomorphic, and ecological, and provided examples of initial project and restoration ideas. Maps were prepared and stakeholders were encouraged to give feedback on the initial ideas, as well as to use the maps to convey their own thoughts regarding potential improvements. Towards the end of the meeting, Chloe Lewis facilitated a short discussion regarding her role with the MSPRA, how an Alliance might be beneficial for the lower South Platte River, how MSPRA could help facilitate an Alliance in the lower South Platte River, and potential funding sources for project implementation.

In addition, monthly conference calls were held with representatives of each County, DOLA, and CWCB, as well as several stakeholders. This group was collectively known as the Master Plan Steering Committee. Furthermore, site visits were conducted by CDM Smith, Anderson Consulting Engineers, and Otak on May 15th through 17th, 2017. The consultants met with several stakeholders, including representatives of the Division of Natural Resources (DNR), the City of Sterling, and private landowners. Notes from these visits are also included in Appendix A.

Section 3

Project Area Description

3.1 Project Area Boundaries

The Master Plan focuses on the section of the lower South Platte River that reaches from the western-most edge of Morgan County to the Nebraska state line, a distance of approximately 125 miles and 143 river miles. Included within the project area are the municipalities of Fort Morgan, Messex, Sterling, Ovid, and Julesburg and other small communities. The flood, fluvial geomorphologic, and ecological risk analyses presented in the Master Plan focus on locations that were among the most adversely impacted by the 2013 and 2015 floods, and those that remain highly vulnerable to future flood events.

3.2 Project Area Description

Within the project area, the South Platte River flows in a relatively well-defined, braided channel, situated in a broad, shallow valley that ranges in width from 1,500 feet to approximately 2,100 feet (FEMA 1989). The channel width varies between 100 feet to over 500 feet wide. The stream gradient ranges from approximately 5 feet per mile to 9 feet per mile (0.1 to 0.2 percent). Riparian vegetation includes trees such as plains cottonwood (*Populus deltoides*), peachleaf willow (*Salix amygdaloides*), green ash (*Fraxinus pennsylvanica*), and box elder (*Acer negundo*), as well as shrubby willows (*Salix* spp.), grasses (*Eragrostis* spp.), and cockleburs (*Xanthium* spp.) (Kittel et al. 1998), with row crops and pastureland situated adjacent to the floodplain. The primary soil types within the project area are well-drained loamy and sandy soils, as well as strongly sloping loams, sands, sandy loams, and clay loams (CSCB 2011). The soils directly adjacent to the river are classified as Fluvaquents-Alda-Bankard (CDWR 1994), which are very deep, poorly to excessively well drained, stratified gravelly, sandy, and loamy textured soils. Fluvaquents are generally found in intermittent streams, floodplain steps, and abandoned channels, and are somewhat poorly drained. Alda soils are generally found in stream terraces, and are also somewhat poorly drained. Bankard soils are generally found in floodplains and stream terraces and are somewhat excessively drained (CSRL 2017).

The drainage area of the upstream point of the project area is 12,235 square miles, and the drainage area of the downstream point of the project area is 22,885 square miles (USGS 2016) – see Figure 1-2. There are several tributaries of the lower South Platte River within the project area, including Kiowa Creek (the confluence of which is just upstream of the Weld-Morgan county line), Bijou Creek, Beaver Creek, Pawnee Creek, and Lodgepole Creek. Kiowa Creek originates in the Black Forest of El Paso County, northeast of Colorado Springs, and drains approximately 716 square miles. Bijou Creek also has headwaters northeast of Colorado Springs, in El Paso County, and drains approximately 1,383 square miles. Beaver Creek, draining approximately 1,106 square miles, originates in northeastern Elbert County, near Agate, CO. Pawnee Creek has its headwaters in the Pawnee National Grasslands in eastern Weld County, and drains approximately 723 square miles; and Lodgepole Creek, with headwaters on Pole Mountain, located southeast of Laramie, Wyoming, drains approximately 3,267 square miles (USGS 2017).

The elevation and climate of the lower South Platte River differs from upstream to downstream within the project area (**Table 3-1**). In general, this region has a semi-arid, continental climate, with limited precipitation. Approximately 75 percent of precipitation falls as rain between April and September, and intense, localized thunderstorms occur throughout the summer months, generating high runoff and reducing soil infiltration. 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. The high winds and low relative humidity drive annual open water evaporation rates of up to 70 inches per year (CSCB 2011).

Table 3-1: Lower South Platte River Project Area Elevation and Climate Data

Parameter	Fort Morgan	Julesburg
Elevation (ft.)	4,324	3,478
Average Annual Precipitation (in.)	14.16	18.22
Average Annual Snowfall (in.)	24	28
Average Maximum Summer Temperature (°F)	89	90
Average Minimum Summer Temperature (°F)	58	61
Average Maximum Winter Temperature (°F)	38	42
Average Minimum Winter Temperature (°F)	11	16

Land use within the project area 100-year floodplain is primarily agricultural, with more than 40 percent of land being used for cultivated crops, pasture, or hay (USGS 2011) – see **Figure 3-1**, and there are more than 26,000 acres of CPW public access land. Land ownership data can be found in **Appendix B**.

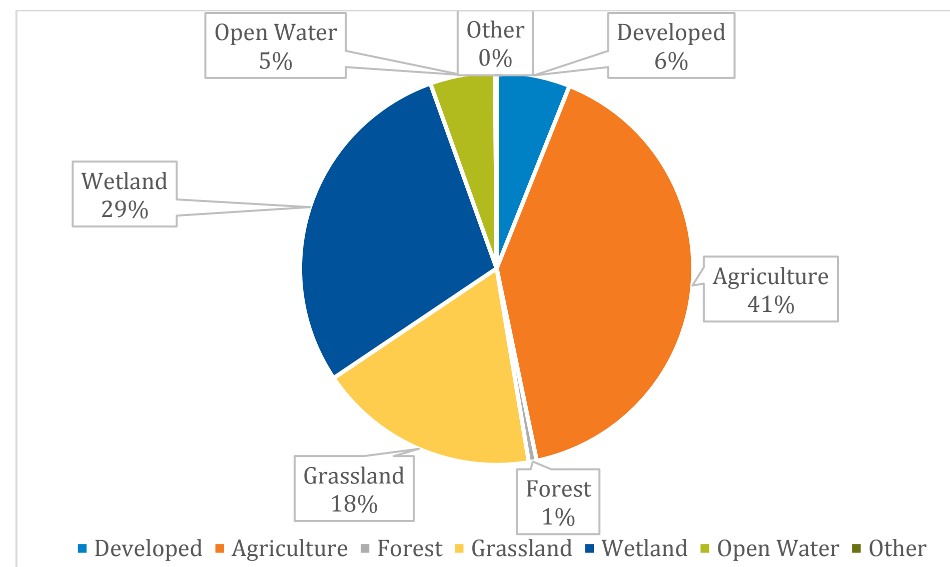


Figure 3-1: Land Use within the Project Area 100-Year Floodplain (USGS 2011)

Agricultural water users along the lower South Platte River depend on consistent, reliable diversions from the river, making them a key stakeholder group to this Master Plan. Colorado Division of Water Resources (DWR) is responsible for administration and enforcement of their water rights. In total there are twenty-one active diversion structures throughout the project reach, owned and operated by ditch companies and individual water users. Water diversion infrastructure (e.g. diversion structures, canals, headgates, etc.) is typically located within the active channel and/or floodplain. The majority of the diversions throughout the project reach experienced some degree of flood impacts during recent floods. This Master Plan sought input from the ditch companies, irrigation districts, water users, and DWR, which was extremely important to understanding impacts and risks, and formulating practical solutions.

3.3 Historical and Current Hydrological and Ecological Conditions

The first recorded descriptions of the lower South Platte River occurred just after the turn of the 19^{th} century, when the Pike Expedition of 1806, and later the Long Expedition in 1819-20, moved through the region (Wohl 2013). Descriptions indicate that the lower South Platte River was very wide, averaging a third of a mile in width (Mutel and Emerick 1984), and very shallow, with a substrate made primarily of sand, and multiple braided channels that were continually moving. Riparian vegetation was sparse because the main channel shifted paths from year to year due to the banks being easily eroded during high flows, preventing cottonwoods and willows from taking root; and historical records suggest that by the time the river neared the Colorado-Nebraska boarder, the South Platte was characterized by intermittent flows, with stretches of surface flow interrupted by stretches of dry streambed (Wohl 2013).

Once settlement on the Colorado Front Range became more pervasive, stream flows fluctuated less during the year. With the development of agriculture, more water was diverted from streams and stored for release later in the growing season. These diversions were supplemented, however, by the addition of trans-basin water, diverted across the Continental Divide from the headwaters of the Colorado River. Baseflow increased and the river became perennial, with continuously flowing water along its length, year-round, which allowed woody riparian plants to grow more densely on the islands and on sand bars within the broad channels of the river (Wohl 2013).

Several factors have acted in conjunction with one another to affect the hydrology of the South Platte River. Off-channel storage and flood control reservoirs, transcontinental inflows, and irrigation dams, among other human-induced changes, have acted to reduce the magnitude and duration of late-spring and early-summer peak flows, eliminate late winter ice flows, and create continuous baseflow throughout the year (Kittel et al. 1998). As a result, high flows no longer scour through the channel, which had previously prevented the establishment of seedlings and had flushed away existing vegetation; ice flows no longer occur to damage and rip out plants rooted on low islands, or to shift the entire channel to one side, limiting the stable ground that seedlings need to survive; and, given a continuous baseflow throughout the channel, vegetation establishment is no longer limited to the late-summer. As vegetation has increased along stream banks, plant roots have helped hold the bank sediment in place, and stems and trunks have slowed the movement of water flowing by, allowing sediment to settle onto the banks. The stream channels have grown steadily narrower as islands and sand bars have stabilized with vegetation (Wohl 2013).

Today, the floodplain is only a fifth as wide as it originally was (Mutel and Emerick 1984), narrowed by denser vegetation; and large stretches of the river have been channelized for agricultural and ranching uses through the installation of riprap and other structures designed to prevent river migration and bank erosion. Armored banks often increase velocities and can lead to increased rates of flooding, as the disconnection from the floodplain does not allow excess water to dissipate energy on the valley floor.

The current hydrological and ecological conditions of the lower South Platte River are markedly different from pre-settlement conditions, and restoration efforts will require balancing the needs of the river, the aquatic and riparian ecosystems, and the communities surrounding the river. These efforts will center around understanding the larger context of historical alterations throughout the region, and using that knowledge to identify the highest priorities and greatest opportunities to mitigate flood, geomorphological, and ecological risks.

3.4 Historical Flooding

Flooding on the eastern plains of Colorado is primarily caused by rain, snowmelt, or a combination of rain falling on snow; however, snowmelt does not usually produce substantial flooding. Rain events that produce flooding range from intense, short-duration, localized thunderstorms to large-scale, multi-day storms that can be accompanied by intense localized thunderstorms.

Major floods in Colorado's eastern plains during the last century include events in 1921, 1935, 1965, 2013, and 2015. In June 1921, widespread rains over several days combined with snowmelt to cause flooding in the South Platte River Basin, extending from the foothills upstream of Denver, to the Colorado-Nebraska state line (USGS 2015). The USGS gauge in Julesburg (USGS 06764000 South Platte River at Julesburg, CO), which has recorded discharge dating back to 1902, indicates that discharge reached 30,800 cfs during this event.

In early June of 1935, an intense rain event, following the wettest May in Colorado-recorded history up to that point, resulted in flooding on Kiowa and Bijou creeks, two plains tributaries to the lower South Platte River. Flow was estimated to be approximately 84,300 cfs in Fort Morgan (USGS 1948), downstream of the confluences of both tributaries, and records indicate that flow was 24,000 cfs in Julesburg.

Rainfall over 5 days in June 1965 resulted in one of the largest floods in eastern Colorado in the 20^{th} century. In the South Platte Basin, a peak streamflow of 466,000 cfs was recorded on Bijou Creek (USGS 2015). At Julesburg, streamflow peaked at 30,000 cfs during this event. This flood resulted in the construction of reservoirs in the Denver area, including Chatfield Reservoir and Cherry Creek Reservoir, to control future flood waters and protect the eastern plains.

More recently, in September of 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, which increased runoff. Flooding resulted in substantial erosion; transport of mud, rock and debris; landslides; and damage to roads, bridges, utilities, and other public infrastructure (**Figure 3-2**). Runoff associated with this rain event sent a pulse of floodwater downstream that led to historic flooding along the lower South Platte River. The river crested in Fort Morgan, CO on September 15 with a discharge of 60,000 cfs (**Figure 3-3**). In Julesburg, CO, the river crested on September 20 with a discharge of 20,200 cfs. At the peak of the 2013 flood, the South Platte River was estimated to span nearly one mile in width and, at Fort Morgan, was estimated to exceed the 100-year flood event.

Finally, in the spring of 2015, the lower South Platte River suffered another flood. Although peak flows in Fort Morgan, CO only reached 15,000 cfs, the river remained at flood stage for nearly 90 days, causing extensive road closures (**Figure 3-4**), flooded homes, and damage to nearby communities.

Figure 3-2: Riverside Park in Fort Morgan on September 16, 2013

Figure 3-3: Barlow Road in Fort Morgan on September 15, 2013

Figure 3-4: Colorado State Highway 144, near Orchard, Colorado, following the September 2015 flooding (CDOT 2015)

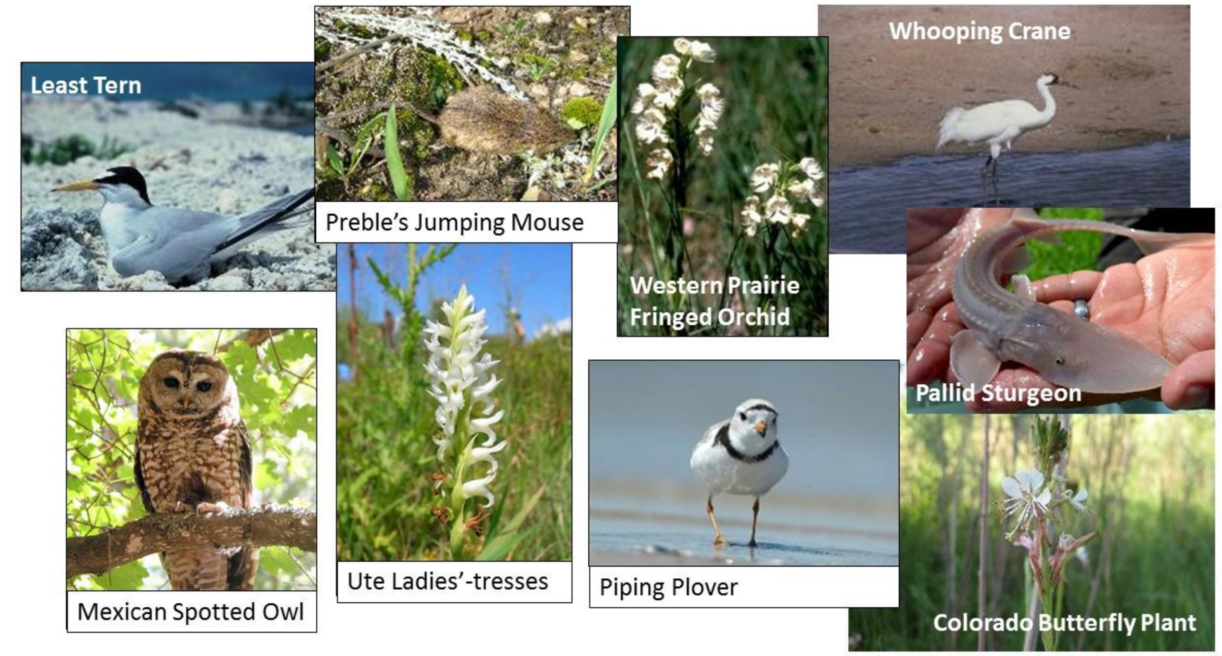


Figure 3-5: Threatened and Endangered Species within the Lower South Platte River Watershed

3.5 Threatened and Endangered Species

The Endangered Species Act, signed into law in 1973, provides for the conservation of species that are endangered or threatened throughout all or a significant portion of their range, and the conservation of the ecosystems on which they depend. As such, the primary information used to determine which species are endangered or threatened are the known or expected range of each species. Additional areas of influence (AOI) for species are also considered. An AOI includes areas outside of the species range if the species could be indirectly affected by activities in that area; for example, placing a dam upstream of a fish population, even if that fish does not occur at the dam site, may indirectly impact the species by reducing or eliminating water flow downstream. Once threatened or endangered species are recognized, critical habitat is identified that contains features essential to the conservation of those species, and that may require special management or protection. Currently, there are no areas designated as critical habitat within the project area boundaries. However, several endangered and threatened species exist within the lower South Platte River watershed.

Within the lower South Platte River watershed, species listed as endangered include the Least Tern (*Sterna antillarum*), Whooping Crane (*Grus americana*), and Pallid Sturgeon (*Scaphirhynchus albus*). Species listed as threatened within the project area include the Preble's Meadow Jumping Mouse (*Zapus hudsonius preblei*), Mexican Spotted Owl (*Strix occidentalis lucida*), Piping Plover (*Charadrius melodus*), Colorado Butterfly Plant (*Gaura neomexicana var. coloradensis*), Ute Ladies'-tresses (*Spiranthes diluvialis*), and Western Prairie Fringed Orchid (*Platanthera praeclara*) (FWS 2017) (**Figure 3-5**).

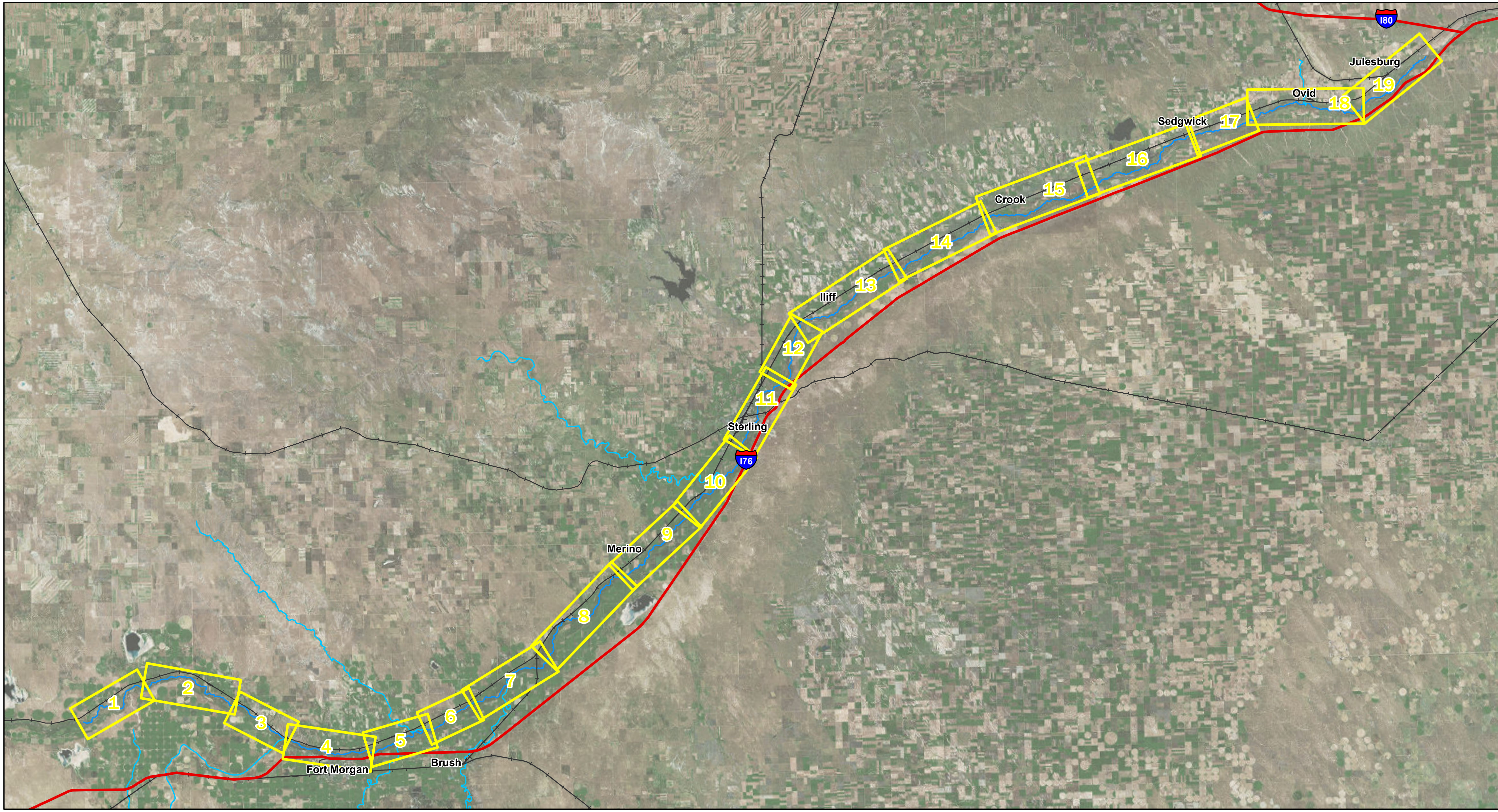
3.6 Overview of Reaches

The lower South Platte River within the project area was divided into 19 reaches (**Figure 3-6**) to facilitate project identification and prioritization. Reach breaks were determined based on geomorphologic features, as well as the existence of infrastructure, such as bridges and irrigation diversion structures. Each reach is briefly described below.

- **Reach 1:** Weld-Morgan County line to the Morgan County Road 5 bridge. Approximately 7.2 river miles in length. Mostly private land ownership.
- **Reach 2:** Morgan County Road 5 bridge to approximately 0.7 miles upstream of the Colorado State Highway 144 bridge, east of Weldona, CO. Approximately 8.5 river miles in length. Mostly private land ownership, and includes the Fort Morgan Canal.
- **Reach 3:** Approximately 0.7 miles upstream of the Colorado State Highway 144 bridge, east of Weldona, CO, to just upstream of the Bijou Creek confluence with the South Platte River. Approximately 5.2 river miles in length. Mostly private land ownership.
- **Reach 4:** Just upstream of the Bijou Creek confluence with the South Platte River to approximately 2.4 river miles upstream of the Morgan County Road 24 bridge. Approximately 6.9 river miles in length. Combination of private and public land ownership (City of Fort Morgan), and includes both the Deuel Snyder and the Upper Platte Beaver Canals.
- **Reach 5:** Approximately 2.7 river miles upstream of the Morgan County Road 24 bridge to approximately 3.1 river miles downstream of the Morgan County Road 24 bridge. Approximately 5.6 river miles in length.

Combination of private land ownership and public access land (Morgan County and Jean K. Tool SWA), and includes both the Lower Platte Beaver and Tremont Ditches.

- **Reach 6:** Approximately 3.1 river miles downstream of the Morgan County Road 24 bridge to the Colorado State Highway 71 bridge, near Snyder, CO. Approximately 3.9 river miles in length. Combination of private land ownership and public access land (Brush SWA).
- **Reach 7:** Colorado State Highway 71 bridge, near Snyder, CO, to approximately 1.3 miles downstream of the Burlington Railroad bridge. Approximately 8.0 river miles in length. Combination of private land ownership and public access land (Cottonwood SWA and Elliot SWA), and includes both the North Sterling Canal and Union Ditch.
- **Reach 8:** Approximately 1.3 miles downstream of the Burlington Railroad bridge to the Colorado State Highway 6 bridge. Approximately 10.6 river miles in length. Combination of private land ownership and public access land (Elliot SWA and Messex SWA), and includes the Pawnee Ditch, Prewitt Inlet Canal, South Platte Ditch, and Tetsel Ditch.
- **Reach 9:** Colorado State Highway 6 bridge, west of Merino, CO, to approximately 1.2 river miles downstream of the Logan County Road 29.5 bridge. Approximately 7.7 river miles in length. Combination of private land ownership and public access land (Atwood SWA), and includes Schneider Ditch.
- **Reach 10:** Approximately 1.2 river miles downstream of the Logan County Road 29.5 bridge to approximately 2.0 river miles upstream of the Colorado State Highway 6 bridge, in Sterling, CO. Approximately 7.8 river miles in length. Combination of private land ownership and public access land (Atwood State Trust Lands [STL], Overland Trail STL, Overland Trail SWA, Dune Ridge SWA, and Knudson SWA), and includes both the Sterling Irrigation Company Ditch #1 and the Springdale Ditch.
- **Reach 11:** Approximately 2.0 river miles upstream of the Colorado State Highway 6 bridge, in Sterling, CO, to approximately 3.7 river miles downstream of the Burlington Northern Santa Fe (BNSF) Railroad bridge in Sterling, CO. Approximately 6.9 river miles in length. Combination of private and public land ownership and public access land (City of Sterling, Knudson SWA, and Bravo SWA), and includes both the Henderson Smith Ditch and the Lowline Ditch.
- **Reach 12:** Approximately 3.7 river miles downstream of the BNSF Railroad bridge in Sterling, CO to approximately 1.1 river miles downstream of the Logan County Road 40 bridge. Approximately 5.3 river miles in length. Combination of private land ownership and public access land (Bravo SWA, Bravo STL, and Ford Bridge STL), and includes both the Bravo Ditch and the Iliff Platte Valley Ditch.
- **Reach 13:** Approximately 1.1 river miles downstream of the Logan County Road 40 bridge to approximately 1.9 river miles upstream of the Logan County Road 65.7 bridge. Approximately 9.2 river miles in length. Mostly private land ownership, and includes the Powel & Blair Ditch.
- **Reach 14:** Approximately 1.9 river miles upstream of the Logan County Road 65.7 bridge to approximately 2.5 river miles upstream of the Colorado State Highway 55 bridge. Approximately 8.6 river miles in length. Combination of private land ownership and public access land (Tamarack Ranch SWA), and includes the Harmony Ditch 1.
- **Reach 15:** Approximately 2.5 river miles upstream of the Colorado State Highway 55 bridge to approximately 0.7 river miles upstream of the Colorado State Highway 93 bridge. Approximately 8.8 river miles in length. Mostly public access land (Tamarack Ranch SWA).
- **Reach 16:** Approximately 0.7 river miles upstream of the Colorado State Highway 93 bridge to approximately 1.7 river miles upstream of the Logan County Road 15 bridge, near Sedgwick, CO. Approximately 10.1 river miles in length. Combination of private land ownership and public access land (Tamarack Ranch SWA and Red Lion Ranch STL).
- **Reach 17:** Approximately 1.7 river miles upstream of the Logan County Road 15 bridge, near Sedgwick, CO, to approximately 3.3 river miles downstream of the Logan County Road 15 bridge. Approximately 5.1 river miles in length. Combination of private land ownership and public access land (Sedgwick Bar SWA).
- **Reach 18:** Approximately 3.3 river miles downstream of the Logan County Road 15 bridge to approximately 4.6 river miles downstream of the Sedgwick County Road 27.9 bridge. Approximately 9.7 river miles in length. Combination of private land ownership and public access land (Pony Express SWA), and includes the Liddle Ditch.
- **Reach 19:** Approximately 4.6 river miles downstream of the Sedgwick County Road 27.9 bridge, near Ovid, CO, to the Colorado-Nebraska state line. Approximately 7.9 river miles in length. Combination of private land ownership and public access land (Pony Express SWA).



South Platte River — Tributary — Interstate — Railroad — Reach Extent

N W E S

0 5 10 15 20 25
Miles

South Platte River Master Plan

Figure 3-6-: Project Area Reach Index

COLORADO Colorado Water Conservation Board Department of Natural Resources

CDM Smith

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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. CDM Smith worked directly with data providers to ensure that the most current and accurate data were incorporated into the evaluation process. Local stakeholders were consulted throughout the master planning process to vet and verify data used for analysis and presentation.

4.1 GIS Data

Geographic information system (GIS) data (**Table 4-1**) used for geospatial analyses were obtained from the following agencies and organizations, and are available electronically in a geodatabase provided in the flash drive attached to this report:

- Colorado Department of Transportation (CDOT)
- Colorado Office of Information Technology (OIT)
- Colorado Oil and Gas Conservation Commission (COGCC)
- CPW
- DWR
- FEMA
- FWS
- Homeland Infrastructure Foundation-Level Data (HIFLD)
- Logan County, Colorado
- Morgan County, Colorado
- Natural Resources Conservation Service (NRCS)
- Sedgwick County, Colorado
- United States Energy Information Administration (EIA)
- United States Geological Survey (USGS)
- Washington County, Colorado

Table 4-1 GIS Data Collected

Data Description	Source
Parcels*	Morgan, Logan, and Sedgwick Counties
Waterbodies	USGS
Local & State Highways	CDOT
Railroads	CDOT
Hydrologic Units	NRCS
Soils	DWR
Land Use	DWR
Diversion Structures	DWR
LiDAR	OIT
Public Access Lands	CPW
Oil Wells	COGCC
Natural Gas Pipelines	HIFLD
Crude Oil Pipelines	EIA
Wetlands	FWS
Preliminary FEMA Floodplains	FEMA

* No parcel data was available for Washington County

4.2 Field Visits

CDM Smith, Anderson Consulting Engineers, and Otak conducted site visits within the project area between May 15 and 17, 2017 to document current conditions of the project area, including erosion and sedimentation areas, flood hazards, and the riparian zone. Various stakeholders from the project area provided access and tours of specific locations during the field visit to help focus efforts on higher risk areas within the nearly 125-mile project reach. Photographss and notes were compiled into a field log provided as **Appendix C** to this document.

Colorado Division of Water Resources staff familiar with the water infrastructure in the lower South Platte River guided CDM Smith, Anderson Consulting Engineers, and Otak throughout the project area to show where sediment accumulation occurs, and which infrastructure was most affected by the 2013 and 2015 floods. This tour also included recently installed water infrastructure that was designed to pass sediment, which may provide a template for additional water infrastructure upgrades within the project area.

City staff from Fort Morgan and Sterling also provided the CDM Smith team with guided tours of the City of Fort Morgan, the Town of Messex, and the City of Sterling. All three municipalities suffered flooding in 2013 and 2015. Staff engineers for the City of Fort Morgan and for the City of Sterling guided the consultants throughout the river corridor of each respective city, explaining where and how flooding occurred and the damages incurred. A resident of the Town of Messex, which suffered extensive flooding in both 2013 and 2015, facilitated the visit, and the team identified mechanisms of the flooding, as well as potential mitigation solutions. The information provided during these visits provided an on-the-ground perspective, which was critical to developing feasible and effective Master Plan project concepts and solutions.

4.3 Hydrology

4.3.1 Hydrologic Models

Following the September 2013 flood event, CDOT partnered with the CWCB and hired the consulting firm URS to determine the magnitude of the flood, and to develop and update existing hydrologic models for several watersheds that experienced significant damage during the event, including the lower South Platte River (URS 2015). The primary goals of the hydrologic analysis were to provide an estimate of peak flows that occurred during the September 2013 flood, update the Flood Frequency Analysis (FFA) for the South Platte River, and to produce updated estimates of predictive peak discharges at key locations, using the fully available period of record, including the large flood flows estimated and/or recorded during the 2013 and 2015 floods.

Peak flow estimates for the September 2013 flood event were based on empirical data using aerial imagery, visible high-water marks, and contour data developed from light detection and ranging (LiDAR). Both the LiDAR data and the aerial imagery were recorded shortly after the flood event and represent post-flood conditions. Discharge levels during the September 2013 flood were estimated by aligning flood extents from the aerial imagery with cross sections developed for the HEC-RAS model. The process involved iteratively adjusting the modeled flow until the water surface elevation and the modeled floodplain width at a given cross section were consistent with the aerial imagery collected during the flood event.

The FFA utilized exceedance probability calculations at available gage sites along the lower South Platte River, including USGS 06758500 South Platte River near Weldona (**Figure 4-1**), USGS 06759500 South Platte River at Fort Morgan (**Figure 4-2**), USGS 06760000 South Platte River at Balzac (**Figure 4-3**), and USGS 06764000 South Platte River at Julesburg (**Figure 4-4**). The exceedance probability is the probability that a flood event of a given magnitude will occur in any given year. For example, a flood with an exceedance probability of 1% is typically referred to as the 100-year flood event, and has a 1% likelihood of occurring in any given year. Furthermore, a flood with an exceedance probability of 4% is referred to as the 25-year flood event and has a 4% likelihood of occurring in any given year. Based on guidelines established by the USGS (USGS 1982), the exceedance probability calculations incorporated into the FFA used the estimated 2013 discharge calculations, as well as discharge calculations from the 2015 flood, which occurred before the study ended, at each gage station to determine discharge for selected flood frequencies (**Table 4-2**).

Table 4-2: Predictive Flows along the Lower South Platte River (URS 2015)

Location	Drainage Area (mi^2)	10-year Recurrence Interval (cfs)	25-year Recurrence Interval (cfs)	50-year Recurrence Interval (cfs)	100-year Recurrence Interval (cfs)	500-year Recurrence Interval (cfs)	Estimated 2013 Discharge (cfs)	Approx. 2013 Recurrence Interval (yrs.)
Orchard	12,200	15,500	26,500	36,700	50,200	96,400	60,000	>100
Weldona	13,200	16,100	27,100	38,100	52,200	100,200	60,000	>100
Fort Morgan	14,600	16,800	28,500	39,700	54,300	104,300	60,000	>100
Sterling	18,100	16,500	26,800	38,600	53,900	107,800	46,000	50 to 100
Julesburg	23,100	13,500	24,100	35,200	49,700	100,900	21,800	25

The results indicate that a 100-year flood event would result in approximately 52,200 cfs and 49,700 cfs at Weldona and Julesburg, respectively (**Table 4-2**). Based on estimated 2013 discharges and the updated FFA, upstream portions of the project reach (Orchard to Fort Morgan) experienced greater than a 100-year event, while the flows attenuated to less than the 100-year event at Sterling, and a 25-year event at Julesburg (URS 2015).

The 2015 FFA is the first hydrology update for this portion of the South Platte River since the development of the 1977 USACE model, which served as the basis for all previous FEMA regulatory Flood Insurance Studies (FIS) since that time. The regulatory flows decreased at the three downstream locations and increased at the upstream end of the reach between 1977 and 2015. The changes between the updated FFA and 1977 USACE study are driven by increased periods of record at gage sites. Each location leveraged variable periods of record (in the original and the updated analysis), so the addition of the new data had an inconsistent effect on the changes to statistical calculations and subsequent peak flow estimates (**Table 4-3**).

Table 4-3: Changes in USACE Regulatory Flows along the Lower South Platte River (URS 2015)

Location	Updated FFA 100-yr Discharge (cfs)	1977 USACE 100-yr Discharge (cfs)	Percent Difference
Orchard	50,200	44,000	17%
Weldona	52,200	42,500	23%
Fort Morgan	54,300	110,000	-51%
Sterling	53,900	84,000	-36%
Julesburg	49,700	61,000	-19%

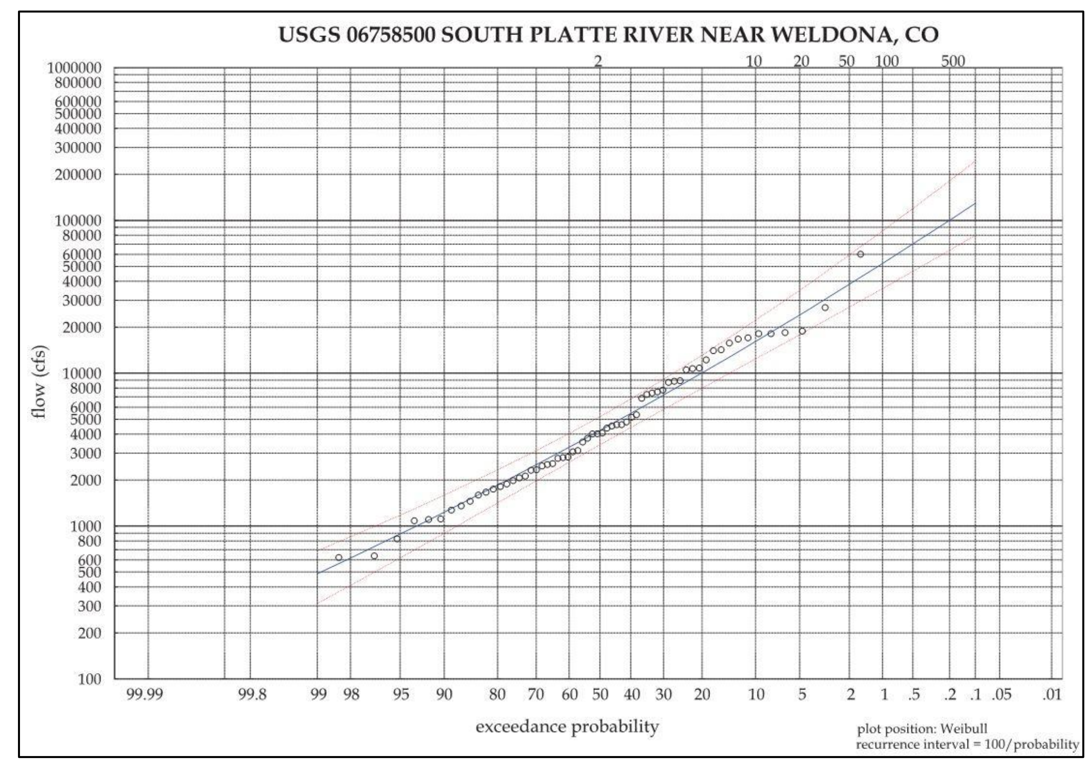


Figure 4-1: Weldona, CO Exceedance Probability, including 2015 data (URS 2015)

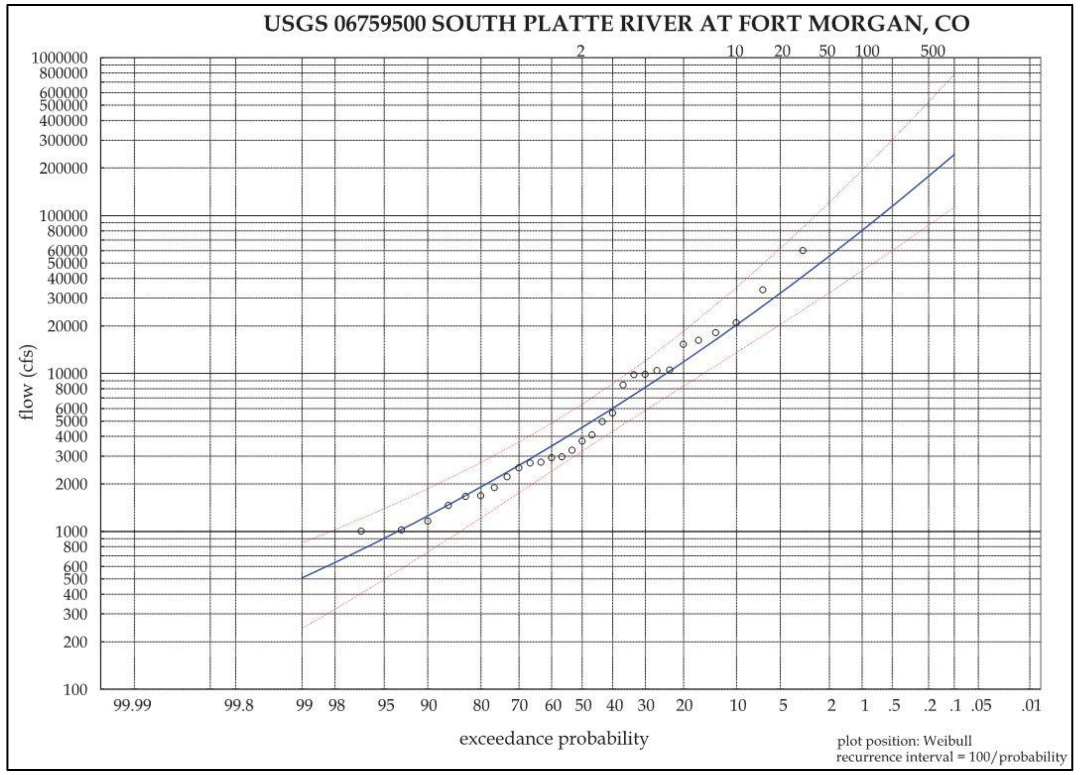


Figure 4-2: Fort Morgan, CO Exceedance Probability, including 2015 data (URS 2015)

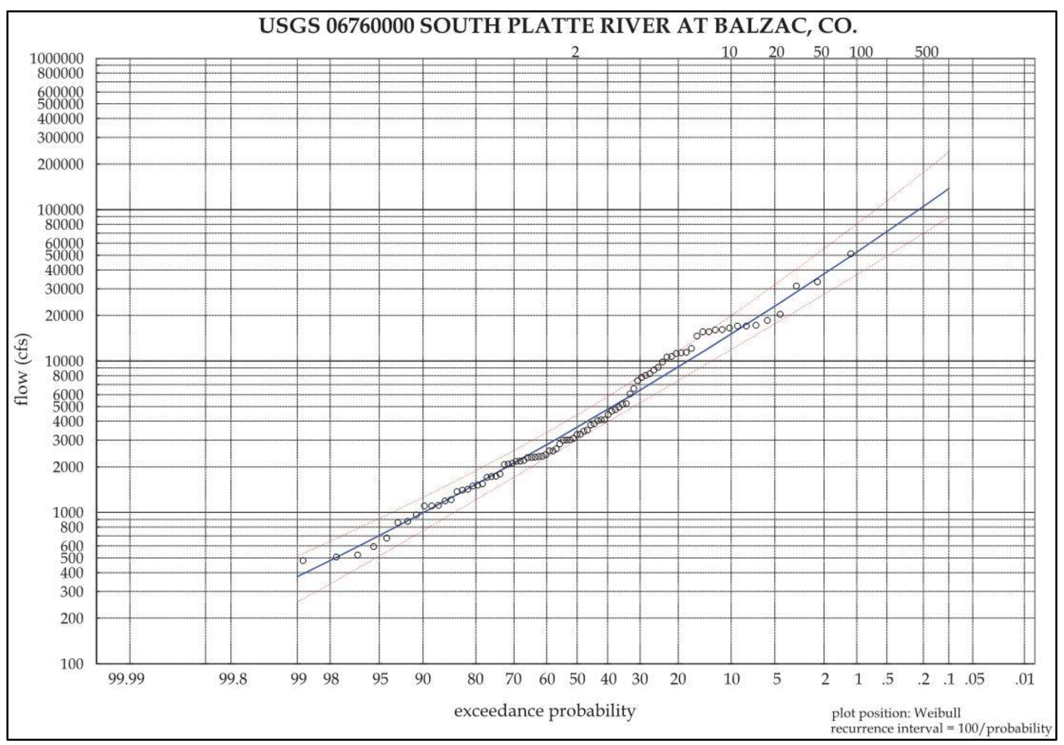


Figure 4-3: Balzac, CO Exceedance Probability, including 2015 data (URS 2015)

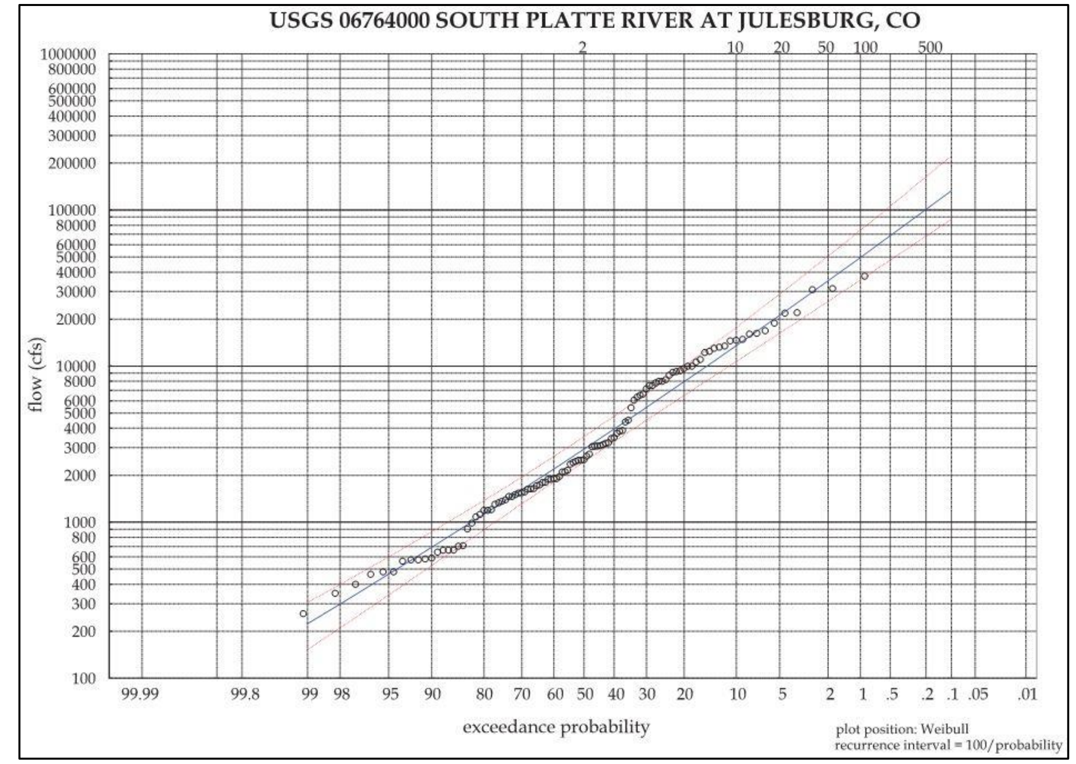


Figure 4-4: Julesburg, CO Exceedance Probability, including 2015 data (URS 2015)

4.3.2 Hydrologic Considerations

Hydrologic considerations are important for any river master plan project. Potential projects for the lower South Platte River should consider low flow, channel-forming flow, and/or design-flood flow, depending on project type. The low flow and seasonal flow design discharges are important for sediment transport and water rights considerations, while the channel-forming and flood flows are critical to channel stability and regulatory flood elevations. An explanation of each of these critical flow categories is provided below.

Low Flow

Low flow conditions define minimum surface water depths and velocities that can support critical fish species habitat. Additionally, water rights depend on flow in the river at a specific place and time, with low flow conditions often representing the limiting factor of design considerations for in-channel projects.

Channel-Forming Flow

Channel-forming flow is often described as the flow that will produce the same channel geometry and planform over a long period of time. This flow is often seen as the flow that controls the active channel formation and drives the geomorphic processes of channel change and sediment migration. The channel-forming flow is often used in channel design as the single surrogate flow that best represents the integrated effects of a complex series of flow events within the river system.

Bankfull discharge is often used as an estimate of the channel-forming flow and is defined as the maximum discharge that the channel can convey before overtopping onto the active floodplain. This flow is typically representative of the 1.5- to 2-year recurrence intervals. Rigorous field work is often required to attain precise bankfull estimates and was not performed as part of this project. The 2-year discharge can be used as a rough surrogate for bankfull discharge, which based on the FFA ranges between ~2,800 cfs and 4,500 cfs throughout the project area. Note the river system's hydrology, hydraulics, and sediment transport have been altered, so the return interval or field estimates may not be a good estimate for the flow that would drive geomorphic processes and ultimately river form.

Design-Flood Flow

The design-flood flow is the maximum flow that could be passed through the channel without causing damage or serious threat to the stability of adjacent structures. Typically, the design-flood flow is representative of the 1% recurrence interval, or the 100-year flood event. The design-flood flow within the project area is generally in the range of approximately 49,700 cfs to 54,300 cfs. In some instances, design-flood flow for a specific project may deviate due to specific local conditions or limitations.

4.4 Hydraulics

The updated hydrology that was completed after the 2013 flood event was later incorporated into a flood modeling and floodplain development project as part of CWCB's Colorado Hazard Mapping Program (CHAMP). Updated hydraulic models were created for many of the rivers along the Colorado Front Range that were affected by the 2013 flood, including the South Platte River. Hydraulic modeling along the lower South Platte River was completed in early 2018 by CWCB. The models and resultant floodplain mapping are currently going through the FEMA independent review process and are still considered in draft format. Once finalized, the CHAMP floodplains will be submitted to FEMA to revise the regulatory floodplains, updating the previous regulatory data developed as part of the 1977 USACE study. As part of CHAMP, detailed-level modeling was conducted on the South Platte River for all of Morgan, Washington, Logan, and Sedgwick counties, except for two short reaches in eastern Logan and western Sedgwick counties, which utilized existing approximate-level modeling techniques, per FEMA standards. Sedgwick County was previously unmapped in the 1977 USACE study.

The draft CHAMP models and Special Flood Hazard Area (SFHA) data (100-year and 500-year mapped floodplains) for the project area were provided by CWCB and their consultant ahead of their publication to support this master planning effort. The CDM Smith project team leveraged the draft models and floodplain data to identify flood hazards, assess potential flood risk, and develop potential master plan projects. **Appendix D** contains maps with the draft SFHA data and an approximate 10-year floodplain developed from the CHAMP models specifically for this study. It is important to note that these data have not been finalized or approved through the typical FEMA regulatory processes and are included in this study exclusively to support the analysis and recommendations as part of the Master Plan. They are not intended to represent approved changes to FEMA regulatory Flood Insurance Rate Maps.

4.5 Geomorphology

The South Platte River, which flows through an alluvial floodplain, has undergone dramatic changes in its flow and sediment regimes in the past two centuries. These changes are the result of development and human influences, including bank stabilization; construction of in-channel structures, such as diversions and bridges; irrigation of adjacent land; and installation of upstream flow-control structures, such as Chatfield and Cherry Creek Reservoirs. These changes have caused a significant shift in river morphology, a process often referred to as river metamorphosis (**Figure 4-5**).

Based on accounts by explorers in the early 1800s, the South Platte River was originally a shallow and wide braided stream, with sparse woody vegetation along the banks and shifting sandbars. As agricultural activities began to flourish in the mid- to late-1800s, diversion of water led to decreased peak flows, and irrigation of land adjacent to the channel caused a rise in groundwater levels and an increase in vegetation along the river corridor. With these changes, the once sparsely vegetated South Platte River became occupied by cottonwoods and other dense vegetation, fixing the river bank and sandbars in place and preventing the channel from shifting (Schumm 1985). Today, the South Platte is a meandering river with a large sediment load, due to large source slowly being transport from the upstream watershed. Construction of in-channel structures has resulted in sediment deposition, formation of medial bars, and an overall decrease in channel capacity.

The features described by Schumm (I985) are evident in the lower South Platte River project area. While it is unrealistic to attempt to return the river to pre-agriculture morphological conditions, understanding the metamorphosis process and the factors contributing to it can help unlock solutions to address reach-wide problems and risk factors. To better understand the river metamorphosis process, the CDM Smith team evaluated sediment transport, effective discharge, and geomorphic trajectories within the project area.

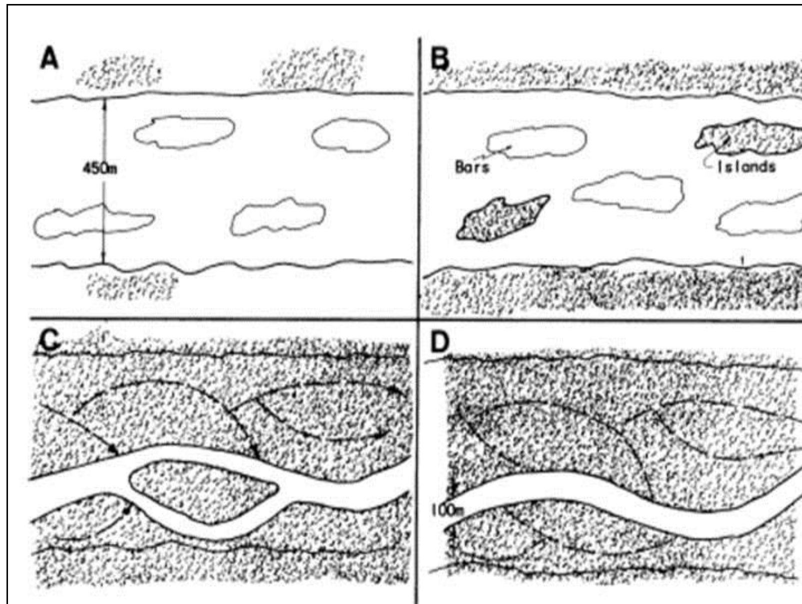


Figure 4-5: Model of South Platte River Metamorphosis. *A)* Early 1800s: discharge is intermittent, bars are transient. *B)* Late 1800s: discharge is perennial, vegetation is thicker on floodplain and islands. *C)* Early 1900s: droughts allow vegetation to establish itself below mean annual high-water 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.)

4.5.1 Sediment Transport

The September 2013 flood carried a tremendous volume of both water and sediment, which contributed to significant deposition and lateral migration of unarmored banks. CDM Smith evaluated sediment transport and effective discharge, which is defined as the discharge that transports the largest portion of the annual sediment yield over a period of years, to assess the effects of sediment transport within the project area. In lieu of conducting an intensive and costly reach-wide sediment transport analysis, stream power was evaluated as a surrogate to give an indication of general trends. Stream power is defined as the rate of energy dissipation against the bed and banks of a stream, per unit length downstream (shear stress times velocity as calculated in HEC-RAS with units of pounds per foot-second).

4.5.1.1 Transport Rates

Sediment transport rates were calculated across a range of flow events at a cross-section located upstream of the Colorado State Highway 52 bridge in Fort Morgan to provide estimates of typical transport rates throughout the project area. This location was selected as an example through a focus area due to the adjacent infrastructure. Transport rates are variable throughout the project area, but this analysis provides a point of reference for project area. The Sediment Transport Capacity module in HEC-RAS was used to calculate sediment transport capacity using the Ackers-White equation (USACE 2016). The Ackers-White equation is a total load equation that accounts for fine sediment primarily transported in suspension (suspended load) and the coarser material primarily transported as bedload. The analysis leveraged sediment gradations from the Middle South Platte River Sediment Transport Modeling and Project Feasibility Study (CDM Smith 2016) which consisted primarily of medium and coarse sand. The gradations from the middle South Platte River were considered consistent with the lower South Platte River sediment gradations, based on field observations performed as part of this study. The small fraction of gravel comprising the sediment gradations were excluded from the HEC-RAS gradation input as these grain sizes are outside the applicable range of the transport equation and the dominant transport mechanism was assumed to be suspended load.

The Sediment Transport Capacity module within HEC-RAS was used to calculate sediment transport rates across a range of flow events, allowing for the development of estimated sediment transport capacities at the cross-section upstream of State High 52 in Fort Morgan for different flow rates (**Figure 4-6**). The estimated transport rates using the Ackers-White equation were found to be consistent with USGS field measurements taken at multiple stream gage locations along the South Platte River near the project area.

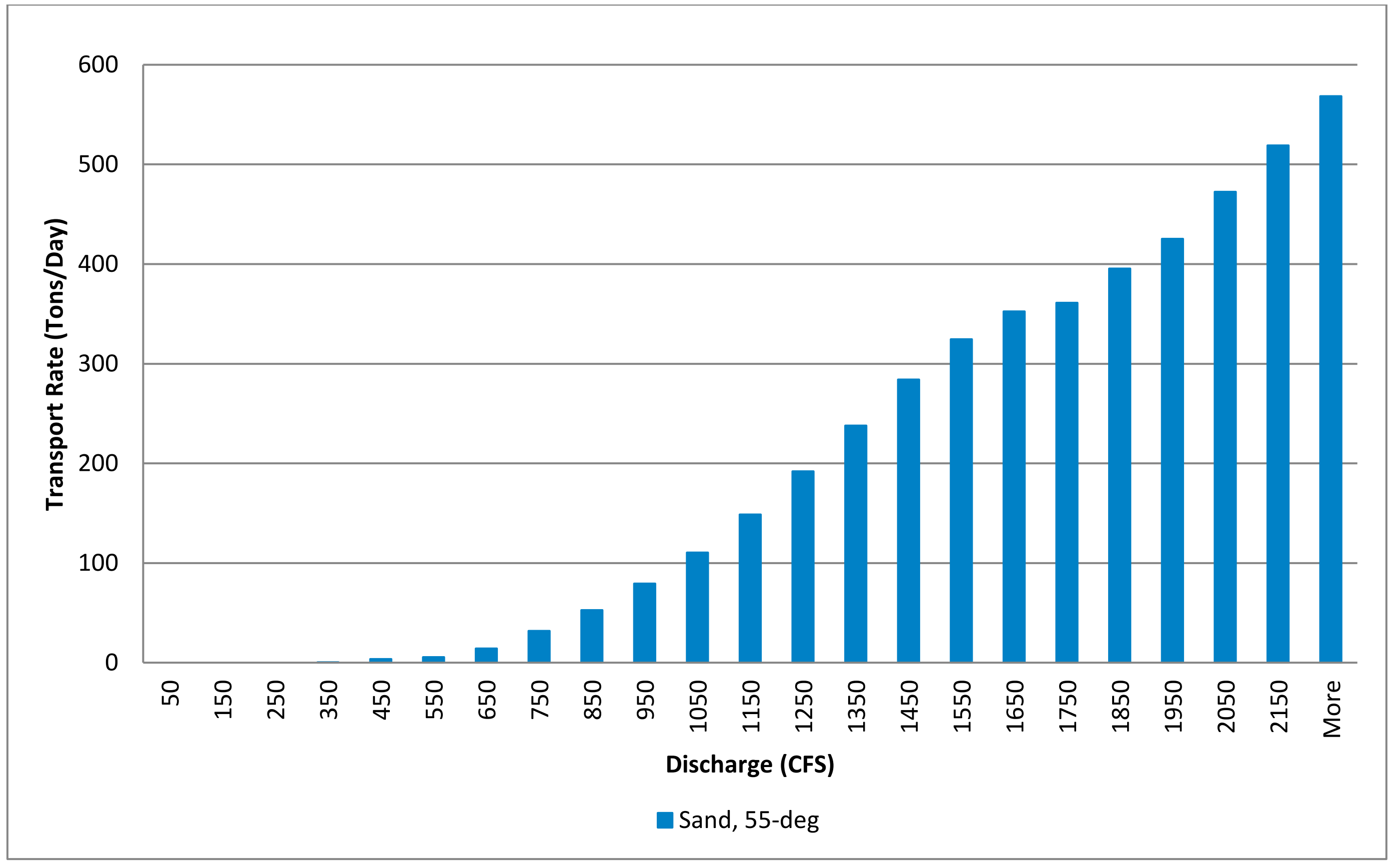


Figure 4-6: Sediment Transport Capacity in Fort Morgan at the Colorado State Highway 52 Bridge Crossing

4.5.1.2 Stream Power

Studies have shown that unit stream power (time rate potential energy expenditure per unit weight) is a critical factor in determining total sediment concentration (Yang and Stall 1974). For this study, in lieu of detailed sediment transport calculations throughout the project reach, unit stream power was used as a rough surrogate for sediment transport to predict the locations of potential streambed degradation (lowering of the streambed) or aggradation (raising of the streambed). Unit stream power was selected as the most representative output, which considers stream power per unit width of the active portion of the channel (versus the entire floodplain). The unit stream power distribution near Fort Morgan was extracted from the draft CHAMP models for the 100- and 10-year recurrence intervals (**Figure 4-7**). Stream power distributions for the remainder of the project area are included in **Appendix E**. Locations of abrupt increases in stream power represent potential locations of streambed degradation and erosion, whereas locations of abrupt decreases in stream power represent potential locations of streambed aggradation driven by sediment deposition. These abrupt changes are often exaggerated at structures (bridges and diversions) and can be misleading due to uncertainty in hydraulic results. Unit stream power trends identified for the lower South Platte River were compared against field observations and desktop review of the project reach to help support conclusions. The project concepts developed as part of this plan leveraged these stream power trends to support the proposed project elements. To predict the streambed profile changes accurately, however, a more detailed sediment transport study should be considered that accounts for detailed sediment and hydraulic conditions along the study reach.

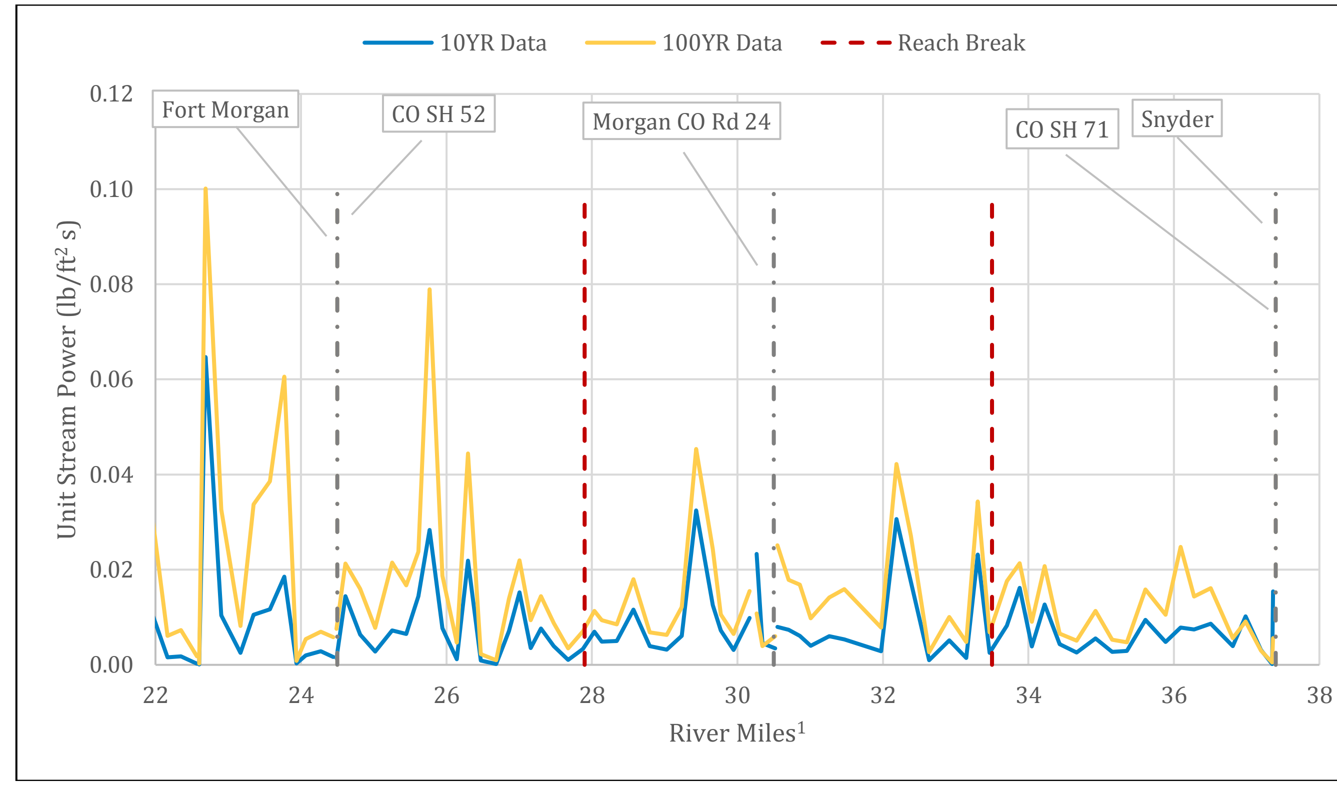


Figure 4-7: Unit Stream Power throughout Reaches 4, 5, and 6
[1] River miles from the Weld-Morgan county line

4.5.2 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). The effective discharge is often compared to the bankfull discharge to further understand key geomorphic processes that drive channel geometry and planform. Calculation of the effective discharge is performed by multiplying sediment transport rates by the probability of flows occurring within a year. The maximum value resulting from the calculation is the discharge that is most effective at transporting sediment within a year. To predict the impact of watershed alterations on channel stability, with respect to sediment loads and hydrology, an effective discharge calculation for the lower South Platte River was performed using the sediment transport rates presented in the previous section and an FFA of mean-daily flow events developed for the USGS Weldona gage. The specific methodology for the effective discharge calculation is described in **Appendix E**. The result of this analysis produced an effective discharge of approximately 1,250 cfs at the cross section upstream of the Colorado State Highway 52 bridge in Fort Morgan. This flow is approximately equal to the 1-year annual peak flow calculated at the Weldona gage, which is on the low end of the 1- to 3-year recurrence interval range typical for effective discharge. Note that the effective discharge is not generally a discharge associated with the most extreme flood events, which may carry large amounts of sediment load, but occur more frequently within a given year.

An effective discharge corresponding to the 1-year event suggests that more moderate flows (less than the bankfull flow) transport the most sediment over time. This could be an indication of an imbalance between the channel geometry and the current hydrologic and sediment regime. Channel instability is the result of an imbalance in sediment supply and transport capacity as the river attempts to achieve “dynamic equilibrium” between the sediment supply and transport capacity by adjusting its geometry, slope, planform, and sediment gradations. If the river were stable, excessive erosion or deposition would not occur over long periods of time. The lower South Platte River is relatively unstable (**Figure 4-7**), which results in more sediment being eroded from source areas (i.e. upstream watershed, steep-slope reaches, stream bed & banks, etc.) and more sediment being deposited in depositional areas (i.e. mild-slope reaches, confluences, bridge crossings, etc.) than one would typically find in a more stable river system.

The effective discharge appears to generally equate to flows within the active channel banks, suggesting that most sediment transport is occurring within the main channel resulting from in-line hydraulic structures (bridges and diversions) within the project area having a significant impact on the sediment transport capability of the river. Field visits, conversations with stakeholders, and review of aerial imagery confirmed this trend. A large portion of the bridges and diversion structures in the project area have significant sedimentation issues. More compelling evidence is apparent at diversion structures with improved sediment passing capabilities, where the annual sediment-related maintenance issues are significantly decreased. Understanding the basic mechanics impacting sediment transport and river stability within the project area provides valuable input into potential projects and solutions that can address causal factors on a holistic level.

4.5.3 Channel and Stream Evolution Models

A Channel Evolution Model (CEM) is a conceptual model that is used to understand the geomorphic response of a study reach to historical disturbances, as well as to future disturbances associated with proposed projects. The CEM concept has progressed over time based on advances in research and greater emphasis placed on habitat and ecosystem benefits. Cluer and Thorne (2014) developed an adaptation of the CEM, referred to as the Stream Evolution Model (SEM), which can be used to help characterize and describe the lower South Platte River.

4.5.3.1 Concept of CEM and SEM

The CEM on which the SEM is based was developed using field observations to generate a generalized five-stage channel evolution sequence for streams of the Yazoo Basin (Schumm et al. 1984). In each reach of an idealized channel, Types I through V occur in series, and will occur in the channel through time at a given location. The CEM describes the systematic response of a channel to base level lowering (i.e., lowering of downstream channel elevations), and encompasses conditions that range from disequilibrium to a new dynamic equilibrium state. The original five-stage CEM was eventually adapted into a six-stage CEM (Simon and Hupp 1986), which includes a "Constructed" stage between Stage I and II of the five-stage CEM; this considers the channelization, straightening, and re-sectioning of streams (**Figure 4-8**).

The SEM builds on the five-stage and six-stage CEMs, and was developed by combining the stages featured in the original CEMs along 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 4-9**). In addition, the SEM replaces linear progression with an evolutionary cycle, and links habitat and ecosystem benefits to physical attributes and system responses to disturbance. The SEM 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 is prevented from progressing to the next stage.

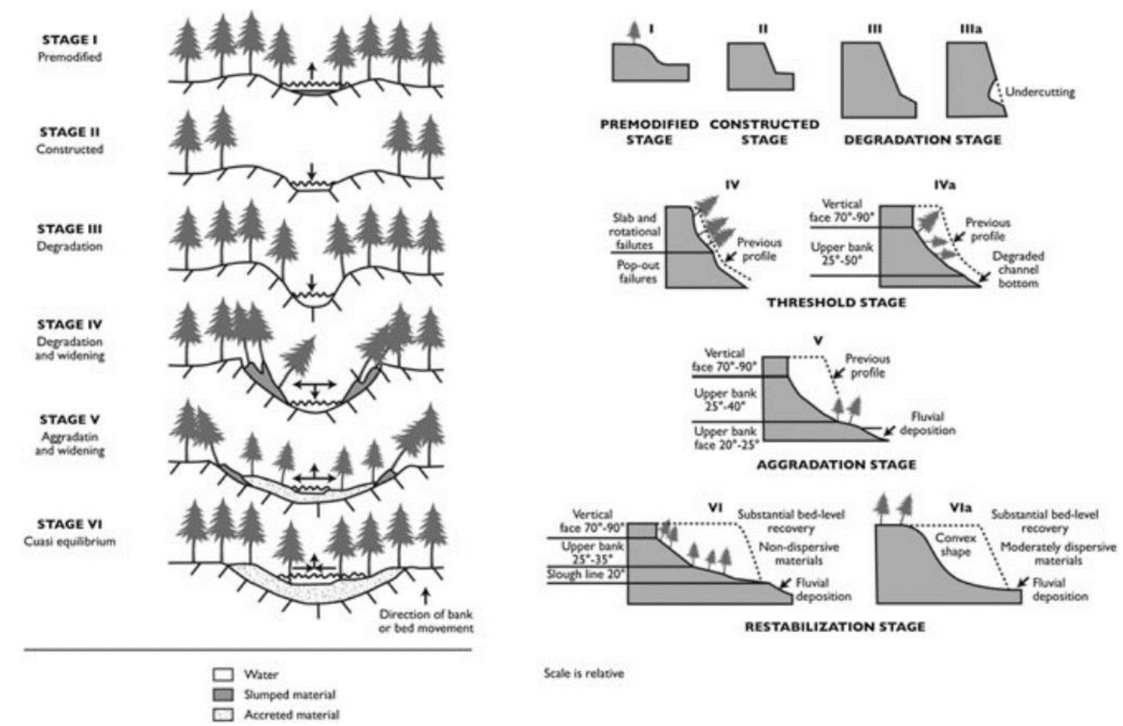


Figure 4-8: Six-stage CEM (Simon and Hupp 1986)

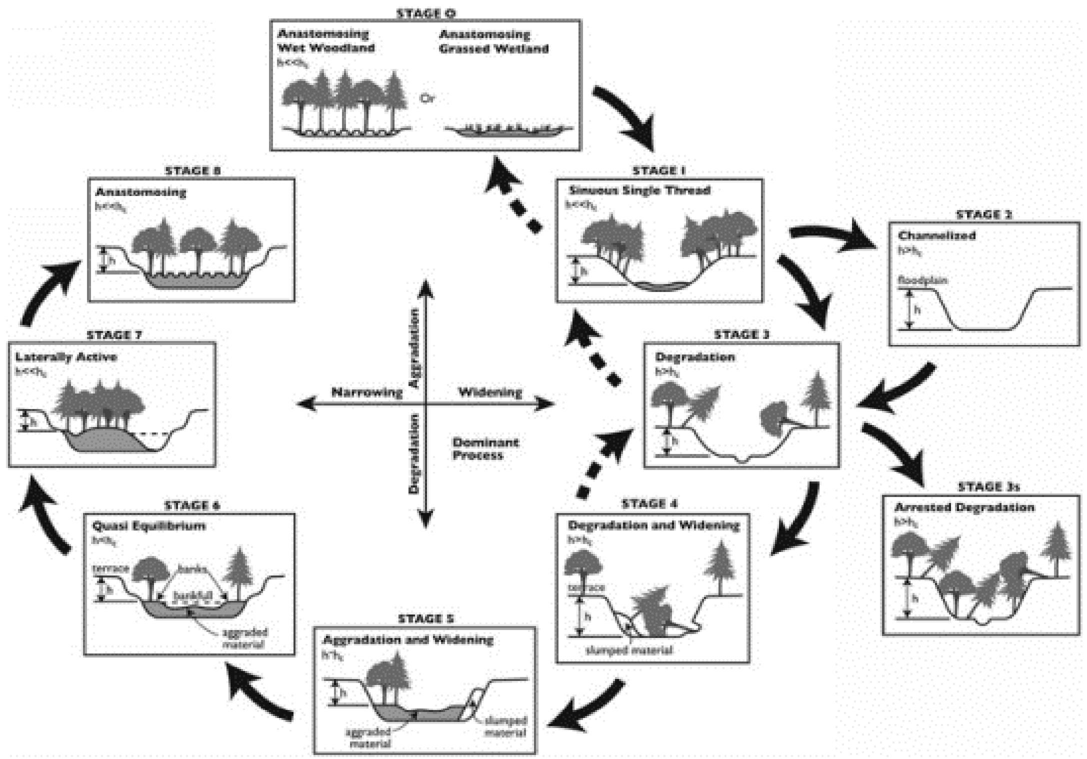


Figure 4-9: SEM (Cluer and Thorne 2014)

4.5.3.2 Application of SEM

While the SEM provides flexibility in characterization of river systems, direct application to the lower South Platte River system is difficult, especially given that the project area spans approximately 143 river-miles and the various reaches may be undergoing different processes and be in different evolutionary stages. Therefore, the SEM was used only as a starting point to define the evolution of the river.

Aggradation is occurring throughout most of the project reaches, which would suggest that the channel is in Stage V of both the CEM and SEM: Aggradation and Widening. Alternatively, based on field observations, the channel appears to be losing hydraulic capacity due to the prevention of channel widening caused by bank armoring and vegetating of lateral bars, and the formation of medial sandbars within the current channel, which reduces the effective channel width. This suggests that the channel may be in a stage similar to Stage 3a of the SEM: Arrested Degradation, where the channel is locked in place, but rather than degrading, it is aggrading via mini-cycles of aggradation and degradation with formation of bars that are shifted and displaced during larger flow events. The loss of hydraulic capacity associated with this cycle is problematic as significant flooding tends to occur on floodplains where agricultural development is prevalent.

When designing stream restoration projects, potential geomorphic responses of the study reaches to the proposed projects need to be investigated, based on a modified CEM or SEM, to understand potential evolutionary paths that the channel could take and to ensure that it does not revert back to current trends of instability. Potential projects should be designed such that the geomorphic trajectory of the river approaches a quasi-equilibrium stage, to the extent possible, at both local and watershed scales.

4.6 Ecology

Ecological risk assessments are an important component of master planning for a flood damaged river so that proposed river modifications do not negatively impact the ecological health of organisms and their habitats, both in the river and in the surrounding floodplains. Design considerations that optimize ecological health have the added benefit of improving available ecosystem services that may potentially increase the economic value of a stream or river channel. Recreational opportunities, such as hike and bike trails, wildlife photography, hunting, fishing, and other water activities, are common in the South Platte River basin and provide an important role in the economies of communities located along the river. The sustainability of these important community functions is dependent on maintaining a healthy ecological environment for the plant, animal, and fish species present within the lower South Platte River basin.

CDM Smith performed visual stream assessments to gain an understanding of the ecological health of the project area and the extent of viable riparian habitat. In addition to providing shelter and a regular food source to wildlife in the area, increased riparian habitat and wetland areas reduce the risk of floods, as vegetative cover buffers the stream channel against the physical effects of high flows by slowing and storing flood waters within the floodplain. In many instances, these floodplains provide refuge habitat for aquatic species during flood events, and as stream flows recede, riparian wetlands slowly release water and aquatic organisms back to the stream through surface and subsurface transport. Slower water releases through such mechanisms aid in maintaining stream flows during dry periods of the year as well. Vegetative cover and their complex root systems also help improve water quality and soil stability by filtering and absorbing water pollutants while holding soils together.

In addition to habitat adjacent to the stream, complex habitat within stream corridors can be beneficial during high flows. Roughness and complexity within the channel dissipates the energy of water and reduces its erosive power. Channel roughness and complexity are impacted by the following characteristics:

- Stream meanders, pools, riffles, and backwaters
- In-stream wetland vegetation
- Stream gradient, width, and depth
- Debris such as trees and bank material
- Overhanging vegetation and roots extending into the stream flow
- Streambed materials such as sand, gravel, rocks, and boulders

Assessment of stream complexity and existing riparian habitat along the lower South Platte River will help decipher appropriate channel improvements that would reduce flood risk while maintaining ecological health in the project area. Results from the ecological risk assessment can be found in Section 5 of this report.

Section 5

Flood, Fluvial Geomorphic, and Ecological Risk Assessments

As part of the Master Plan development process, CDM Smith, with the assistance of Anderson Consulting Engineers and Otak, performed flood, fluvial geomorphic, and ecological risk assessments to better understand the reaches of the lower South Platte River that are most vulnerable. Each of the risk assessments were developed to identify the likelihood (potential) of 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 possible severity of, each type of impact for each reach. The following sections describe the methodology and results of each assessment. Detailed characterizations of each of the 19 reaches in the project area are provided in tables at the end of this section.

5.1 Flood Risk Assessment

5.1.1 Methods

CDM Smith and Anderson Consulting Engineers performed a flood risk assessment for the study area that incorporated delineated structures and high value assets (i.e. water treatment plants, electrical infrastructure, etc.), the FEMA 100-year floodplain, reported damage following the 2013 and 2015 floods, hydraulic model data at bridge structures from the draft FEMA CHAMP model (FEMA 2016b), and the approximate 10-year floodplain that was 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 banks and inundating the floodplain was classified for each reach within the project area under the 10-year and 100-year flood flow conditions. Structures adjacent to the river within the project area were identified, based on aerial imagery, and an overall estimate the number of structures in the draft FEMA special flood hazard area (SFHA) 100-year floodplain (FEMA 2016b) and in the approximate 10-year floodplain was developed (**Table 5-1**). Each reach was assigned a flood risk potential score of low (1), medium (2), or high (3), based on the following criteria:

- **1 – Low Potential**
  - Floodplains consist of undeveloped riparian zones and/or agricultural lands, and there are less than five structures per mile in the 100-year floodplain
- **2 – Medium Potential**
  - Five to 15 structures per river mile are located within the 100-year floodplain
- **3 – High Potential**
  - More than 15 structures per river mile are located within the 100-year floodplain
  - More than 10 structures per river mile are located within the 10-year floodplain

5.1.2.2 Flood Risk Severity Scores

The possible severity or extent of damage that may result from flooding was classified for each reach within the project area. Each reach was assigned a flood risk severity score of low (1), medium (2), or high (3) based primarily on the number of high-value assets, critical infrastructure, and bridges that would potentially be impacted by the 10-year and 100-year flood events. The assets and infrastructure within the floodplain were identified and categorized using aerial imagery, available photographs, and site visits then tabulated for each reach based on the draft FEMA SFHAs (FEMA 2016b) and the approximate 10-year floodplain (**Table 5-1**). Documented impacts from the 2013 and 2015 flood events (per news stories and conversations with stakeholders) that were not represented by the previous criteria were also considered as part of the severity index for each reach. The following criteria were used to assign a flood hazard severity score to each reach:

- **1 – Low Severity**
  - One or fewer high-value assets or critical infrastructure are located within the 10-year or 100-year floodplains
  - Minimal impacts or damage were reported or documented from the 2013 and/or 2015 flood events
- **2 – Medium Severity**
  - Two high-value assets or critical infrastructure are located within the 10-year or 100-year floodplains
  - Minor to moderate impacts or damage were reported or documented from the 2013 and/or 2015 flood events
- **3 – High Severity**
  - Three or more high-value assets or critical infrastructure are located within the 10-year or 100-year floodplains
  - Moderate to significant impacts or damage were reported or documented from the 2013 and/or 2015 flood events

Table 5-1: Estimated Number of Structures per Mile and Total High-Value Assets within the 10-Year and 100-Year Floodplains for Each Project Reach

Reach	Potential: Approximate Number of Structures per River Mile (total structures in floodplain listed in parentheses for reference)		Severity: High-Value Assets or Critical Infrastructure per Reach*	
	10-year Floodplain	100-year Floodplain	10-year Floodplain	100-year Floodplain
1	0 (4)	1 (10)	1	1
2	0 (0)	4 (36)	0	2
3	0 (0)	0 (0)	0	1
4	0 (1)	2 (12)	0	3
5	1 (5)	2 (12)	0	1
6	2 (6)	4 (14)	0	1
7	1 (7)	2 (18)	1	2
8	0 (1)	1 (13)	2	2
9	0 (1)	3 (26)	1	2
10	1 (5)	4 (29)	0	1
11	3 (17)	63 (431)	0	5
12	1 (3)	2 (9)	0	0
13	0 (2)	30 (271)	1	1
14	0 (3)	4 (37)	0	1

Reach	Potential: Approximate Number of Structures per River Mile (total structures in floodplain listed in parentheses for reference)		Severity: High-Value Assets or Critical Infrastructure per Reach*	
	10-year Floodplain	100-year Floodplain	10-year Floodplain	100-year Floodplain
15	1 (8)	15 (132)	1	1
16	1 (9)	1 (12)	0	1
17	0 (1)	5 (23)	0	1
18	0 (1)	3 (26)	0	2
19	1 (4)	2 (11)	0	2

*Includes municipal utility infrastructure and impacted bridge structures – note that these are not normalized by reach distance

Data used to determine flood risk potential and flood risk severity can be found in **Appendix F**.

5.1.3 Flood Risk Matrix and Results

A flood risk scoring matrix (**Table 5-2**) was developed based on the flood risk potential and flood severity score criteria discussed in Section 5.1.2. The scoring matrix was used to assign an overall rank of Low, Medium, or High flood risk to each reach (**Figure 5-1**). Four reaches were categorized as having a High flood risk, three reaches were categorized as having a Medium flood risk, and the remaining twelve reaches were categorized as having Low flood risk (**Table 5-3**).

Table 5-2: Risk Score Matrix

Potential	Severity		
	1	2	3
1	2- Low	3- Low	4- Medium
2	3- Low	4- Medium	5- High
3	4- Medium	5- High	6- High

Table 5-3: Flood Potential, Severity, and Overall Risk Scores

Reach	Flood Potential Score	Flood Severity Score	Overall Flood Risk Category
1	1-Low	2-Medium	3-Low
2	1-Low	2-Medium	3-Low
3	1-Low	1-Low	2-Low
4	1-Low	3-High	4-Medium
5	1-Low	1-Low	2-Low
6	1-Low	1-Low	2-Low
7	1-Low	3-High	4-Medium
8	1-Low	3-High	4-Medium
9	1-Low	3-High	4-Medium
10	1-Low	1-Low	2-Low
11	3-High	3-High	6-High
12	1-Low	1-Low	2-Low
13	3-High	2-Medium	5-High
14	1-Low	1-Low	2-Low
15	3-High	2-Medium	5-High
16	1-Low	1-Low	2-Low
17	1-Low	1-Low	2-Low
18	1-Low	2-Medium	3-Low
19	1-Low	2-Medium	3-Low

5.2 Fluvial Geomorphic Risk Assessment

5.2.1 Methods

Otak performed a fluvial geomorphic assessment of the lower 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. Otak performed the assessment based on:

- Geomorphic reach delineation and characterization
- Relative elevation model (REM) assessment
- Identification of the active channel (AC), erosional hazard area (EHA), and historical river corridor (HRC)
- Identification of at-risk infrastructure, lands, and property
- Quantification of reach-averaged hydraulic processes
- Identification of potential erosion areas
- Delineation of relative risk of fluvial hazard on a reach-by-reach basis

The methodology used in each of these assessments is described below. Additional details are provided in **Appendix G**.

5.2.1.1 Reach Delineation

Reach delineation subdivides the channel into areas of similar geomorphic and hydrologic properties, which can assist in mapping fluvial features and informing the relative hazards and risks in different areas. Significant changes in geomorphology and hydrologic regime in turn affect channel planform and vegetation which were also used to inform the locations of reach breaks. Reach breaks are typically defined by changes in:

- Channel and valley gradient
- Geologic controls on channel elevation
- Confinement from the valley or land development
- Tributary junctions
- The presence of dams or diversions that significantly alter the hydrologic regime
- Political boundaries

The reach breaks for the study area were determined based on the variation of valley confinement and urban or agricultural development influence, channel planform, and valley gradient as observed in the topography and aerial photography. Tributary influence, vegetative changes, and political boundaries were also considered in the determination of the reach breaks.

5.2.1.2 Relative Elevation Model:

The relative elevation model (REM) was created from 2016 LiDAR digital topography to show the relative elevation of the river corridor and valley above the bottom of the active channel (**Figure 5-2**). This process removes the broad scale valley gradient, so comparisons can be made between any regions within the study area based on relative elevations above the active channel, as opposed to absolute elevations, which are influenced by valley slope. The process of creating the REM was completed through GIS processing of LiDAR data by denoting the location of the channel bottom, then detrending and extracting that elevation from the topography, and subtracting that elevation from the surrounding river corridor and valley elevations. The exact methods and appropriate GIS tools are outlined in the Planning-Level Channel Migration Zone (pCMZ) methodology (WSDOE, 2014).

The REM enhances the ability to visualize and quantify fluvial features within the active and historical river corridor compared to the original topography (**Figure 5-2**). The high-resolution topography (1-meter resolution

LIDAR) used to create the REM was an important factor in the visibility of fluvial features and the mapping precision of the REM and subsequent FHZ, due to the relatively small scale of many fluvial features. The REM allows us to identify and quantify the active river channel and the historical river corridor (**Figure 5-2**) based on relative elevation and distinct geomorphic features currently and/or historically confining the river corridor.

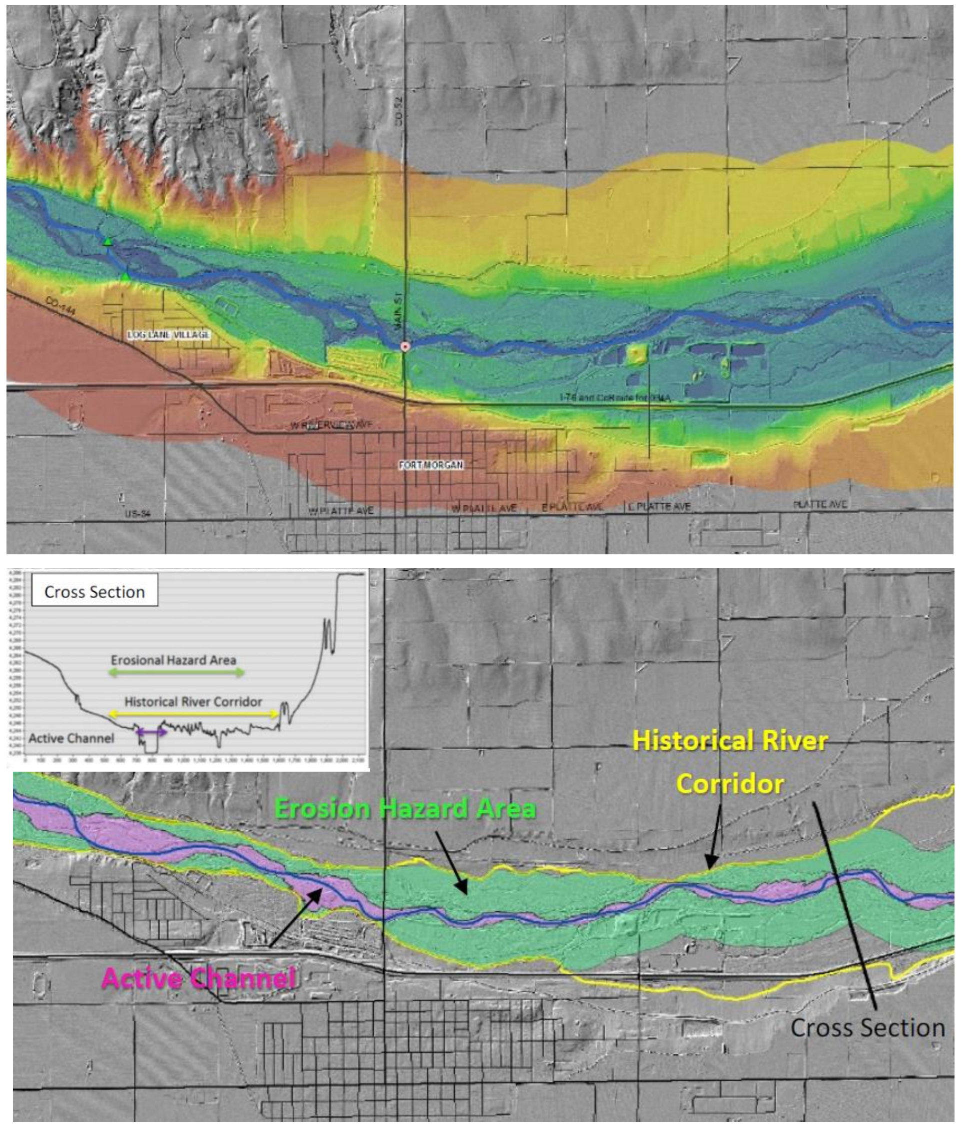


Figure 5-2: Relative Elevation Model (REM) at Fort Morgan

5.2.1.3 Fluvial Hazard Zones

Based on the REM, GIS, and aerial imagery analyses we identified and delineated three fluvial hazard zones: the active channel, the erosional hazard area, and the historical river corridor (**Figure 5-2**).

- The active channel (AC) is the region the river currently occupies or could occupy over an annual timeframe. This is the region most susceptible to fluvial impact and change, where the channel is actively transporting water and sediment driving erosion and deposition along the bed and banks. In the photograph to the right, the active channel is visually identified by the active sediment plain, bound on each side with dense vegetation.
- The erosional hazard area (EHA) is based on calculation of the potential channel migration over a 100-year timeframe (**Figure 5-2**). An average river migration rate was calculated based on time-series analysis of aerial imagery for select locations throughout the project reaches. The river migration rate was then extrapolated over 100 yr. to create a buffer adjacent to the active channel representative of areas with long-term hazard potential. For this broad-scale watershed analyses we determined an average migration rate of 13 ft/yr, based on numerous lateral meander migration measurements identified in the aerial imagery – giving an erosional hazard area buffer of 1,317 ft.
- The historical river corridor (HRC) is the area the river has occupied in the past. Based on GIS and REM analysis, the historical river corridor can be defined by distinct features that currently or have historically confined the river corridor (such as, steep bedrock walls, high previously incised terraces, etc.).

5.2.1.4 Identification of At-Risk Infrastructure, Lands, and Property

By overlaying mapping of the active channel, erosional hazard area, and historical river corridor we can identify areas most likely to be impacted by fluvial and flooding processes – with likelihood of impact decreases with distance from the river from the active channel, through the erosional hazard area, to the historical river corridor. However, fluvial risk only applies to areas containing assets of value, as there are lower consequences of fluvial impacts to areas with limited current value. Therefore, by identifying valued infrastructure within the fluvial hazard zones we can highlight the most (or least) at-risk infrastructures susceptible to fluvial impacts. Yet, mapping the entire river corridor, even areas without current assets, provides a broad overview of fluvial hazard, which can help guide future development and land use. Here we have differentiated at-risk infrastructure into three broad and generalized categories: 1) Low population, low building density areas that have no buildings within the active channel and only 0-5 buildings within the erosional hazard area. 2) medium population and building density areas, often associated with small towns or more populated areas close to the river with 1-2 building within the active channel and 6-10 buildings within the erosional hazard zone. 3) high population, high density areas associated with more densely populated urbanized towns with >2 building/assets within the active channel and > 10 buildings within the erosional hazard area.

5.2.1.5 Reach-Averaged Hydraulic Processes

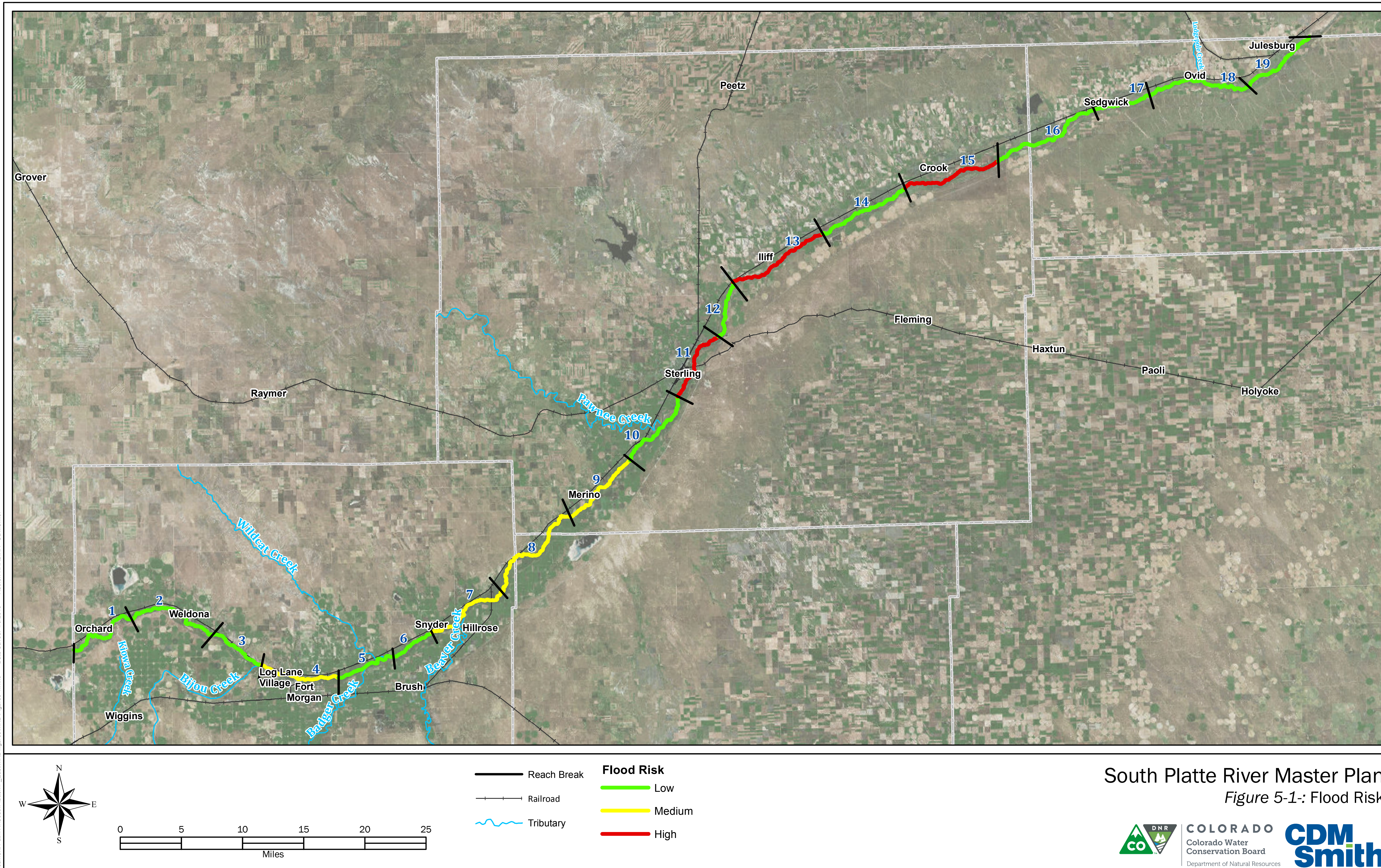
Hydraulic analysis data were provided by CDM Smith, based on CHAMPs flood hazard modeling results. Stream power, discharge, and velocity data were acquired for the 10 yr. and 100 yr. flood stages at each of the flood model cross sections, and then averaged across each of the individual reaches. Stream power is a measure of a rivers ability to perform work on the channel bed and banks, and is therefore a key indicator of the rivers ability to alter the channel corridor and influence fluvial hazard and risk. Therefore, reach-averaged stream power was the primary hydraulic metric used in the fluvial hazard assessment and risk designation. All reach-averaged hydraulic results are presented in the attached Summary Table.

5.2.1.6 Identification of Potential Erosion Zones

The FHZs delineate a broad-scale assessment of fluvial hazard along the river corridor. However, it should be noted that some areas, such as on the outside of pronounced meander bends, are more prone to experience erosion or alteration due to fluvial processes than other less fluvially active areas. We have identified "potential erosion areas", where a section of the river with high potential for erosion and migration is either encroaching on critical infrastructure or has potential to erode the active channel outside of the historical river corridor. These points highlight specific erosional hazard areas beyond the broad-scale FHZs.

5.2.1.7 Fluvial Geomorphic Potential and Severity

Fluvial geomorphic risk was determined on a reach-by reach basis by independently assessing and scoring the fluvial geomorphic potential and the fluvial geomorphic severity. The combination of the fluvial geomorphic potential and severity determines the fluvial geomorphic risk for each reach.



South Platte River Master Plan

Figure 5-1-: Flood Risk

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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 fluvial erosion and channel alteration under future high flow conditions was investigated for each reach based on reach-averaged stream power (discussed above) and qualitative assessment of valley confinement, channel characteristics, and erosion and lateral meander migration potential, based on topographic data, relative elevation models, aerial imagery, and FHZ mapping. Each reach was assigned a fluvial impact potential score of low (1), medium (2), or high (3) denoting the potential for planform change due to fluvial erosion and migration during future high flow stages. It should be noted that this is a reach scale assessment, and that there is some erosion potential on the outside of nearly all meander bends in the project area. The following criteria was used for each fluvial geomorphic potential classification:

- **1 – Low Potential**
  - Low reach-averaged stream power (10 yr = <0.45 lbs/ft s; 100 yr = <1.0 lbs/ft s)
  - Partially to well confined valleys by bedrock and/or large terraces with minimal opportunities to over-widen
  - Low erosion and lateral migration potential, with low sinuosity meanders confined well within channel corridor and a well-connected floodplain and/or riparian habitat zone
- **2 – Medium Potential**
  - Medium reach-averaged stream power (10 yr = 0.45 – 0.6 lbs/ft s; 100 yr = 1.0-1.5 lbs/ft s)
  - Partially confined valleys with moderate sinuosity meanders and moderate lateral meander migration and erosion potential
  - Partially connected floodplain with some riparian habitat
- **3 – High Potential**
  - High reach-averaged stream power (10 yr > 0.6 lbs/ft s; 100 yr > 1.5 lbs/ft s)
  - Partially or unconfined valleys or valleys that have been channelized and confined by urban
  - development
  - Poorly-connected or disconnected floodplains with limited to no riparian corridor
  - Medium to high meander migration and erosion potential

5.2.2.2 Fluvial Geomorphic Risk Severity Scores

The severity of impacts from fluvial erosion and channel alteration under future high flow condition was assessed independently of the fluvial geomorphic potential for each reach. The severity of future fluvial impacts was determined based on the number of assets within the active channel and erosional hazard zone, the number of potential erosion areas – where the channel is encroaching on critical assets or the boundary of the historical river corridor, and the type of land use bounding the river corridor. Each reach was assigned a fluvial geomorphic severity score of low (1), medium (2), or high (3) denoting the severity of potential damage to buildings, infrastructure, and land use. The following criteria was used for each fluvial geomorphic severity classification:

- **1 – Low Severity**
  - Low population with low density buildings and assets (no buildings in AC; 0-5 in EHZ)
  - Minimal (0-2) potential erosion areas
  - The channel corridor is predominantly bound by vacant land or a riparian buffer
- **2 – Medium Severity**
  - Minimal assets within AC (1-2) and moderate assets within the EHA (6-10)
  - Moderate potential erosion areas (3-4) encroaching on assets or HRC boundary
  - Channel corridor bound by mostly farmland with minimal riparian buffer
- **3 – High Severity**
  - Higher populations with higher building densities (e.g., towns), with >2 assets within AC and >10 buildings/assets within the EHA
  - Significant potential erosion areas (>5) encroaching on assets, buildings, or HRC boundary
  - Channel corridor primarily bound by significant assets, towns, and urbanization

5.2.3 Fluvial Geomorphic Risk Matrix and Results

Based on the fluvial geomorphic risk potential and severity score criteria discussed in Section 5.2.2, an overall risk of Low, Medium, or High was assigned to each reach (**Figure 5-3**) according the same risk score matrix used for the flood risk assessment (**Table 5-2**). Based on the fluvial geomorphic risk assessment, four reaches were categorized as having a High fluvial geomorphic risk, four reaches were categorized as having a Medium fluvial geomorphic risk, and the remaining eleven reaches were categorized as having Low fluvial geomorphic risk (**Table 5-4**).

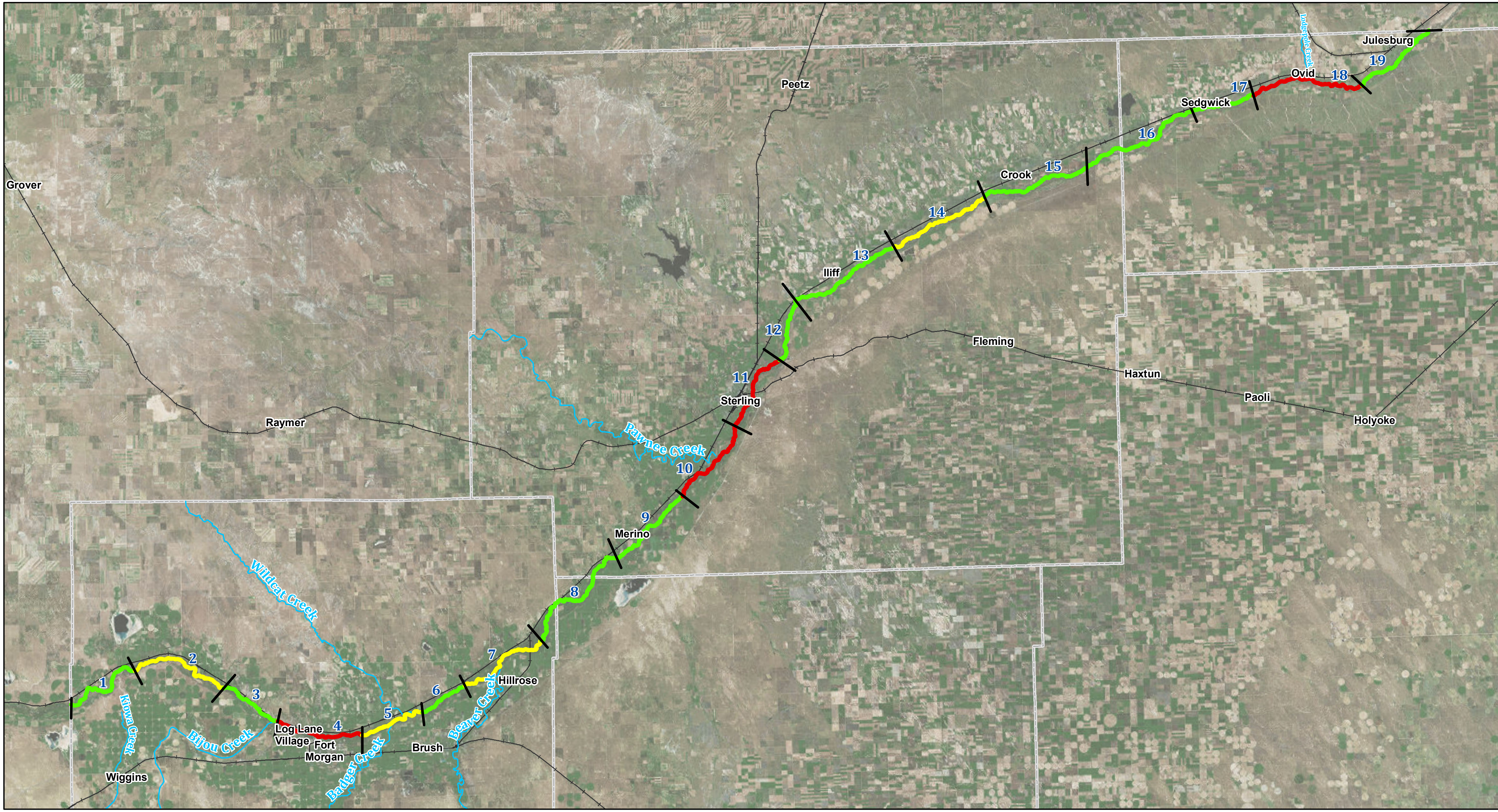
Table 5-4: Fluvial Geomorphic Potential, Severity, and Overall Risk Scores

Reach	Fluvial Geomorphic Potential Score	Fluvial Geomorphic Severity Score	Overall Fluvial Geomorphic Risk Category
1	2-Medium Potential	1-Low Severity	3 - Low
2	2-Medium Potential	2-Medium Severity	4 - Medium
3	1-Low Potential	1-Low Severity	2 - Low
4	3-High Potential	3-High Severity	6 - High
5	2-Medium Potential	2-Medium Severity	4 - Medium
6	1-Low Potential	1-Low Severity	2 - Low
7	2-Medium Potential	2-Medium Severity	4 - Medium
8	2-Medium Potential	1-Low Severity	3 - Low
9	1-Low Potential	1-Low Severity	2 - Low
10	2-Medium Potential	3-High Severity	5 - High
11	3-High Potential	3-High Severity	6 - High
12	1-Low Potential	1-Low Severity	2 - Low
13	1-Low Potential	1-Low Severity	2 - Low
14	2-Medium Potential	1-Low Severity	3 - Medium
15	1-Low Potential	1-Low Severity	2 - Low
16	1-Low Potential	1-Low Severity	2 - Low
17	1-Low Potential	1-Low Severity	2 - Low
18	2-Medium Potential	3-High Severity	5 - High
19	1-Low Potential	1-Low Severity	2 - Low

5.3 Ecological Risk Assessment

5.3.1 Methods

As part of the overall Master Planning effort, CDM Smith also performed an ecological assessment to evaluate the overall condition of the stream, riparian areas, and instream habitats within the project area to aid in the prioritization of reaches relative to potential ecological restoration efforts. CDM Smith used the Stream Visual Assessment Protocol Version 2 (SVAP2) (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.



World Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community USDA NAIP 2015

South Platte River Master Plan

Figure 5-3-: Fluvial Geomorphic Risk

COLORADO Colorado Water Conservation Board Department of Natural Resources

CDM Smith

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However, due to the lack of public access along considerable portions of the lower South Platte River within the study area, the SVAP2 assessment also incorporated aerial imagery and other data from various state and federal agencies into the assessment. Each of the 19 reaches within the study area were evaluated individually based on the 13 elements and criteria outlined in the SVAP2 protocol (Table 5-5).

Table 5-5: SVAP2 Ecological Elements

Ecological Elements	Element Criteria
1. Channel Condition	Evaluates the geomorphic shape of the channel relative to the floodplain
2. Hydrologic Alteration	Evaluates change to streamflow relative to a natural flow regime
3. Bank Condition	Assesses bank stability
4. Riparian Area Quantity	Determines the width of the riparian area in relation to bankfull width
5. Riparian Area Quality	Assesses riparian plant diversity
6. Canopy Cover	Determines the percentage of overhanging stream vegetation
7. Water Appearance	Assesses water 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	Identifies the number and depth of pools
11. Barriers to Movement	Identifies barriers to movement of aquatic species
12. Fish Habitat Complexity	Identifies and quantifies different fish habitat types
13. Aquatic Invertebrate Habitat	Identifies and quantifies aquatic invertebrate habitat types

The SVAP2 ecological elements were evaluated separately for each bank of the river (i.e. river left and river right, as one looks downstream), and each element was assigned a score between 1 and 10 based on the apparent ecological condition. Scores were developed independently for river left and river right but were ultimately 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, i.e. the sum of ecological scores divided by the number of ecological elements recorded, which yielded the overall ecological condition score for each reach. These overall scores were then used to classify each reach according to the five main classifications provided in the SVAP2 methodology (**Table 5-6**). The assessment and scoring for each ecological element in every reach can be found in **Appendix H**.

5.3.2 Ecological Risk and Restoration Priority Scores

5.3.2.1 Ecological Risk Scores

Each of the 19 reaches in the project area was assigned an ecological risk value of low (1), medium (2), or high (3) based on the score acquired during the SVAP2 evaluation, which is outlined in **Appendix H**. The classification serves to catalog the relative ecological health of each reach as it currently exists. Reaches with better current ecological condition have responded more favorably to long-term changes in the river corridor and to recent flood events. The higher scoring reaches are, therefore, generally considered more resilient and of lower ecological risk moving forward. The following criteria were used for each classification:

- **1 – Low Risk**
  - Ecological condition score: 6.7 to 10.0
- **2 – Medium Risk**
  - Ecological condition score: 3.4 to 6.6
- **3 – High Risk**
  - Ecological condition score: 0 to 3.3

5.3.2.2 Ecological Restoration Priority Scores

In lieu of the severity assessment used for the flood and fluvial geomorphic risk assessments, an ecological restoration priority level of low (1), medium (2), or high (3) was assigned to each reach based on land ownership and whether restoration projects would be effective in establishing or improving healthy and functioning ecosystem. The following criteria were used for each classification:

- **1 – Low Priority**
  - Reaches located on private land, and that have little potential for restoration
- **2 – Medium Priority**
  - Reaches located on private land that have good potential for restoration
- **3 – High Priority**
  - Reaches located on public land that have good potential for restoration

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 to manage due to the private ownership status.

Table 5-6: SVAP2 Ecological Condition Criteria

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.

5.3.3 Ecological Risk Matrix and Results

Based on the ecological risk and restoration priority score criteria discussed in Section 5.3.2, an overall rank of Low, Medium, or High potential for restoration was assigned to each reach (**Figure 5-4**), according to the ecological potential for restoration score matrix (**Table 5-7**). Based on the ecological assessment, nine reaches were categorized as having a high potential for restoration, nine reaches were categorized as having a medium potential for restoration, and the remaining reach was categorized as having low potential for restoration (**Table 5-8**).

Table 5-7: Ecological Potential for Restoration Score Matrix

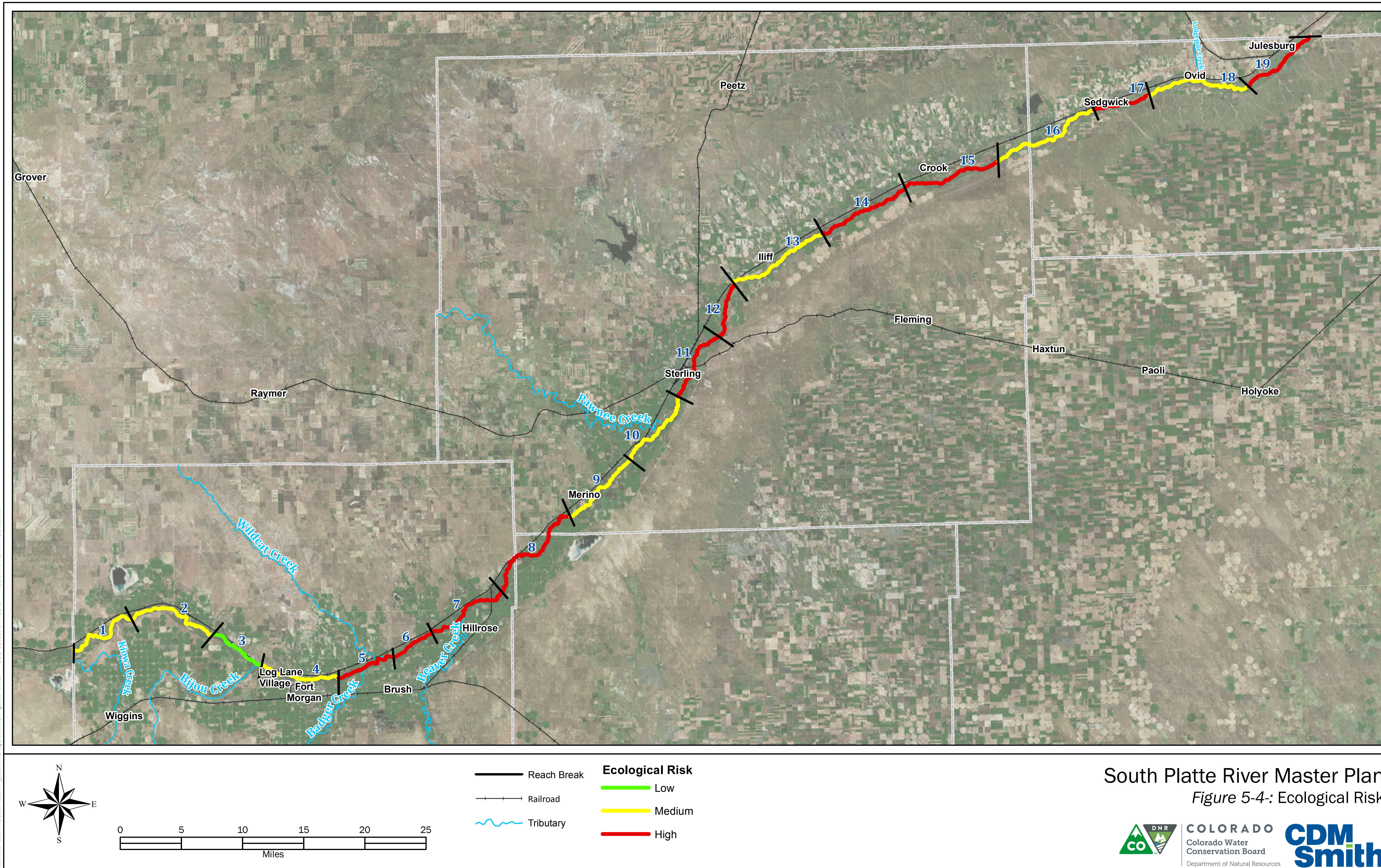
Ecological Risk	Ecological Restoration Priority		
	1	2	3
1	2 - Low	3 - Low	4 - Medium
2	3 - Low	4 - Medium	5 - High
3	4 - Medium	5 - High	6 - High

Table 5-8: Ecological Risk, Restoration Priority, and Overall Risk Scores

Reach	Ecological Risk Score	Ecological Restoration Priority Score	Overall Ecological Risk Category
1	2-Medium Risk	2-Medium Priority	4 - Medium
2	2-Medium Risk	2-Medium Priority	4 - Medium
3	2-Medium Risk	1-Low Priority	3 - Low
4	2-Medium Risk	2-Medium Priority	4 - Medium
5	2-Medium Risk	3-High Priority	5 - High
6	2-Medium Risk	3-High Priority	5 - High
7	2-Medium Risk	3-High Priority	5 - High
8	2-Medium Risk	3-High Priority	5 - High
9	2-Medium Risk	2-Medium Priority	4 - Medium
10	2-Medium Risk	2-Medium Priority	4 - Medium
11	2-Medium Risk	3-High Priority	5 - High
12	2-Medium Risk	3-High Priority	5 - High
13	2-Medium Risk	2-Medium Priority	4 - Medium
14	2-Medium Risk	3-High Priority	5 - High
15	2-Medium Risk	3-High Priority	5 - High
16	2-Medium Risk	2-Medium Priority	4 - Medium
17	2-Medium Risk	3-High Priority	5 - High
18	2-Medium Risk	2-Medium Priority	4 - Medium
19	2-Medium Risk	3-High Priority	5 - High

5.4 Reach Characterization and Risk Assessment Details

A characterization and summary of each of the 19 reaches, including details on the river characteristics, river statistics, and the individual flood, fluvial geomorphic, and ecological risk assessment scores for each reach is provided in **Tables 5-9** through **5-27**. The respective scores for flood potential and severity, fluvial geomorphic potential and severity, and ecological risk and restoration priority were used to develop an overall risk score and classification for each reach that are also presented in the tables below. These overall reach scores are discussed in detail in Section 6 of this report.



South Platte River Master Plan

Figure 5-4-: Ecological Risk

Table 5-9: Reach 1 Summary

RIVER CHARACTERISTICS	
Valley Setting	The channel sits in a partially confined valley with a partially connected floodplain.
Channel Characteristics	The channel is broad with large amplitude meander bends. The channel is single thread, but multi-thread channels develop at low flows. The channel corridor is primarily bordered by riparian zone and a partially connected floodplain.

RIVER STATISTICS			
Average Stream Power 10-year (lbs/ft^2 s)	0.68	Structures in the Active Channel	0
Average Stream Power 100-year (lbs/ft^2 s)	1.47	Structures in the Erosional Hazard Area	3
Number of Diversions Passing Sediment	0	Structures in the Historical River Channel	9
Number of Diversions Not Passing Sediment	0	Potential Erosion Points	7
Critical Infrastructure in the Active Channel	0	NPDES in the Active Channel	0
Critical Infrastructure in the Erosional Hazard Area	0	NPDES in the Erosional Hazard Area	0
Critical Infrastructure in the Historical River Channel	0	NPDES in the Historical River Channel	0

RISK ASSESSMENT RESULTS		
Flood Risk	**Risk: 3** **Risk Potential Score: 1** **Risk Severity Score: 2**	There are minimal infrastructure and assets within this reach; however, the CO SH 144 may overtop at the 10-year event.
Fluvial Geomorphic Risk	**Risk: 3** **Risk Potential Score: 2** **Risk Severity Score: 1**	Risk of lateral migration and erosion on outside of meander bends, primarily into agricultural land and riparian zone. There is medium/high stream power and migration/erosion potential, with limited assets located within the Erosional Hazard Area.
Ecological Risk	**Potential for Restoration: 4** **Risk Score: 2** **Restoration Priority Score: 2**	***SVAP2 Average Score: 5.8.*** Invasive species are present in the riparian zone. The water is slightly turbid with some algal growth and limited fish habitat complexity. Canopy cover over the stream channel is limited, and there are excessive vegetation gaps in the riparian zone.
Overall Risk Score	**10 - Low**	
Restoration Recommendations	No specific projects were identified within this reach.	

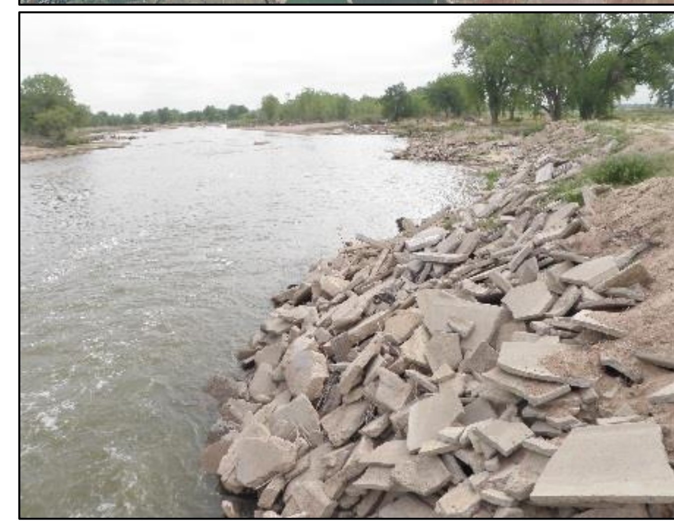
Table 5-10: Reach 2 Summary

RIVER CHARACTERISTICS	
Valley Setting	The channel is in a partially confined valley, with a partially connected floodplain and riparian zone.
Channel Characteristics	The channel has a long, broad right-hand bend and small-scale meanders. The river is single thread, with the exception of several areas where the valley widens and multi-threads and islands develop. The channel is primarily bordered by riparian habitat and floodplain, except where it is abutted by agricultural land. Most assets remain outside of the erosional hazard area, but the channel is encroaching on assets that lie just outside the erosional hazard area. The channel narrows and straightens as is approaches the geologically controlled "pinch point" at the start of the narrows, which is at the downstream terminus of the reach.

RIVER STATISTICS			
Average Stream Power 10-year (lbs/ft^2 s)	0.47	Structures in the Active Channel	0
Average Stream Power 100-year (lbs/ft^2 s)	1.05	Structures in the Erosional Hazard Area	2
Number of Diversions Passing Sediment	1	Structures in the Historical River Channel	30
Number of Diversions Not Passing Sediment	0	Potential Erosion Points	5
Critical Infrastructure in the Active Channel	0	NPDES in the Active Channel	0
Critical Infrastructure in the Erosional Hazard Area	0	NPDES in the Erosional Hazard Area	0
Critical Infrastructure in the Historical River Channel	0	NPDES in the Historical River Channel	0

RISK ASSESSMENT RESULTS		
Flood Risk	**Risk: 3** **Risk Potential Score: 1** **Risk Severity Score: 2**	Bridge infrastructure within this reach are elevated above the 100-year floodplain, but overtop at the roadway approaches adjacent to the bridges is likely at lower recurrence interval events.
Fluvial Geomorphic Risk	**Risk: 3** **Risk Potential Score: 2** **Risk Severity Score: 1**	Broad bending, low-sinuosity channel with medium stream power. Moderate lateral migration and erosion potential primarily encroaching on agricultural land, with the exception of assets located near potential erosion areas on outer meander bends just upstream of Goodrich and on the south channel banks south of Weldona, where the channel is encroaching on the Historical River Channel.
Ecological Risk	**Potential for Restoration: 4** **Risk Score: 2** **Restoration Priority Score: 2**	***SVAP2 Average Score: 4.5.*** There is little canopy cover and limited fish habitat complexity. There is some algal growth in back channels, as well as structures present in the channel that restrict the movement of aquatic species.

Overall Risk Score	**11 - Medium**
Restoration Recommendations	No specific projects were identified within this reach.



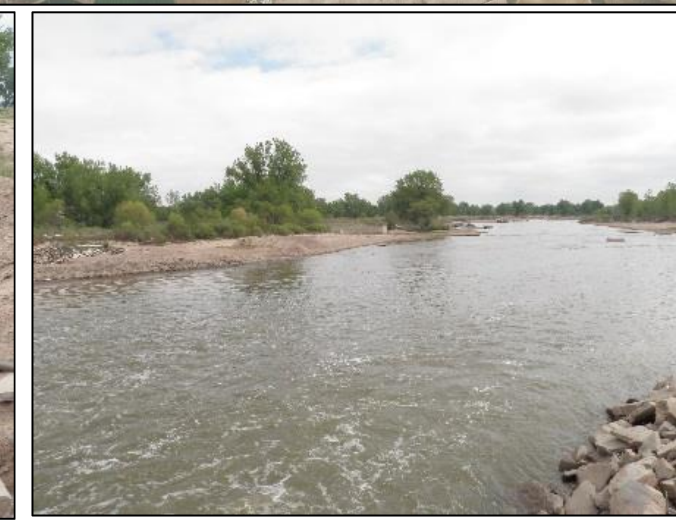


Table 5-11: Reach 3 Summary

RIVER CHARACTERISTICS	
Valley Setting	The channel is in a confined valley. The channel is incised with only internal (low flow) riparian habitat and floodplain.
Channel Characteristics	The river is a straight, single tread channel, with multi-threads at low/medium flows. Steep, geologically controlled channel with high stream power has resulted in a straight, narrow, and incising channel corridor.

RIVER STATISTICS			
Average Stream Power 10-year (lbs/ft^2 s)	0.94	Structures in the Active Channel	0
Average Stream Power 100-year (lbs/ft^2 s)	2.38	Structures in the Erosional Hazard Area	0
Number of Diversions Passing Sediment	0	Structures in the Historical River Channel	0
Number of Diversions Not Passing Sediment	0	Potential Erosion Points	7
Critical Infrastructure in the Active Channel	0	NPDES in the Active Channel	0
Critical Infrastructure in the Erosional Hazard Area	0	NPDES in the Erosional Hazard Area	0
Critical Infrastructure in the Historical River Channel	0	NPDES in the Historical River Channel	0

RISK ASSESSMENT RESULTS		
Flood Risk	**Risk: 2** **Risk Potential Score: 1** **Risk Severity Score: 1**	Minimal assets and infrastructure within and adjacent to the floodplain.
Fluvial Geomorphic Risk	**Risk: 2** **Risk Potential Score: 1** **Risk Severity Score: 1**	Straight, low-sinuosity channel with high stream power in a confined valley. Lateral migration and erosion potential is limited by steep confining valley walls (bedrock to the North, large agricultural terrace to the South). No Assets within the channel corridor and agricultural land on adjacent terrace to the south.
Ecological Risk	**Potential for Restoration: 3** **Risk Score: 2** **Restoration Priority Score: 1**	***SVAP2 Average Score: 5.6.*** There are no artificial barriers that prohibit the movement of aquatic species. Invasive species are present in the riparian zone and there are very few fish habitat types present. The stream channel is slightly turbid and lacks canopy cover.
Overall Risk Score	**7 - Low**	
Restoration Recommendations	No specific projects were identified within this reach.	

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Table 5-12: Reach 4 Summary

RIVER CHARACTERISTICS	
Valley Setting	The river runs through a valley that is confined by urban channelization with minimal floodplain and riparian corridor.
Channel Characteristics	The channel has low sinuosity and high stream power, with a broad left-hand bend. The channel is single thread, with multi-threads at low/medium flows, and forced narrowing by urbanization.

RIVER STATISTICS			
Average Stream Power 10-year (lbs/ft^2 s)	1.27	Structures in the Active Channel	0
Average Stream Power 100-year (lbs/ft^2 s)	2.07	Structures in the Erosional Hazard Area	7
Number of Diversions Passing Sediment	0	Structures in the Historical River Channel	7
Number of Diversions Not Passing Sediment	2	Potential Erosion Points	6
Critical Infrastructure in the Active Channel	0	NPDES in the Active Channel	0
Critical Infrastructure in the Erosional Hazard Area	0	NPDES in the Erosional Hazard Area	2
Critical Infrastructure in the Historical River Channel	0	NPDES in the Historical River Channel	2

RISK ASSESSMENT RESULTS		
Flood Risk	**Risk: 3** **Risk Potential Score: 1** **Risk Severity Score: 3**	Reach saw significant flood impacts during the 2013 flood event, with some key infrastructure located within the floodplain.
Fluvial Geomorphic Risk	**Risk: 6** **Risk Potential Score: 3** **Risk Severity Score: 3**	Straight, low sinuosity, and channelized by urban development with high stream power. High lateral migration and erosion potential with channel encroaching on the historical river corridor, agricultural land to the North, and significant assets in Fort Morgan to the South.
Ecological Risk	**Potential for Restoration: 4** **Risk Score: 2** **Restoration Priority Score: 2**	***SVAP2 Average Score: 4.2.*** Physical structures are present that restrict the movement of aquatic species, and there are large gaps in riparian vegetation. Algal growth is present, and there are very few aquatic habitat types.
Overall Risk Score	**14 - High**	
Restoration Recommendations	Mitigate factors that contribute to flooding by establishing an overflow channel and redirecting flow (see Section 7.2.1).	

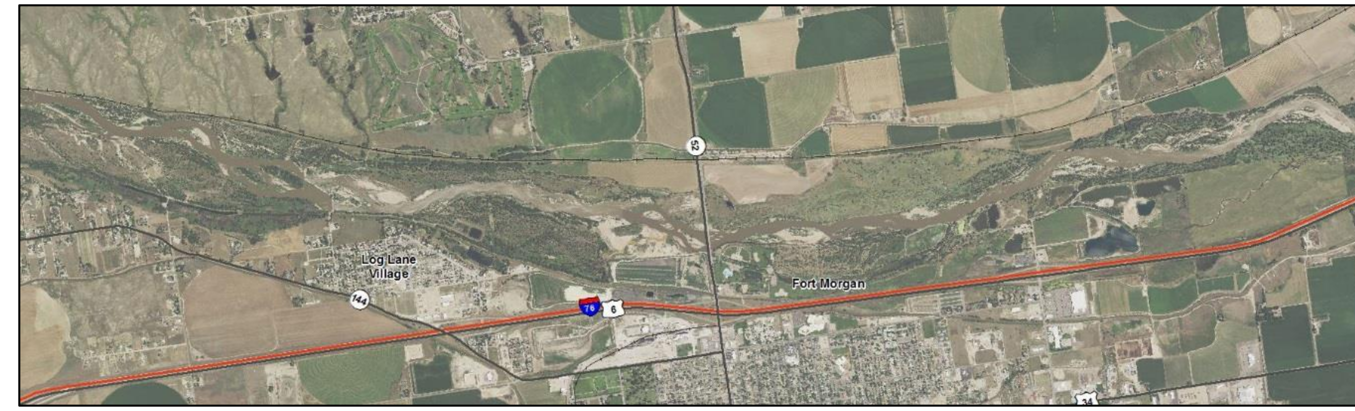

Table 5-13: Reach 5 Summary

RIVER CHARACTERISTICS	
Valley Setting	The channel runs through a partially confined valley with a partially connected floodplain and riparian corridor.
Channel Characteristics	The channel is predominantly straight, single thread, with multi-threads and sandbars at low/medium flows, and one region with four high-frequency, low-amplitude meander bends (within the SWA). There is variable floodplain and riparian corridor connectivity, where connectivity is increased within the SWA and decreased adjacent to farm land.

RIVER STATISTICS			
Average Stream Power 10-year (lbs/ft^2 s)	0.57	Structures in the Active Channel	0
Average Stream Power 100-year (lbs/ft^2 s)	1.14	Structures in the Erosional Hazard Area	5
Number of Diversions Passing Sediment	1	Structures in the Historical River Channel	5
Number of Diversions Not Passing Sediment	1	Potential Erosion Points	3
Critical Infrastructure in the Active Channel	0	NPDES in the Active Channel	0
Critical Infrastructure in the Erosional Hazard Area	0	NPDES in the Erosional Hazard Area	0
Critical Infrastructure in the Historical River Channel	0	NPDES in the Historical River Channel	0

RISK ASSESSMENT RESULTS		
Flood Risk	**Risk: 2** **Risk Potential Score: 1** **Risk Severity Score: 1**	Minimal infrastructure and assets within and adjacent to the active floodplain.
Fluvial Geomorphic Risk	**Risk: 4** **Risk Potential Score: 2** **Risk Severity Score: 2**	Medium to low sinuosity with medium stream power. Moderate lateral migration and erosion potential with channel encroaching on agricultural land, ~ 5 assets within the erosional hazard area, or on riparian corridor (within the SWA). Additional assets located adjacent to the historical river corridor.
Ecological Risk	**Potential for Restoration: 5** **Risk Score: 2** **Restoration Priority Score: 3**	***SVAP2 Average Score: 5.0.*** Physical structures are present that restrict the movement of aquatic species. Invasive species are present in the riparian zone, but there are relatively few vegetation gaps. Canopy cover over the stream channel is moderate.
Overall Risk Score	**11 - Medium**	
Restoration Recommendations	No specific projects were identified within this reach.	

Table 5-14: Reach 6 Summary

RIVER CHARACTERISTICS	
Valley Setting	The channel sits in a partially confined valley with a connected floodplain and riparian corridor.
Channel Characteristics	The river is a straight, very low-sinuosity, single-thread channel, with multi-threads and sandbars at low/medium flows. The channel has both floodplain and riparian corridor connectivity.

RIVER STATISTICS			
Average Stream Power 10-year (lbs/ft^2 s)	0.47	Structures in the Active Channel	0
Average Stream Power 100-year (lbs/ft^2 s)	0.85	Structures in the Erosional Hazard Area	4
Number of Diversions Passing Sediment	0	Structures in the Historical River Channel	11
Number of Diversions Not Passing Sediment	1	Potential Erosion Points	0
Critical Infrastructure in the Active Channel	0	NPDES in the Active Channel	0
Critical Infrastructure in the Erosional Hazard Area	0	NPDES in the Erosional Hazard Area	0
Critical Infrastructure in the Historical River Channel	0	NPDES in the Historical River Channel	0

RISK ASSESSMENT RESULTS		
Flood Risk	**Risk: 2** **Risk Potential Score: 1** **Risk Severity Score: 1**	Minimal assets and infrastructure within and adjacent to the floodplain; however, the south bridge approach to the SH 71E bridge appears to overtop at the 50-year event.
Fluvial Geomorphic Risk	**Risk: 2** **Risk Potential Score: 1** **Risk Severity Score: 1**	Straight, low-sinuosity channel with low/medium stream power. Minimal lateral migration and erosion potential with no significant channel meander bends. Channel is bordered by floodplain and riparian corridor with minimal assets except at the outer edges of the erosional hazard area.
Ecological Risk	**Potential for Restoration: 5** **Risk Score: 2** **Restoration Priority Score: 3**	***SVAP2 Average Score: 6.2.*** There are no artificial barriers that restrict aquatic species movement. Canopy cover over the stream channel is moderate, and there is little algal growth.
Overall Risk Score	**9 - Low**	
Restoration Recommendations	No specific projects were identified within this reach.	

Table 5-15: Reach 7 Summary

RIVER CHARACTERISTICS	
Valley Setting	The channel sits in a partially confined valley with a partially connected floodplain and riparian corridor.
Channel Characteristics	The channel has broad, low-frequency meanders with small-scale, internal, high-frequency, low-amplitude meander bends. The river is a variable single- and multi thread channel, with braiding and sandbars at low/medium flows. The channel has a connected floodplain and riparian corridor, except where meanders are migrating out of the historical river channel and onto agricultural land.

RIVER STATISTICS			
Average Stream Power 10-year (lbs/ft^2 s)	0.65	Structures in the Active Channel	0
Average Stream Power 100-year (lbs/ft^2 s)	1.10	Structures in the Erosional Hazard Area	7
Number of Diversions Passing Sediment	1	Structures in the Historical River Channel	18
Number of Diversions Not Passing Sediment	0	Potential Erosion Points	1
Critical Infrastructure in the Active Channel	0	NPDES in the Active Channel	0
Critical Infrastructure in the Erosional Hazard Area	0	NPDES in the Erosional Hazard Area	2
Critical Infrastructure in the Historical River Channel	0	NPDES in the Historical River Channel	2

RISK ASSESSMENT RESULTS		
Flood Risk	**Risk: 5** **Risk Potential Score: 2** **Risk Severity Score: 3**	The 2013 flood caused damage to roadway infrastructure in this reach, which had significant impacts downstream. The breach of the railroad trapped substantial amounts of water in the Town of Messex, which had to return flow path to the river.
Fluvial Geomorphic Risk	**Risk: 4** **Risk Potential Score: 2** **Risk Severity Score: 2**	Sinuous, meandering channel with medium/high stream power. Moderate lateral migration and erosion potential with areas where significant assets are located within the erosional hazard area on the outside of meander bends, as well as regions where the channel is encroaching/eroding into the historical river channel and agricultural land. Conversely, other large portions of the channel are buffered by floodplain and riparian habitat.
Ecological Risk	**Potential for Restoration: 5** **Risk Score: 2** **Restoration Priority Score: 3**	***SVAP2 Average Score: 4.7.*** Invasive species are present in the riparian zone, but there are relatively few gaps in vegetation. Canopy cover over the stream channel is moderate. There are physical barriers within the channel that restrict the movement of aquatic species, and there few aquatic habitat types.
Overall Risk Score	**14 - High**	
Restoration Recommendations	Recommended projects within this reach include raising the Morgan County Road 33 bridge approaches, sediment removal, implementing a two-stage channel design, and implementing additional culvert crossings along the railroad bridge (see Section 7.2.2).	

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Table 5-16: Reach 8 Summary

RIVER CHARACTERISTICS	
Valley Setting	The channel sits in a partially confined valley with a partially connected floodplain and riparian corridor.
Channel Characteristics	The channel has broad, low-frequency meanders with internal, high-frequency, low-amplitude bends. It is a variable single- and multi-thread channel, with braiding and sandbars at low/medium flows. The floodplain and riparian corridor are connected, except where meanders are migrating out of the historical river channel and onto agricultural land.

RIVER STATISTICS			
Average Stream Power 10-year (lbs/ft^2 s)	0.43	Structures in the Active Channel	0
Average Stream Power 100-year (lbs/ft^2 s)	0.92	Structures in the Erosional Hazard Area	5
Number of Diversions Passing Sediment	1	Structures in the Historical River Channel	12
Number of Diversions Not Passing Sediment	3	Potential Erosion Points	3
Critical Infrastructure in the Active Channel	0	NPDES in the Active Channel	0
Critical Infrastructure in the Erosional Hazard Area	0	NPDES in the Erosional Hazard Area	0
Critical Infrastructure in the Historical River Channel	0	NPDES in the Historical River Channel	0

RISK ASSESSMENT RESULTS		
Flood Risk	**Risk: 4** **Risk Potential Score: 1** **Risk Severity Score: 3**	This reach includes the Town of Messex, which is outside of the 100-year floodplain, but suffered severe flooding in 2013 due to overtopping of the railroad and of Tetsel Ditch.
Fluvial Geomorphic Risk	**Risk: 3** **Risk Potential Score: 2** **Risk Severity Score: 1**	Sinuous, meandering channel with low stream power. Lateral migration and erosion potential on outside of meander bends where the channel is encroaching/eroding into the historical river corridor and agricultural land. Inside bends and transition/straight sections of the channel are buffered by floodplains, point bars, and riparian habitat. Assets dominantly located on the inside of meander bends outside, or on the edge, of the erosional hazard area.
Ecological Risk	**Potential for Restoration: 5** **Risk Score: 2** **Restoration Priority Score: 3**	***SVAP2 Average Score: 5.4.*** Physical structures within the channel restrict the movement of aquatic species. Canopy cover over the stream channel is moderate, but invasive species are present in the riparian zone, and there are excessive gaps in vegetation.

Overall Risk Score	**12 - Medium**
Restoration Recommendations	Mitigate standing water in Messex by installing a flow direction berm, installing a flood-control gate for the Tetsel Ditch, and constructing drainage improvements (see Section 7.2.3).

Table 5-17: Reach 9 Summary

RIVER CHARACTERISTICS			
Valley Setting	The channel sits in a partially confined valley with a partially connected floodplain and riparian corridor.		
Channel Characteristics	The channel is a relatively straight, low-sinuosity reach with low-amplitude meander bends. It is a variable single- and multi-thread channel, with braiding and sandbars at low/medium flows. The floodplain and riparian corridor are partially connected, except where meanders are migrating out of the historical river corridor and onto agricultural land.		
RIVER STATISTICS			
Average Stream Power 10-year (lbs/ft^2 s)	0.41	Structures in the Active Channel	0
Average Stream Power 100-year (lbs/ft^2 s)	0.95	Structures in the Erosional Hazard Area	1
Number of Diversions Passing Sediment	0	Structures in the Historical River Channel	2
Number of Diversions Not Passing Sediment	1	Potential Erosion Points	1
Critical Infrastructure in the Active Channel	0	NPDES in the Active Channel	0
Critical Infrastructure in the Erosional Hazard Area	0	NPDES in the Erosional Hazard Area	0
Critical Infrastructure in the Historical River Channel	0	NPDES in the Historical River Channel	0
RISK ASSESSMENT RESULTS			
Flood Risk	**Risk: 4** **Risk Potential Score: 1** **Risk Severity Score: 3**	Two bridge approaches within this reach overtop at the 10-year event.	
Fluvial Geomorphic Risk	**Risk: 2** **Risk Potential Score: 1** **Risk Severity Score: 1**	Low-sinuosity channel with low stream power. Minimal lateral migration and erosion potential on outside of low-amplitude meander bends and where the channel is encroaching/eroding into the historical river corridor and agricultural land. Assets dominantly located outside, or on the edge, of the erosional hazard area.	
Ecological Risk	**Potential for Restoration: 4** **Risk Score: 2** **Restoration Priority Score: 2**	***SVAP2 Average Score: 4.6.*** Physical structures within the channel restrict aquatic movement. There is very little canopy cover over the stream channel and there are excessive gaps in riparian vegetation.	
Overall Risk Score	**10 - Low**		
Restoration Recommendations	No specific projects were identified within this reach.		

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Table 5-18: Reach 10 Summary

RIVER CHARACTERISTICS	
Valley Setting	The channel sits in a partially confined valley with a partially connected floodplain and riparian corridor, bound by agricultural land.
Channel Characteristics	The river is a straight, low-sinuosity reach with a broad active channel zone with multi-thread channels and islands. There is braiding and sandbar formation at low/medium flows. The floodplain and riparian corridor are partially confined by agricultural land encroached by the channel.

RIVER STATISTICS			
Average Stream Power 10-year (lbs/ft^2 s)	0.52	Structures in the Active Channel	0
Average Stream Power 100-year (lbs/ft^2 s)	1.01	Structures in the Erosional Hazard Area	9
Number of Diversions Passing Sediment	1	Structures in the Historical River Channel	14
Number of Diversions Not Passing Sediment	1	Potential Erosion Points	1
Critical Infrastructure in the Active Channel	0	NPDES in the Active Channel	0
Critical Infrastructure in the Erosional Hazard Area	0	NPDES in the Erosional Hazard Area	0
Critical Infrastructure in the Historical River Channel	0	NPDES in the Historical River Channel	0

RISK ASSESSMENT RESULTS		
Flood Risk	**Risk: 2** **Risk Potential Score: 1** **Risk Severity Score: 1**	Minimal assets and infrastructure within the 100-year floodplain.
Fluvial Geomorphic Risk	**Risk: 5** **Risk Potential Score: 2** **Risk Severity Score: 3**	Low-sinuosity, multi-thread channel with medium stream power. Lateral migration and erosion potential on outside of low-amplitude meander bends and where the channel is encroaching/eroding agricultural land. Increasing density of assets within the erosional hazard area moving downstream towards Sterling.
Ecological Risk	**Potential for Restoration: 4** **Risk Score: 2** **Restoration Priority Score: 2**	***SVAP2 Average Score: 4.9.*** Canopy cover over the stream channel is moderate, but there are excessive gaps in riparian vegetation. Physical structures are present in the channel that restrict aquatic movement, and there are few aquatic habitat types.
Overall Risk Score	**11 - Medium**	
Restoration Recommendations	No specific projects were identified within this reach.	

Table 5-19: Reach 11 Summary

RIVER CHARACTERISTICS	
Valley Setting	The channel sits in a valley confined by urban channelization and agriculture, with minimal floodplain and riparian corridor.
Channel Characteristics	The channel is narrow and linear and has been channelized by urban and agricultural development. It is primarily an urban-controlled, single-thread channel with some multi-threads at low/medium flows. The minimal floodplain and riparian corridor is confined by urban and agricultural land.

RIVER STATISTICS			
Average Stream Power 10-year (lbs/ft^2 s)	0.51	Structures in the Active Channel	0
Average Stream Power 100-year (lbs/ft^2 s)	1.10	Structures in the Erosional Hazard Area	40
Number of Diversions Passing Sediment	0	Structures in the Historical River Channel	234
Number of Diversions Not Passing Sediment	2	Potential Erosion Points	1
Critical Infrastructure in the Active Channel	0	NPDES in the Active Channel	0
Critical Infrastructure in the Erosional Hazard Area	0	NPDES in the Erosional Hazard Area	12
Critical Infrastructure in the Historical River Channel	1	NPDES in the Historical River Channel	12

RISK ASSESSMENT RESULTS		
Flood Risk	**Risk: 6** **Risk Potential Score: 3** **Risk Severity Score: 3**	This reach includes a complicated presence of water diversion infrastructure, SWAs, road and bridge infrastructure, residential properties, and high-risk municipal and commercial infrastructure, all within the floodplain, and in a condensed reach of the river.
Fluvial Geomorphic Risk	**Risk: 6** **Risk Potential Score: 3** **Risk Severity Score: 3**	Narrow, low-sinuosity channel with medium/high stream power and significant development driven channelization. High lateral migration and erosion potential with the channel encroaching/eroding on urban and/or agricultural land along the entire reach. Significant assets within the erosional hazard area, with the highest density centered on Sterling.
Ecological Risk	**Potential for Restoration: 5** **Risk Score: 2** **Restoration Priority Score: 3**	***SVAP2 Average Score: 4.7.*** There are physical structures in the channel that restrict aquatic movement. There are large gaps in riparian vegetation and invasive species are present in the riparian zone. The water is slightly turbid and livestock seem to have unlimited access to the stream during parts of the year.
Overall Risk Score	**17 - High**	
Restoration Recommendations	Flood-proof critical infrastructure, manage the river corridor through non-structural means, including sediment removal and land management, and establish a stream restoration plan (see Section 7.2.4).	

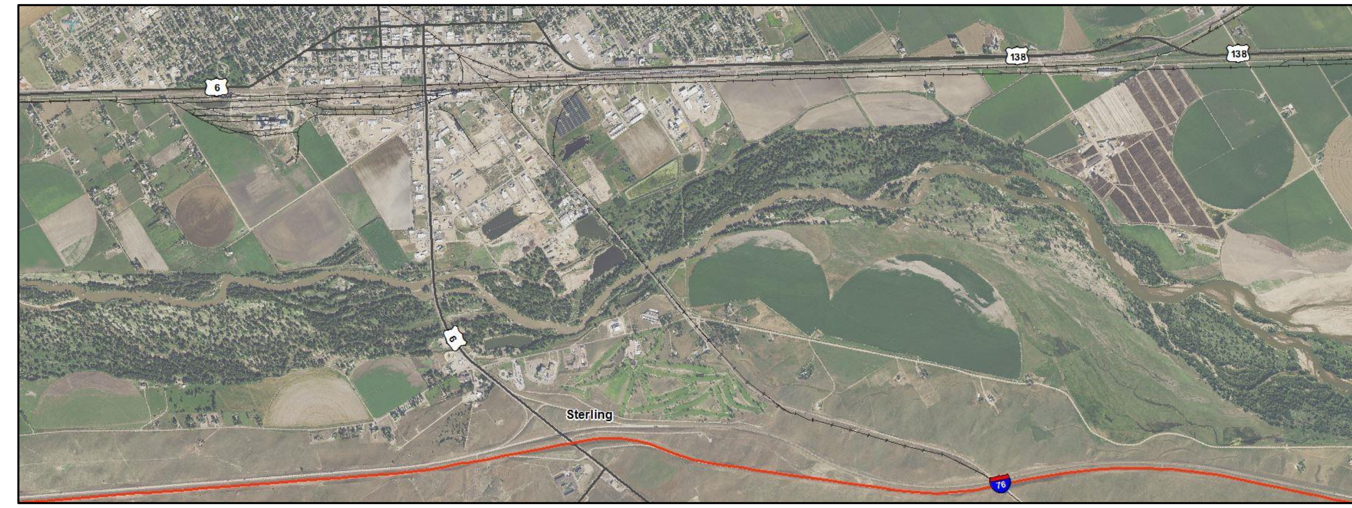

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Table 5-20: Reach 12 Summary

RIVER CHARACTERISTICS	
Valley Setting	The channel sits in a partially confined valley with a narrow, partially connected floodplain and riparian corridor.
Channel Characteristics	The river is a linear, multi-thread channel with a narrow floodplain and riparian corridor, confined by agricultural land.

RIVER STATISTICS			
Average Stream Power 10-year (lbs/ft^2 s)	0.43	Structures in the Active Channel	0
Average Stream Power 100-year (lbs/ft^2 s)	0.83	Structures in the Erosional Hazard Area	3
Number of Diversions Passing Sediment	0	Structures in the Historical River Channel	6
Number of Diversions Not Passing Sediment	2	Potential Erosion Points	1
Critical Infrastructure in the Active Channel	0	NPDES in the Active Channel	0
Critical Infrastructure in the Erosional Hazard Area	0	NPDES in the Erosional Hazard Area	0
Critical Infrastructure in the Historical River Channel	0	NPDES in the Historical River Channel	0

RISK ASSESSMENT RESULTS		
Flood Risk	**Risk: 2** **Risk Potential Score: 1** **Risk Severity Score: 1**	Several small county roads are within the 100-year floodplain.
Fluvial Geomorphic Risk	**Risk: 2** **Risk Potential Score: 1** **Risk Severity Score: 1**	Near-linear, low-sinuosity channel with low stream power. Moderate lateral migration and erosion potential with channel encroaching/eroding on bounding agricultural land. Minimal assets within the erosional hazard area.
Ecological Risk	**Potential for Restoration: 5** **Risk Score: 2** **Restoration Priority Score: 3**	***SVAP2 Average Score: 5.5.*** Canopy cover over the stream channel is moderate, and there is little algal growth. Physical structures are present that restrict aquatic movement and there are few aquatic habitat types present.
Overall Risk Score	**9 - Low**	
Restoration Recommendations	No specific projects were identified within this reach.	

Table 5-21: Reach 13 Summary

RIVER CHARACTERISTICS	
Valley Setting	The channel sits in a partially confined valley with a partially connected floodplain and riparian corridor.
Channel Characteristics	The river is a near-linear, multi-thread channel along a broad left-hand bend, with braiding and sandbar development at low/medium flows. The floodplain and riparian corridor is confined by agricultural land.

RIVER STATISTICS			
Average Stream Power 10-year (lbs/ft^2 s)	0.37	Structures in the Active Channel	1
Average Stream Power 100-year (lbs/ft^2 s)	0.85	Structures in the Erosional Hazard Area	3
Number of Diversions Passing Sediment	0	Structures in the Historical River Channel	267
Number of Diversions Not Passing Sediment	2	Potential Erosion Points	2
Critical Infrastructure in the Active Channel	0	NPDES in the Active Channel	0
Critical Infrastructure in the Erosional Hazard Area	0	NPDES in the Erosional Hazard Area	0
Critical Infrastructure in the Historical River Channel	0	NPDES in the Historical River Channel	1

RISK ASSESSMENT RESULTS		
Flood Risk	**Risk: 5** **Risk Potential Score: 3** **Risk Severity Score: 2**	The majority of the Town of Iliff is located within the 100-year floodplain, and the north approach to the Logan County Road 55 bridge appears to overtop at the 10-year flood event.
Fluvial Geomorphic Risk	**Risk: 2** **Risk Potential Score: 1** **Risk Severity Score: 1**	Near-linear, low-sinuosity channel with low stream power. Moderate lateral migration and erosion potential with channel encroaching/eroding into bounding agricultural land. Minimal assets within the erosional hazard area, and the town of Iliff is on the inside of the bend and outside of the erosional hazard area.
Ecological Risk	**Potential for Restoration: 4** **Risk Score: 2** **Restoration Priority Score: 2**	***SVAP2 Average Score: 5.0*** The water is slightly turbid and there are physical structures present that restrict aquatic movement. There is very little canopy cover and there are excessive gaps in riparian vegetation.
Overall Risk Score	**11 - Medium**	
Restoration Recommendations	No specific projects were identified within this reach.	

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Table 5-22: Reach 14 Summary

RIVER CHARACTERISTICS			
Valley Setting	The channel sits in a partially confined valley with a partially connected floodplain and riparian corridor.		
Channel Characteristics	The channel is linear and multi-thread, with braiding and sandbar development at low/medium flows. The floodplain and riparian corridor are confined by agricultural land.		
RIVER STATISTICS			
Average Stream Power 10-year (lbs/ft^2 s)	0.86	Structures in the Active Channel	0
Average Stream Power 100-year (lbs/ft^2 s)	0.85	Structures in the Erosional Hazard Area	2
Number of Diversions Passing Sediment	1	Structures in the Historical River Channel	37
Number of Diversions Not Passing Sediment	3	Potential Erosion Points	1
Critical Infrastructure in the Active Channel	0	NPDES in the Active Channel	0
Critical Infrastructure in the Erosional Hazard Area	0	NPDES in the Erosional Hazard Area	0
Critical Infrastructure in the Historical River Channel	0	NPDES in the Historical River Channel	0
RISK ASSESSMENT RESULTS			
Flood Risk	**Risk: 2** **Risk Potential Score: 1** **Risk Severity Score: 1**	Roadway infrastructure and agricultural land are the main assets at risk of flooding.	
Fluvial Geomorphic Risk	**Risk: 3** **Risk Potential Score: 2** **Risk Severity Score: 1**	Linear, low-sinuosity channel with medium stream power. Moderate lateral migration and erosion potential with channel encroaching/eroding into bounding agricultural land. Minimal assets within the erosional hazard area.	
Ecological Risk	**Potential for Restoration: 5** **Risk Score: 2** **Restoration Priority Score: 3**	***SVAP2 Average Score: 4.5.*** Physical structures are present that restrict the movement of aquatic species. Canopy cover is moderate, and invasive species are present in the riparian zone.	
Overall Risk Score	**10 - Low**		
Restoration Recommendations	No specific projects were identified within this reach.		

Table 5-23: Reach 15 Summary

RIVER CHARACTERISTICS			
Valley Setting	The channel sits in a partially confined valley with a partially connected floodplain and riparian corridor.		
Channel Characteristics	The channel is broad with large amplitude meander bends. The channel is single thread, but multi-thread channels develop at low flows. The channel corridor is primarily bordered by riparian zone and a partially connected floodplain.		
RIVER STATISTICS			
Average Stream Power 10-year (lbs/ft^2 s)	0.33	Structures in the Active Channel	0
Average Stream Power 100-year (lbs/ft^2 s)	0.70	Structures in the Erosional Hazard Area	0
Number of Diversions Passing Sediment	0	Structures in the Historical River Channel	132
Number of Diversions Not Passing Sediment	3	Potential Erosion Points	0
Critical Infrastructure in the Active Channel	0	NPDES in the Active Channel	0
Critical Infrastructure in the Erosional Hazard Area	0	NPDES in the Erosional Hazard Area	0
Critical Infrastructure in the Historical River Channel	0	NPDES in the Historical River Channel	1
RISK ASSESSMENT RESULTS			
Flood Risk	**Risk: 5** **Risk Potential Score: 3** **Risk Severity Score: 2**	The Town of Crook sits within the 100-year floodplain, and likely experiences flooding at the 25-year event.	
Fluvial Geomorphic Risk	**Risk: 2** **Risk Potential Score: 1** **Risk Severity Score: 1**	Low-sinuosity, meandering channel with low stream power. Moderate lateral migration and erosion potential with channel encroaching/eroding into bounding agricultural land. Minimal assets within the erosional hazard area.	
Ecological Risk	**Potential for Restoration: 5** **Risk Score: 2** **Restoration Priority Score: 3**	***SVAP2 Average Score: 5.3.*** Canopy cover over the stream channel is moderate and there are few vegetation gaps in the riparian zone. Physical structures are present that restrict the movement of aquatic species.	
Overall Risk Score	**12 - Medium**		
Restoration Recommendations	Install a FEMA-certified levee, perform land management and sediment removal, and construct a high-water bypass for the Colorado State Highway 55 bridge (see Section 7.2.5).		

Table 5-24: Reach 16 Summary

RIVER CHARACTERISTICS	
Valley Setting	The channel sits in a partially confined valley with a partially connected floodplain and riparian corridor.
Channel Characteristics	The river is a low-sinuosity, multi-thread channel, with braiding and sandbar development at low/medium flows. The floodplain and riparian corridor is confined by agricultural land.

RIVER STATISTICS			
Average Stream Power 10-year (lbs/ft^2 s)	0.53	Structures in the Active Channel	1
Average Stream Power 100-year (lbs/ft^2 s)	0.67	Structures in the Erosional Hazard Area	3
Number of Diversions Passing Sediment	1	Structures in the Historical River Channel	12
Number of Diversions Not Passing Sediment	0	Potential Erosion Points	2
Critical Infrastructure in the Active Channel	0	NPDES in the Active Channel	0
Critical Infrastructure in the Erosional Hazard Area	0	NPDES in the Erosional Hazard Area	0
Critical Infrastructure in the Historical River Channel	0	NPDES in the Historical River Channel	1

RISK ASSESSMENT RESULTS		
Flood Risk	**Risk: 2** **Risk Potential Score: 1** **Risk Severity Score: 1**	At-risk assets generally consist of agricultural land.
Fluvial Geomorphic Risk	**Risk: 2** **Risk Potential Score: 1** **Risk Severity Score: 1**	Low-sinuosity, meandering channel with medium/low stream power. Moderate lateral migration and erosion potential with channel encroaching/eroding into bounding agricultural land. Minimal assets within the erosional hazard area.
Ecological Risk	**Potential for Restoration: 4** **Risk Score: 2** **Restoration Priority Score: 2**	***SVAP2 Average Score: 5.8.*** There is very little algal growth present and canopy cover over the stream channel is moderate. There are no artificial barriers to restrict the movement of aquatic species.
Overall Risk Score	**8 - Low**	
Restoration Recommendations	No specific projects were identified within this reach.	

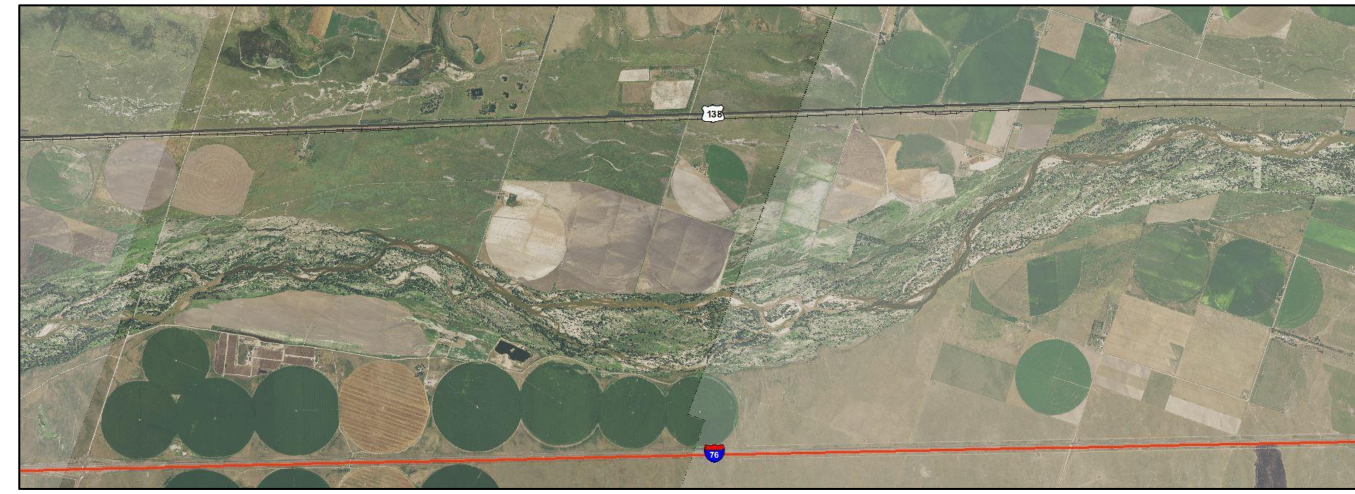

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Table 5-25: Reach 17 Summary

RIVER CHARACTERISTICS	
Valley Setting	The channel sits in a partially confined valley with a partially connected floodplain and riparian corridor.
Channel Characteristics	The river is a low-sinuosity, multi-thread channel, with braiding and sandbar development at low/medium flows. The floodplain and riparian corridor is confined by agricultural land.

RIVER STATISTICS			
Average Stream Power 10-year (lbs/ft^2 s)	0.42	Structures in the Active Channel	0
Average Stream Power 100-year (lbs/ft^2 s)	0.77	Structures in the Erosional Hazard Area	1
Number of Diversions Passing Sediment	0	Structures in the Historical River Channel	21
Number of Diversions Not Passing Sediment	0	Potential Erosion Points	0
Critical Infrastructure in the Active Channel	0	NPDES in the Active Channel	0
Critical Infrastructure in the Erosional Hazard Area	0	NPDES in the Erosional Hazard Area	0
Critical Infrastructure in the Historical River Channel	0	NPDES in the Historical River Channel	0

RISK ASSESSMENT RESULTS		
Flood Risk	**Risk: 2** **Risk Potential Score: 1** **Risk Severity Score: 1**	Minimal infrastructure and assets within the 100-year floodplain.
Fluvial Geomorphic Risk	**Risk: 2** **Risk Potential Score: 1** **Risk Severity Score: 1**	Low-sinuosity meander channel with low stream power. Moderate lateral migration and erosion potential with channel encroaching/eroding into bounding agricultural land. Minimal assets within the erosional hazard area.
Ecological Risk	**Potential for Restoration: 5** **Risk Score: 2** **Restoration Priority Score: 3**	***SVAP2 Average Score: 5.2.*** Physical structures are present that restrict the movement of aquatic species. Canopy cover over the stream channel is moderate, but invasive species are present in the riparian zone.
Overall Risk Score	**9 - Low**	
Restoration Recommendations	No specific projects were identified within this reach.	

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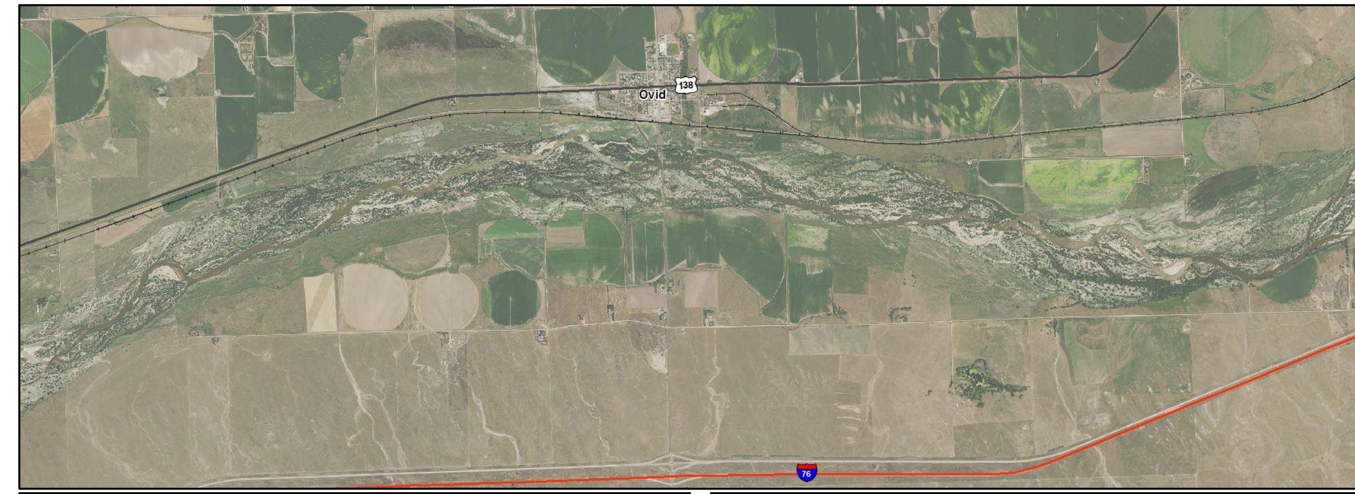
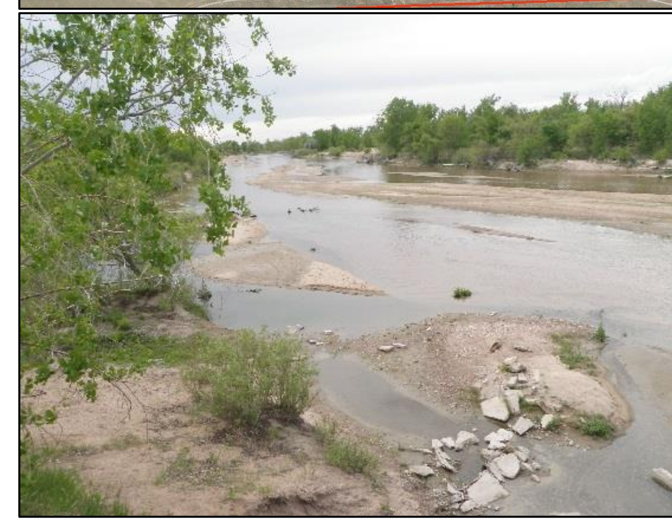
Table 5-26: Reach 18 Summary

RIVER CHARACTERISTICS	
Valley Setting	The channel sits in a partially confined valley with a partially connected floodplain and riparian zone.
Channel Characteristics	The channel is multi-thread with broad-scale, low-frequency meanders and small-scale, high-frequency, low-amplitude meanders, and braiding and sandbar development at low/medium flows. The floodplain and riparian corridor are predominantly confined by agricultural land with urban development near the Town of Ovid.

RIVER STATISTICS			
Average Stream Power 10-year (lbs/ft^2 s)	0.42	Structures in the Active Channel	0
Average Stream Power 100-year (lbs/ft^2 s)	1.03	Structures in the Erosional Hazard Area	13
Number of Diversions Passing Sediment	1	Structures in the Historical River Channel	20
Number of Diversions Not Passing Sediment	2	Potential Erosion Points	2
Critical Infrastructure in the Active Channel	0	NPDES in the Active Channel	0
Critical Infrastructure in the Erosional Hazard Area	1	NPDES in the Erosional Hazard Area	1
Critical Infrastructure in the Historical River Channel	1	NPDES in the Historical River Channel	1

RISK ASSESSMENT RESULTS		
Flood Risk	**Risk: 3** **Risk Potential Score: 1** **Risk Severity Score: 2**	The Town of Ovid sits within this reached and experienced moderate flooding during the 2013 storm event.
Fluvial Geomorphic Risk	**Risk: 5** **Risk Potential Score: 2** **Risk Severity Score: 3**	Multi-thread meander channel with medium stream power. Moderate lateral migration and erosion potential on the outside of meander bends. The channel is encroaching/eroding on the bounding agricultural land over most of the reach, as well as at the outside of the large meander bend near the Town of Ovid. There are significant assets within the erosional hazard area where the channel is encroaching on Ovid.
Ecological Risk	**Potential for Restoration: 4** **Risk Score: 2** **Restoration Priority Score: 2**	***SVAP2 Average Score: 5.0.*** Physical structures are present that restrict the movement of aquatic species. Canopy cover over the stream channel is moderate, and there is slight algal growth.
Overall Risk Score	**12 - Medium**	
Restoration Recommendations	Flood-proof the wastewater treatment plant, realign the river channel, and upgrade the Liddle diversion structure (see Section 7.2.6).	





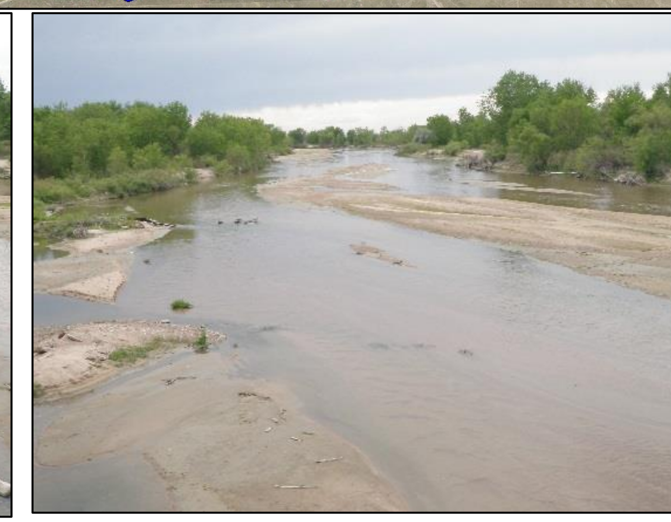


Table 5-27: Reach 19 Summary

RIVER CHARACTERISTICS	
Valley Setting	The channel sits in a partially confined valley with a partially connected floodplain and riparian corridor.
Channel Characteristics	The river is a linear, multi-thread channel with small-scale, high-frequency, low-amplitude meanders, with braiding and sandbar development at low/medium flows. The floodplain and riparian corridor are confined by agricultural land.

RIVER STATISTICS			
Average Stream Power 10-year (lbs/ft^2 s)	0.47	Structures in the Active Channel	1
Average Stream Power 100-year (lbs/ft^2 s)	1.20	Structures in the Erosional Hazard Area	1
Number of Diversions Passing Sediment	0	Structures in the Historical River Channel	9
Number of Diversions Not Passing Sediment	0	Potential Erosion Points	1
Critical Infrastructure in the Active Channel	0	NPDES in the Active Channel	0
Critical Infrastructure in the Erosional Hazard Area	0	NPDES in the Erosional Hazard Area	0
Critical Infrastructure in the Historical River Channel	1	NPDES in the Historical River Channel	1

RISK ASSESSMENT RESULTS		
Flood Risk	**Risk: 3** **Risk Potential Score: 1** **Risk Severity Score: 2**	Critical infrastructure is located within the 100-year floodplain, but appears to be elevated and unaffected during large-scale events.
Fluvial Geomorphic Risk	**Risk: 2** **Risk Potential Score: 1** **Risk Severity Score: 1**	Linear, multi-thread channel with low/medium stream power. Moderate lateral migration and erosion potential on the outside of small-scale meander bends. The channel is encroaching/eroding on the bounding agricultural land throughout the reach. There are minimal assets within the erosional hazard area.
Ecological Risk	**Potential for Restoration: 5** **Risk Score: 2** **Restoration Priority Score: 3**	***SVAP2 Average Score: 5.5.*** There are no artificial barriers that restrict the movement of aquatic species. Canopy cover over the stream channel is moderate and there are few gaps in riparian vegetation.
Overall Risk Score	**10 - Low**	
Restoration Recommendations	Flood-proof the wastewater treatment plant, realign the river channel, and remove sediment and debris from the floodplain (see Section 7.2.7).	

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Section 6

Risk Scores and Designations

6.1 Overall Risk Scores

An overall risk score was calculated for each reach by summing the flood, fluvial geomorphic, and ecological risk scores assigned to each reach, as described in previous sections. This resulted in each reach being assigned an overall risk score between six and 18 (**Table 6-1**). These overall risk scores were then used to assign each reach an overall risk designation as follows:

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

The overall risk designation developed for each reach ranged from a low score of seven (Reach 3) to a high score of 17 (Reach 11). In total, eight reaches were designated as having low overall risk, nine were designated as having medium overall risk, and two reaches were designated as having high overall risk (**Figure 6-1**).

Table 6-1: Overall Reach Risk Designations

Reach	Flood Risk			Fluvial Geomorphic Risk			Ecological Risk			Overall Risk Score
	Potential	Severity	Score	Potential	Severity	Score	Risk	Priority	Score	
1	1	2	3 - Low	2	1	3 - Low	2	2	4 - Medium	10 - Low
2	1	2	3 - Low	2	2	4 - Medium	2	2	4 - Medium	11 - Medium
3	1	1	2 - Low	1	1	2 - Low	2	1	3 - Low	7 - Low
4	1	3	4 - Medium	3	3	6 - High	2	2	4 - Medium	**14 - High**
5	1	1	2 - Low	2	2	4 - Medium	2	3	5 - High	11 - Medium
6	1	1	2 - Low	0	1	1 - Low	2	3	5 - High	8 - Low
7	1	3	4 - Medium	2	2	4 - Medium	2	3	5 - High	13 - Medium
8	1	3	4 - Medium	2	1	3 - Low	2	3	5 - High	12 - Medium
9	1	3	4 - Medium	1	1	2 - Low	2	2	4 - Medium	10 - Low
10	1	1	2 - Low	2	3	5 - High	2	2	4 - Medium	11 - Medium
11	3	3	6 - High	3	3	6 - High	2	3	5 - High	**17 - High**
12	1	1	2 - Low	1	1	2 - Low	2	3	5 - High	9 - Low
13	3	2	5 - High	1	1	2 - Low	2	2	4 - Medium	11 - Medium
14	1	1	2 - Low	1	1	2 - Medium	2	3	5 - High	9 - Low
15	3	2	5 - High	1	1	2 - Low	2	3	5 - High	12 - Medium
16	1	1	2 - Low	1	2	3 - Low	2	2	4 - Medium	9 - Low
17	1	1	2 - Low	1	1	2 - Low	2	3	5 - High	9 - Low
18	1	2	3 - Low	2	3	5 - Medium	2	2	4 - Medium	12 - Medium
19	1	2	3 - Low	2	2	4 - Low	2	3	5 - High	12 - Medium

6.2 Overall Risk Designations

An overall risk of Low, Medium, or High was given to each reach based on a discrete numerical risk designation that was based on the flood, fluvial geomorphic, and ecological risk assessment results. The resulting reach designations can serve as a roadmap for maximizing the returns on investment during the 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.

6.2.1 High Priority Reaches

- **Reach 4**: This reach runs through the City of Fort Morgan, which saw significant flood impacts during the 2013 flood. Much of Fort Morgan sits above the floodplain, but some key infrastructure and assets were adversely impacted by the 2013 flood. The primary impacts included the overtopping and closure of Colorado State Highway 52, the breach of the berm adjacent to Riverside Park and subsequent flooding, the flooding at the Barlow Road interchange, and damage to the Upper-Platte Beaver diversion. In general, this reach can be considered geomorphically unstable due to the laterally constrained floodplain and to the geomorphic barriers present along this reach that serve to disrupt conveyance of sediment downstream. Ecological and environmental hazards are also present within the 100-year floodplain and could potentially be at risk during future flood events, including a water and sewer facility and a capped landfill.

- **Reach 11**: The risk assessments and numeric risk designation process resulted in this reach having the greatest overall risk in the Master Plan project area. A large number of structures and infrastructure, primarily in the City of Sterling, are within the Draft CHAMP 100-year floodplain, as evidenced by the considerable impacts to these features that occurred during the 2013 and 2015 flood events. The flood and geomorphic risks through this reach are complicated by the presence of considerable water diversion infrastructure, SWAs, road and bridge infrastructure, residential properties, and high-risk municipal and commercial infrastructure within the floodplain, all within a condensed and constrained reach of the river. Addressing all of the complex issues present along this reach will require an equally complex set of solutions.

6.2.2 Medium Priority Reaches

- **Reach 2**: Goodrich, a small town at the upstream limit of Reach 2, sits within the Draft CHAMP 100-year FEMA floodplain and experienced considerable flood impacts during the 2013 flood event. Both bridges within this reach, Colorado State Highway 39A and Morgan County Road 9, are elevated above the 100-year floodplain, but the roadway approaches adjacent to the bridges have potential to overtop during flows associated with lower recurrence interval events. The potential for lateral river channel migration exists at both bridge crossings. Goodrich and southern Weldona are both within the historic river channel (HRC), elevating the overall geomorphic risk of the reach.

- **Reach 5:** Flood risk is moderate throughout this reach, although minimal infrastructure and relatively few assets reside within and adjacent to the active floodplain. However, agricultural land adjacent to the floodplain is within the EHA and is at risk of lateral migration and erosion; and the Tremont-Lower Beaver diversion structure may experience sedimentation at the diversion and within the canals. In addition, the Morgan County Road 24 north roadway approach overtops at flows associated with an approximately 25-year event, even though the bridge crossings are elevated above the floodplain.

- **Reach 7:** Significant damage to the roadway infrastructure along this reach occurred as a result of the 2013 flood, including damage to the Morgan County Road 33 bridge and approaches, the Burlington Northern Santa Fe (BNSF) Railroad, and Morgan County Road W7. The breach of the railroad west of the floodplain contributed to downstream flooding into the Town of Messex, as described under Reach 8. Assets adjacent to the floodplain are within the mapped EHA, resulting in elevated geomorphic risk. The North Sterling

Diversion, the Morgan County Road 33 bridge, and the Burlington Railroad bridge are located in series at the downstream end of the reach, contributing to significant flood and sedimentation issues.

- **Reach 8**: This reach encompasses the northwest corner of Washington County, including Messex. Although Messex is located outside of the updated FEMA 100-year floodplain, the town experienced significant flood impacts during the 2013 and 2015 flood events. These flood impacts were caused by issues in the adjacent upstream reach (Reach 7), which was designated as having a High risk, due to the flooding in Messex, while Reach 8 was given a risk designation of Medium. Portions of Morgan County Road W7, and the railroad tracks near the Washington County line, were overtopped in 2013, leading to conveyance of flood waters through low-lying terrain toward Messex. The railroad embankment trapped flood water on the north side of the railroad embankment. Additionally, the Tetsel Ditch overtopped its banks upstream of Messex, further contributing to the flood issues.
- **Reach 10:** Flood risk is low for this reach, with minimal assets and infrastructure within the Draft CHAMP 100-year FEMA floodplain. High potential for lateral migration and erosion hazards elevate the geomorphic risk, particularly at the in-line channel structures that exist within this reach: the Logan County Road 33.5 bridge crossing, Springdale Diversion, and Sterling No. 1 Diversion.
- **Reach 13**: The Town of Iliff did not experience significant flood impacts during the 2013 flood, but based on the Draft CHAMP 100-year FEMA floodplain, the majority of the town sits inside of the 100-year floodplain. The Logan County Road 55 bridge crossings are elevated above the 500-year floodplain, but the north approach to the bridge appears to have the potential to overtop at approximately the 10-year event flow level, further contributing to the flood risk in this reach. A considerable portion of the Powell Ditch (~1.75 miles) is within the floodplain and potentially requires significant maintenance following large flow events. The Powell-Blair diversion likely requires up to annual upstream sand dam maintenance to ensure flows reach the point of diversion.
- **Reach 15**: The entirety of the Town of Crook sits within CWCB's draft CHAMP 100-year FEMA floodplain. Review of the hydraulic model results indicate that the town may experience significant flooding down to the 25-year flood. This significant flood risk potential is a product of the low elevation of Crook and the surrounding areas, which depend on flood protection from the railroad and Harmony Ditch embankments. Geomorphic risk factors were assessed as low based on minimal infrastructure within the EHA.
- **Reach 18**: Ovid experienced moderate flood damage during the 2013 flood due to backwater entering the town through small drainage crossings under the railroad tracks adjacent to the South Platte River. The river is extremely dynamic in this area and has a high lateral migration potential. Ovid is located within the EHA, indicating a high geomorphic risk. The Sedgwick County Road 27.8 Bridge and the Liddle Diversion infrastructure require significant maintenance due to the dynamic nature of the active floodplain in this area.
- **Reach 19:** Although overall risk is classified as medium for this reach, the Town of Julesburg's wastewater treatment facility is contained within the Draft CHAMP 100-year floodplain. Closer review of the model indicates that the pond's berm is elevated and may be dry during a 100-year flood event, but the facility itself appears to be at risk at flows consistent with the 10-year event. The U.S. Highway 385 bridge crossing experienced significant scour during both the 2013 and 2015 flood events, and as of March 2018, is currently undergoing CDOT repairs. Downstream of the bridge, Sedgwick County Road 32 5/10 runs parallel to the river on the south side of the floodplain and has experienced undercutting and erosional hazards in the past. Following road repairs, bank protection and spur dikes were installed to help mitigate impacts and reduce future risk.

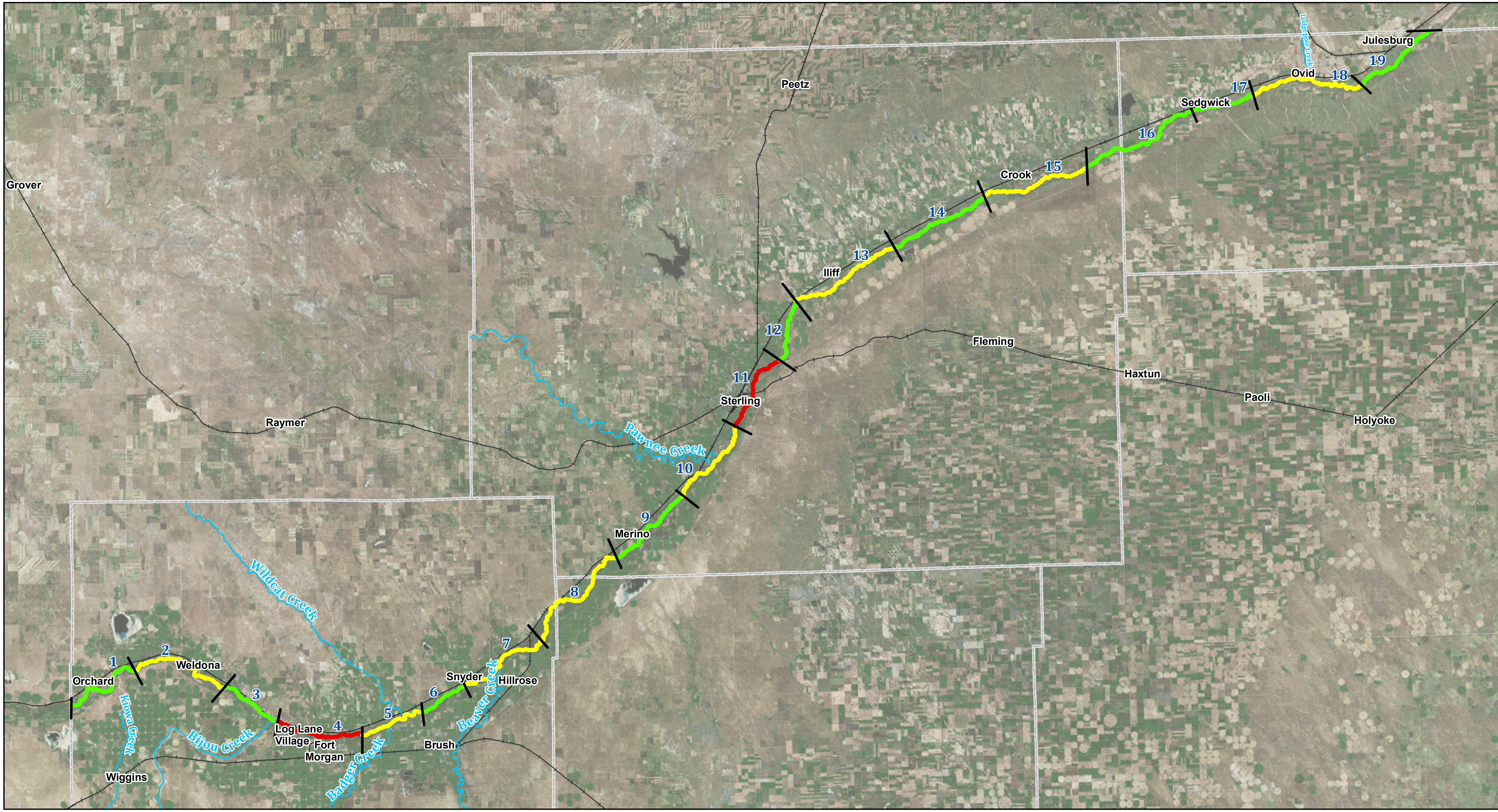
6.2.3 Low Priority Reaches

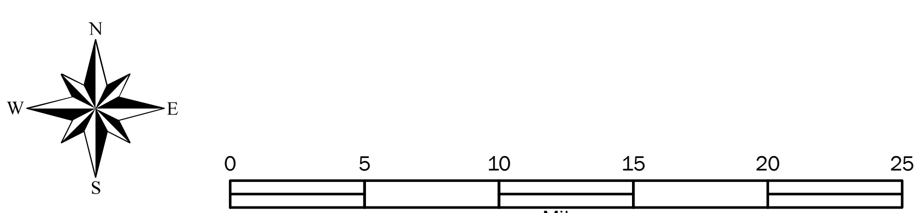
- **Reach 1**: Bank erosion and lateral channel migration have caused significant undercutting and road damage along Colorado State Highway 144 east of the river channel in Reach 1. As of March 2018, CDOT is realigning this stretch of roadway to mitigate this hazard. Flood risk is rated as medium in this reach due to the potential of the roadway to overtop at the 10-year event, but few structures and minimal other infrastructure appear to be within the Draft CHAMP 100-year FEAM floodplain. Similarly, aside from the roadway, minimal assets and infrastructure exist within the EHA.
- **Reach 3:** This portion of the South Platte River passes through a confined valley colloquially known as The Narrows. Overall risk is low due to the naturally confined floodplain and minimal assets and infrastructure adjacent or within the floodplain. The Morgan County Road 12 bridge approach appears to overtop at approximately the 25-year flood event, representing the highest risk asset in Reach 3.
- **Reach 6:** Overall risk is low through this channel with minimal assets and infrastructure at risk from flood or geomorphic hazards. Several small county roads southeast of the active floodplain are within the Draft CHAMP 100-year FEMA floodplain. Additionally, the southern bridge approach to the Colorado State Highway 71E bridge crossing overtops at approximately the 50-year event. A large portion of the roadway approach runs perpendicular to the floodplain, potentially causing substantial backwater that would impact upstream agricultural land.
- **Reach 9:** The Logan County Road 8 and Logan County Road 29.5 bridge roadway approaches both overtop at approximately the 10-year flood level, accounting for the elevated flood risk assigned to this reach. However, the stream power is low in this reach and erosional hazard and migration potential are generally minimal. The Schneider Diversion is highly dependent on the upstream sand dam to convey low flows to the point of diversion.
- **Reach 12:** Both the Bravo Diversion and the Iliff-Platte Valley Diversion rely on upstream sand dams to maintain flow to their points of diversion and require significant maintenance. In addition, several small county roads are within the 100-year floodplain east of the Logan County Road 40 bridge crossing. However, due to the lack of structures and other infrastructure within the Draft CHAMP 100-year FEMA floodplain, both the flood and geomorphic risks are low throughout this reach.
- **Reach 14:** Roadway infrastructure and agricultural land are the main assets at risk to flooding and geomorphic hazards along Reach 14. Generally, risk is rated as low throughout this reach, but a considerable length of U.S. Highway 138 runs parallel to the South Platte River and is within the Draft CHAMP 100-year floodplain. The Harmony Diversion structure is reliant on an upstream sand dam, which results in annual maintenance requirements. Migration potential is moderate through the reach, but the lack of assets and infrastructure in the EHA keep the geomorphic risk moderate.
- **Reach 16:** Overall risk is low with at-risk assets along this reach generally consisting of agriculture land. Similar to upstream reaches, U.S. Highway 138 runs parallel to the South Platte River and is within the Draft CHAMP 100-year FEMA floodplain for a portion of the reach. The Sedgwick County Road 93 bridge approaches likely overtop at flood events less than the 100-year event.
- **Reach 17:** Overall risk is characterized as low for this reach, mainly due to minimal infrastructure and assets within the floodplain or the mapped EHA. The Draft CHAMP 100-year FEMA floodplain indicates potential flood impacts at the eastern edge of the Town of Sedgwick, but few structures are inside the floodplain. U.S. Highway 138 is almost completely contained within the 100-year floodplain, between Sedgwick and Ovid (includes portion of Reach 18).

6.2.4 Infrastructure Inventory and Risk Analysis

The 2013 and 2015 floods unveiled significant deficiencies in bridges and roadway infrastructure throughout the region, as noted under many of the reach descriptions in the previous section. Because the South Platte River forms a natural barrier between many of the counties and communities throughout the project reach, closure of the major bridge crossings poses a significant risk to emergency access routes. Additionally, impacts to bridge and roadway infrastructure due to flooding and erosional hazards have a potentially large financial impact. This Master Plan identifies risk factors for all of the bridge crossings in the project area and provides an assessment of the potential risks based on risk level and the potential scale of impacts. This information was used to identify potential solutions (presented in Section 7 of this report) for the highest risk roadway infrastructure, while also considering ongoing and recent roadway projects and improvements. **Table 6-2** provides a complete bridge inventory and high-level risk assessment description.

Agriculture is one of the most prominent industries along the South Platte River in eastern Colorado and individuals and institutions involved in this industry represent a major stakeholder group for this Master Plan. The 2013 and 2015 flood events also impacted the majority of the water users in the project reach to some degree. A rigorous analysis was conducted as part of the master planning process to inventory all available data for water diversion infrastructure, identify flood and geomorphic risk factors, and assess risk based on these factors. **Tables 6-3** through **6-5** present a summary of the data collected and the subsequent risk analysis.





Reach Break
Railroad
Tributary

Overall Risk
Low
Medium
High

World Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community USDA NAIP 2015

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South Platte River Master Plan

Figure 6-1-: Overall Risk

COLORADO Colorado Water Conservation Board Department of Natural Resources

CDM Smith

Table 6-2: Bridge Inventory and Risk Assessment

County		Crossing			Location		Year Built	Owner	Ongoing CDOT Project	Flood Risk	Geomorphic Risk	Overall Risk	National Bridge Assessments*		CHAMP Flood Model Data		Notes
	Reach	Name	AKA Name	Type	Mile Post	Nearest Town							Channel Protection Score	Scour Score	Flood Event to Impact Bridge Low Chord	Flood Event to Overtop Road Approach (direction from bridge)	
Morgan	1	SH 144 A	MCR 1+	Highway	6.6	Orchard		CDOT	Yes	High	High	High			>500-yr	10-yr (south)	Significant bank loss and channel migration south of bridge crossing - ongoing CDOT project to realign road and address errosion hazard
	2	SH 39 A	MCR 5	Highway	7.1	Goodrich		CDOT		Medium	Low	Medium			>500-yr	50-yr (north)	Low bridge capacity potentially impacting Town of Goodrich upstream during 100-yr event
	2	Warren St	MCR 9.5	Road		Weldona	2003	Morgan		Medium	Low	Medium	7, 7	5, 4	>500-yr	25-yr (north and south)	Draft 100-yr floodplain shows north and south approaches overtopped; floodplain highly constricted at bridge; possible channel migration issues
	3	SH 144 A	MCR 12	Highway	20.4	Weldona		CDOT		Medium	Low	Medium	7	5	100-yr	25-yr (south)	South approach may have overtopped in 2013; highly constricted floodplain (topograhically controlled - start of Narrows), potential pinchpoint exacerbating upstream flooding
	4	SH 52 B	MCR 18	Highway	87.4	Fort Morgan	1962	CDOT	Yes	High	High	High			50-yr	500-yr (north and south)	Bridge deck overtopped in 2013; levees on south bank upstream and downstream of bridge, floodplain does not indicate that approaches are overtopped during flood events; aerial image from June 2016 has flow of around 5500 cfs - flow contained in main channel at bridge
	5	MCR 24		Road		Brush	1992	Morgan		Medium	Low	Medium	7	5	>500-yr	25-yr (north)	Channel locked in at upstream diversion (Tremont and Lower Beaver) and at bridge crossing; channel constricted at diversion and bridge; canals north and south of channel likely impacted during floods
	6	SH 71 E	MCR 29.5	Highway	181.4	Snyder	1980	CDOT		Medium	Low	Medium	8	8	>500-yr	50-yr (south)	Thick vegeation upstream and downstream limiting capacity at bridge; no adjacent structures appear to be at risk due to bridge capacity
	7	MCR 33	Cooper Bridge	Road		Hillrose	1987	Morgan		High*	Low	High	7	5	500-yr	50-yr (south)	Floodplain runs up against CR 33 south of the bridge; north approach is overtopped by 100-yr floodplain; upstream diversion and canal are likely at risk during any significant flood event
	7	Burlington RR		Railroad		Hillrose		Burlington RR		High*	Low	High			500-yr	10-yr (north)	Significant backwater upstream of RR embankment based on draft 100-yr floodplain; north tracks overtopped - may be contributing to Messex flooding problems
Washington	8	WCR 59		Road		Messex		Washington		Medium	Medium	Medium	6	8	>500-yr	10-yr (south)	Bridge appears to have low hydraulic capacity - three separate crossings; large sand bar formation in main channel; approaches likely overtopped in significant flood events
Logan	8	US 6 J		Highway	389.6	Merino	1966	CDOT	Yes	Medium	Low	Low	8	5	>500-yr	100-yr (north and south)	Bridge appears to have low hydraulic capacity; overflow channel not activated often; large woody vegetation reducing capacity
Logan	9	LCR 8		Road		Merino	1996	Logan		Medium	High	High	7	5	>500-yr	10-yr (east and west)	High channel migration risk; large floods likely overtop bridge and long portion of the northwestern approach; floodplain constricted by road on south side and development/agriculture on north side
	9	LCR 29.5		Road		Merino		Logan		Medium	Medium	Low			>500-yr	10-yr (north and south)	Boath approaches overtopped based on draft 100-yr floodplain; road does not appear elevated out of floodplain
	10	SH 63 A	LCR 33.5	Highway	56.0	Atwood	1982	CDOT	Yes	High	High	High	6	5	500-yr	50-yr (north and south)	Bridge overtopped based on draft 100-yr floodplain; Springdale Ditch may be impacted during floods due to backwater; erosion risk at bridge abutments
	11	US 6 J		Highway	405.5	Sterling	1975	CDOT	Yes	High	High	High	7	5	500-yr	25-yr (west)	Many structures in floodplain; approaches likely overtop jeopardizing bridge and road ground; potential channel migration; bank armoring to divert water pushes flow to north; decreasing sediment conveyance
	11	Nebraska Kansas & Colorado RR		Railroad		Sterling		Nebraska Kansas & Colorado RR		High	Medium	High			100-yr	25-yr (west)	Significant debris accumulation at bridge - likely exacerbates hydraulic and sediment conveyance
	12	LCR 40		Road		Ford		Logan		High	High	High			>500-yr	500-yr (east)	Channel migration likely jeopardizes road and approach; road and bridge crossing does not align well with channel; sediment transport issues likely affect hydraulic conveyance; constrained floodplain to the south pushes flow back to the north
	13	LCR 55		Road		Iliff	1990	Logan		Medium	Low	Low	7	8	>500-yr	10-yr (north)	Appears to be in pretty good shape; approaches may overtop in large flood events; historical images look mostly stable over time
	14	LCR 65.7				Iliff/Crook	2011	Logan		Medium	Medium	Medium	8	8	Not in Model		Potential loss of ground and road due to cut bank upstream of bridge on north bank; floodplain narrows downstream of bridge crossing due to topography - likely causing a reduction in conveyance during high flow events; sediment deposition pushes flow to north
	15	SH 55 A	LCR 81	Highway	1.0	Crook	1986	CDOT	Yes	Medium	High	Medium	8	8	>500-yr	10-yr (north)	Erosion upstream of bridge jeopardizing bridge and approach; highly vegetated within active floodplain - decreasing hydraulic and sediment capacity; draft 100-yr floodplain indicates deck and approaches overtopped
	16	LCR 93		Road		Crook	1984	Logan		Medium	Low	Medium	7	5	Not in Model		Approaches likely overtop during high flow events, downstream road in jeopardy due to bank loss; channel migration limited by vegetation on mid-channel bars - increases scour potential at bridge; main channel section through bridge is very narrow; elevated floodplain south of channel pushes flow back to north

Table 6-3: Water Diversion Structure Inventory

Water Conservation Dist.	Water Dist. No. & Name	County Name	Mater Plan Reach No.	Diversion										Sanddam(s)			Notes
				Name	Nearest Town	Lat (N)	Long (W)	Approximate Total Dam Width (feet)	Sediment Passage Capabilities	River Control Gate Type	Approx. River Control Width (ft)	Dam Type	Approx. Dam Width (feet)	Sanddam(s), Distance Upstream Headgate (miles)	Sanddam Location	Approximate Sand Dam Length Along Bank (feet)	
	1. South Platte: Greeley to Balzac	Morgan	2	Fort Morgan	Weldona	40°21'14.00"N	104° 0'60.00"W	250	Yes	Bladder	100	Concrete	150	0.0, 0.35	Lt. Abut. Lt. Bank	380, 310	260' Wide Main Ch. Structure ~450 ft D/S??Grade Control????. Upstream 'Sanddam' is a concrete/cribbing permanent structure to prevent channel avulsion. Canal siphons under Bijou Ck ~10 mi D/S of HG, N. Side of river required bank stabilization after 2013 & 2015 Floods.
Lower South Platte			4	Deuel Snyder & Upper Platte Beaver	Log Lane Village	40°16'35.00"N	103°50'7.00"W	1310	No	8' Radial, 8' Boards, 2-30' Slides	80	Concrete Rollover Wall	1230	0.00	Lt. Bank	120	Looking to install sediment passing structure per Joe Frank&2009 CWCB Loan Application, Structural defficient in places, foundation leakage, near surface bedrock.
			5	Tremont & Lower Platte Beaver	Brush	40°16'51.00"N	103°42'5.00"W	215	No	Slide Gate	15	Concrete	200	None	N/A	N/A	Historically has had a lot of sediment deposition upstream with minimal to no sediment passage capabilities. Tremont Ditch in floodplain collects sediment during normal operations and at flood stages.
			7	North Sterling	Snyder	40°21'8.00"N	103°32'26.00"W	195	Yes	Concrete with 4-8'W?x??'H Radials	40	Concrete??	155	0.06, 0.15	Rt.Bank, Rt.Bank	300, 380	During normal ops. diversion facility appears capable of sediment passage. Flood gate located upstream of MCR W7 Crossing. Measurement station appears to be located downstream of MCR 33 Wasteway.
			8	Tetsel & Prewitt	Hillrose	40°22'46.00"N	103°28'44.00"W	350	No	Slide	10	Concrete	340	-0.02 to .02, 0.30	Lt. Abut, Lt. Bank	300, 280	Lack of sediment passage capabilities leading to upstream left bank avulsions. Getting flows to Tetsel system requires Tetsel Inlet Canal to cross/utilize river bottom channels.
		Wash-ington	8	South Platte	Messex	40°24'38.00"N	103°26'17.00"W	200	Poor	Slide, Check Boards	~4, 20	Concrete Wall/Sill	175	0.00	Lt. Abut.	130	Mininimal sediment passage capabilities leads to left abutment sanddam erosion.
	...th Platte: Balzac to Stateline	Logan	8	Farmers Pawnee	Messex	40°27'25.00"N	103°23'27.00"W	220	Yes	Bladder	100	Concrete Wall/Sill	120	0.60	Rt.Bank	690	New post 2013 & 2015 Flood structure.
			9	Davis Bros	Merino	40°28'18.00"N	103°20'46.00"W	N/A	N/A	None	N/A	---	---	N/A	---	---	Historic data exists but no current point of diversion per SEO. APOD-Water rights converted to wells. No ditch company.
			9	Schneider	Merino	40°30'0.00"N	103°18'40.00"W	170	No	None	N/A	Concrete Wall/Sill	170	0.35	Lt. Bank	1000	Upstream sanddam failure (1998, 2013, 2015?) periodically leads to river avulsion from headgate.
			10	Springerdale	Atwood	40°32'5.00"N	103°16'30.00"W	165	Poor	Boards in Slot	35, 40	Concrete Wall	35, 20, 35	1.10	Rt. Abut.	400	
			10	Sterling No.1	Atwood	40°32'44.00"N	103°15'25.00"W	360	Yes	Bladder	100	Concrete Wall/Sill	100	0.00	Rt. Abut.	160-200	
			11	Henderson Smith	Sterling	40°35'51.50"N	103°12'15.00"W	100	No	Wooden Cribbing	30	Sanddam*	N/A	0.00*, 0.24	Lt. Abut., Lt. Bank	70, 300	Very unstable location for diversion and headgate. Lots of sand and frequent loss of sanddams. Has winter time operations.
			11	Sterling No.2	Sterling	40°36'6.00"N	103°12'9.00"W	N/A	N/A	None	N/A	---	---	N/A	---	---	No visible point of diversion since 1998. SEO indicates an Active status and water right converted to Altenative Point of Delivery (APOD) - Well.
			11	Lowline	Sterling	40°37'16.00"N	103°11'19.00"W	100	No	Timber Board?	15	Timber Board??	85	0.22	Rt.Bank	100	Difficult to keep river at diversion. Upstream sanddam frequently lost. CDOT project to harden/resileant sanddam? Diversion has winter time operations.
			12	Bravo	Ford	40°40'32.00"N	103° 7'56.00"W	205	No	Slides	15	Concrete	45	0.00 1.10	Lt. Abut., Rt. Bank	145, 630	Listed as Active Status by SEO. Appears to have sever downcutting/erosion on downstream side of diversion dam. Upstream sand dams subject to frequent loss.
			12	Iliff & Platte	Ford	40°43'31.00"N	103° 7'27.00"W	1000	No	None	N/A	Sanddam*	1000	0.15, 0.70*	Rt.Bank Rt.Bank	300, 1000	Diversion of main channel flows is currently done with a sanddam. Flow enters a 3/4 mile long inlet canal that also picks up a tributary creek. Headgate/wasteway combo controls flow entering canal.
			13	Jud Brush	Ford	40°43'40.63"N	103° 6'30.51"W	N/A	N/A	None	N/A	---	---	N/A	---	---	Historic data exists but no current point of diversion per SEO. Currently APOD-Wells
			13	Lone Tree	Iliff	40°44'24.04"N	103° 3'48.84"W	Unk	No	Unk	Unk	Unk	Unk	None	---	---	Diversion Dam not visible since 1998. HG visible in 2013 photo. Ditch looks unused. Listed as Active Status by SEO. Currently APOD - Wells.
			13	Powel & Blair	Iliff	40°46'56.50"N	103° 0'15.00"W	860	No	None	N/A	Sanddam*	860	0.17, 1.75*	Rt.Bank Rt.Bank	160, 860	Diversion of main channel flows is currently done with a sanddam. Flow enters a 1.75 mile long inlet canal that also picks up a tributary creek. Headgate/wasteway combo controls flow entering canal. Inlet channel dammed off below sand dam wasteway during non-irrigation season.

Table 6.4: Water Diversion, Canal, and Headgate Inventory

Water Conservation District	Water District No. & Name	County	Study Reach No.	Diversion Name	Canal/Ditch Name	Nearest Town	Lat (N)	Long (W)	River Bank/ Side Location	Length of Inlet Channel (miles)	Headgate Type	Headgate Size	Total Decreed Rate/Discharge (cfs)	Length Canal System Located in Floodplain (mi)	Wasteway Location Downcan	Nearest Town Below Canal	Nearest Town Downcanal from Diversion (miles)	Owner
	1. South Platte: Greeley to Balzac	Morgan	2	Fort Morgan	Fort Morgan Canal	Weldona	40°21'14.00"N	104° 0'60.00"W	Right/South	N/A	Overshot [1]	1-30'Wx??'H	958.9	2.0	0.06	None	N/A	Not Listed in SEO Database.
Lower South Platte			4	Deuel Snyder & Upper Platte Beaver	Deuel & Snyder Canal	Log Lane Village	40°16'35.00"N	103°50'7.00"W	Left/North	N/A	No Data [1]	1-8'Wx??H	248.0	1.0	0.35	None	N/A	Deuel & Synder Improvement Company
					Upper Platte Beaver Canal				Right/South	N/A	Radial [1]	3-8'Wx??'H	759.5	0.5	Possibly 0.40	Fort Morgan	2.5	Upper Platte & Beaver Canal Company
			5	Tremont & Lower Platte Beaver	Tremont Ditch	Brush	40°16'51.00"N	103°42'5.00"W	Left/North	N/A	Slide [1]	2-5'Wx??'H	878.0	3.0	1.80	Snyder	7.0	Not Listed in SEO Database.
					Lower Platte Beaver Canal				Right/South	N/A	Slide [1]	2-10'Wx??'H	1734.0	4.3	None	None	N/A	Not Listed in SEO Database.
			7	North Sterling	North Sterling Canal	Snyder	40°21'8.00"N	103°32'26.00"W	Left/North	N/A	Overshot [1]	3-10'Wx??'H	2971.0	1.2	0.9 & 6.5	Messex	8.5	Not Listed in SEO Database.
					Union Ditch				Left/North	N/A	Slide [1]	2-5"Wx??'H	49.7	5.0	0.80	None	N/A	Not Listed in SEO Database.
			8	Tetsel & Prewitt	Tetsel Ditch	Hillrose	40°22'46.00"N	103°28'44.00"W	Left/North	1.25	Concrete/Pipes thru sanddam		37.0	3.0	1.35	Messex	4.8	Not Listed in SEO Database.
					Prewitt Inlet Canal				Right/South	N/A	Slide	9-4'Wx??'H	1540.0	1.0	1.02	None	N/A	Not Listed in SEO Database.
		Washington	8	South Platte	South Platte Ditch	Messex	40°24'38.00"N	103°26'17.00"W	Right/South	N/A	Boards	14'	402.6	2.0	0.87, second one further D/S [1]	None	N/A	Not Listed in SEO Database.
	64. South Platte: Balzac to Stateline	Logan	8	Farmers Pawnee	Farmers Pawnee Ditch	Messex	40°27'25.00"N	103°23'27.00"W	Left/North	N/A	Bladder	30'	435.3	1.7	0.75	Merino	3.0	Not Listed in SEO Database.
			9	Schneider	Schneider Ditch	Merino	40°30'0.00"N	103°18'40.00"W	Right/South	N/A	Boards	20	213.6	0.5	0.32	None	N/A	Not Listed in SEO Database.
			10	Springerdale	Springdale Ditch	Atwood	40°32'5.00"N	103°16'30.00"W	Left/North	0.05	Slide	5-4'Wx??'H	255.4	1.0	0.50	None	N/A	Not Listed in SEO Database.
			10	Sterling No.1	Sterling Irr. Co Ditch 1	Atwood	40°32'44.00"N	103°15'25.00"W	Left/North	N/A	Radial	2-6?'Wx??'H	836.8	5.0	1.80 & 3.10	Sterling	5.0	STERLING IRRIGATION CO (SEETCH, KATHERIN)
			11	Henderson Smith	Henderson Smith Ditch	Sterling	40°35'51.50"N	103°12'15.00"W	Right/South	N/A	Check Boards/ Open Channel	30'W	584.2	2.8	2.10	None	N/A	STERLING, CITY OF (STERLING CITY MANAGER)
			11	Lowline	Lowline Ditch	Sterling	40°37'16.00"N	103°11'19.00"W	Left/North	1.5	Open Channel	30'W	95.8	2.5	0.36 & 1.50	None	N/A	City of Sterling
			12	Bravo	Bravo&Farmers People's Ditch	Ford	40°40'32.00"N	103° 7'56.00"W	Right/South	0.63	No Data [1]	38'W	187.4	0.1	0.60	None	N/A	Not Listed in SEO Database.
			12	Iliff & Platte	Iliff&Platte Valley Ditch	Ford	40°43'31.00"N	103° 7'27.00"W	Left/North	N/A	Slide [1]	30'W	405.0	0.8	None	Iliff	4.8	Not Listed in SEO Database.
			13	Powel & Blair	Powell & Blair Ditch	Iliff	40°46'56.50"N	103° 0'15.00"W	Left/North	1.75	No Data [1]	15'W	275.0	2.6	None	None	N/A	POWELL DITCH CO
			14	Ramsey	Ramsey Ditch	Iliff	40°47'44.26"N	102°56'45.71"W	Left/North	N/A	None	None		All	None	None	N/A	LAFLEUR, KEVIN
			14	Harmony	Harmony Ditch #1	Crook	40°49'23.00"N	102°52'28.00"W	Left/North	N/A	Bladder or Overshot [1]	30'W	1789.0	1.6	1.50	Crook	6.3	Not Listed in SEO Database.
		Sedgwick	17	Peterson	Peterson Ditch	Sedgwick	40°55'24.00"N	102°32'57.00"W	Left/North	0.07	Slides	5-6'Wx?'H?	989.0	2.8	None In Fldpln. Yes, one above Ovid	Ovid	10.5	G & L SERVICES (FRAME, LARRY)
			18	South Reservation	South Reservation Ditch	Ovid	40°56'33.00"N	102°26'48.00"W	Right/South	N/A	Slidegate [1]	1?-10'Wx?'H?	80.0	1.5	None	None	N/A	Not Listed in SEO Database.
			18	Liddle	Liddle Ditch	Ovid	40°57'17.50"N	102°23'1.50"W	Left/North	N/A	Wood Chk Board	1-10'Wx4'H	145.0	1.2	None	None	N/A	LIDDLE DITCH CO (HAYNES, TIM)

Notes:

1 Based on desktop analysis; needs to be confirmed

Table 6-5: Water Diversion and Irrigation Infrastructure Risk Assessment

Water Conservation District	Water District No. & Name	County	Study Reach No.	Diversion Name	Canal/Ditch Name	Diversion Dam(s)	Inlet Canal	Headgate	Canal/Ditch in Floodplain	Wasteway	Notes	Risk
	1. South Platte: Greeley to Balzac	Morgan	2	Fort Morgan	Fort Morgan Canal	H/H	N/A	L/M	L/L	H/M	Lt. abutment sanddam historical scours out. Minor erosion around HG & WW after floods.	M
Lower South Platte			4	Deuel Snyder & Upper Platte Beaver	Deuel & Snyder Canal	H/H	N/A	H/M	L/L	M/M	Lt. abutment sanddam subject to loss during flooding. Wasteway looks in poor condtion could be subject to overtopping and scour during flood. Good vegetation between active channel and canal in floodplain.	M
					Upper Platte Beaver Canal	H/H	N/A	H/M	H/M	N/A	River control portion of diversion in poor condition. Leaking in foundation. Slide gates in poor condition. No visible wasteway, canal in floodplain will overtop left bank upstream of measurement structure if headgate overtopped. Canal along right river bank appears stable, probably founded on bedrock.	H
			5	Tremont & Lower Platte Beaver	Tremont Ditch	H/M	N/A	M/H	H/H	L/L	Headgate located in main channel high potential for scour, Canal in floodplain fills in with sediment.	H
					Lower Platte Beaver Canal	H/M	N/A	M/M	H/L	N/A	Headgate into right bank of main channel. Canal in floodplain with no wasteway.	M
			7	North Sterling	North Sterling Canal	M/H	N/A	M/M	L/L	L/L	Canal upstream of MCR W7 fills up with sediment during out of bank floods. Diversion dam promoting need for upstream sand dams on right bank. 0.9 mi. Wasteway facility looks old and undersized. Spills at 6.5 mi Wasteway may contribute to flooding in Messex duriing certain flood events.	M
					Union Ditch	M/H	N/A	M/M	L/M	L/L	Occassional ditch fill up with sand. Controled wasteway facility less than 5 years old.	L
			8	Tetsel & Prewitt	Tetsel Ditch	H/H	H/H	H/H	H/L	M/M	Floodwaters go around and scour left abutment of dam. Inlet canal easily flooded and filled in with sediment. Headgate&Wasteway structure old & damaged by 2013-15 flooding.	H
					Prewitt Inlet Canal	H/H	N/A	L/M	L/L	L/L	See comment above on diversion dam.	M
		Washington	8	South Platte	South Platte Ditch	H/H	N/A	H/M	H/H	M/M	Left abutment of dam has overtopped and scourred out. River captured by canal D/S HG. Left bank of canal downstream of HG in 2016 aerial shows evidence of multiple blow outs.	H
	...lzac to Stateline	Logan	8	Farmers Pawnee	Farmers Pawnee Ditch	M/L	N/A	M/M	L/L	L/L	Diversion Rebuilt after 2013. All facilities look stable with minimal signs of local erosion.	L
			9	Schneider	Schneider Ditch	H/H	N/A	H/M	H/M	H/L	Frequent loss of sanddam leads to river avulsion and abandonment of diversion. Lack of sediment passage at diversion is filling upstream channel and will lead to more frequent avulsions and abandonments. Wasteway appears undersized for flood control.	H
			10	Springerdale	Springdale Ditch	H/H	H/L	H/L	H/H	H/L	Upstream sanddam and canal between headgate and wasteway subjected to erosion. Canal to wasteway fills in with sediment during flooding and inlet canal may require frequent sediment removal during normal ops.	H
			10	Sterling No.1	Sterling Irr. Co Ditch 1	H/H	N/A	H/L	H/L	H/L	First 1.5 mi of canal in active floodplain. 3.10 mi wasteway in Poor Condition. Canal in 500-year floodplain up to LCR 24.	H
			11	Henderson Smith	Henderson Smith Ditch	H/H	H/M	H/H	H/H	L/L	Very unstable location for diversion & headgate. Canal very ineffecient from headgate to U.S.6.	H
			11	Lowline	Lowline Ditch	H/H	H/M	M/L	H/H	M/M	Prefferred channel during floods appears to be incised making abandonment of fixed diversion likely. Upper reach of inlet canal especially around gravel pits unstable. Former sanddam hardend into a passive wasteway at 0.36 mi. downstream of diversion. Headgate&1.5 mi. Wasteway structure in a relatively protected location along inlet canal.	H

Section 7

Recommendations and Conclusions

7.1 Recommendations and Conceptual Design Strategies

The Master Plan includes recommended actions designed to reduce risk and restore the lower South Platte River to a healthy and 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 public.

7.1.1 Restoration and Risk Reduction Objectives

In general, the lower South Platte River channel is affected by bank stabilization, construction of in-channel structures such as diversions and bridges, and the installation of upstream flow-control structures. These modifications have worked to prevent the passage of sediment by reducing the flows necessary to flush sediment through the system, which has caused aggradation upstream of structures. Additionally, a decrease in the riparian zone of the lower South Platte River has exacerbated recent flood events, preventing attenuation of high flows and increasing the likelihood of channel scour and streambank erosion. Objectives to counteract these negative impacts may include both structural options, such as retrofitting bridges and/or diversions, and non-structural options, such as vegetation management, floodplain connection, and debris reduction.

The following are general restoration objectives intended to rehabilitate the lower South Platte River:

- Modify the channel planform, bedform, and/or profile as a means of stabilizing the river, eliminating constrictions, restoring floodplain connection, and establishing natural ecosystem functions. Channel modifications could also improve sediment transport.

- Retrofit, replace, or remove irrigation diversion structures to allow sediment passage, and to support aquatic species movement and migration. Several diversion structures throughout the project area have been retrofitted with "bladder dams," which have helped to prevent the buildup of sediment behind the structure.

- Retrofit or replace bridges that are too narrow and inhibit lateral migration of the river. The lower South Platte River has historically been prone to movement within the floodplain, generally driven by a combination of bank erosion and point bar deposition that result in multiple channels. The constant movement of the river can be hazardous to structures within the floodplain, such as bridges, as the main channel and side channels of the river may not remain *under* the bridge.

- Remove debris from bridges, infrastructure, and diversion structures. Removing debris will improve channel hydraulic conveyance, reduce or eliminate backwater, and improve sediment transport during high flows. In addition, prepare and maintain operation and maintenance plans to structures currently without those plans.

- Identify locations that can be used to capture debris and sediment before it impacts 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.

- Reestablish a healthy riparian zone along the banks of the lower South Platte River, reconnecting the channel to the floodplain. A wide riparian zone is necessary and beneficial as it allows for channel migration, mitigates flood stage waters, filters pollutants and excess sediment from the river, and attenuates river flow, which reduces the erosive energy of the water. This could be achieved by setting back berms, or by re-grading the existing banks.

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

- Maintain and preserve low risk reaches that have relatively high functioning ecosystems, fluvial geomorphic stability, and low flood hazards.

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

Examples of project types and potential policies that may help meet the objectives of the lower South Platte River project area include:

- Development or 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
- Establishment of new riparian zones through setbacks and conservation easements
- Acceptance of FEMA and CWCB floodplain re-mapping efforts (i.e., CHAMP)
- Development of FEMA non-regulatory products
  - Flood Risk Dataset, which would show changes since last the Flood Insurance Rate Maps (FIRMs), risk assessment, areas of mitigation interest, depth and analysis grids
  - Flood Risk Map
  - Flood Risk Report
- Enhancement and preservation of existing habitat and recreation areas

Not all of the project types and potential policies will be practical or reasonably implemented in all reaches. For example, although property buyout is technically feasible to address various risks, this strategy can be both economically and politically challenging; but it may be worth it to the Counties to identify land owners through public outreach activities who may be willing to voluntarily consider property transfers to the state or to non-governmental organizations, such as Ducks Unlimited or Great Outdoors Colorado, for riparian corridor enhancements.

7.1.2 Project Types

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

Sediment Management

Sediment management is a short-term solution to a long-term problem. It involves the removal of sediment deposits upstream of structures, such as diversion structures and bridges, to increase conveyance and to reduce or eliminate backwater. Management of sediment within the channel is a maintenance application that is intended to be used in combination with other projects that address causal issues to prevent future sediment deposits from forming in these areas.

Bridge Modification

Some bridge structures within the project area could be upgraded or replaced to increase their hydraulic capacity to convey high flows.

Channel Modification or Realignment

The channel planform, bedform, and/or profile could be altered as a means of improving sediment transport, reconnecting the channel to its floodplain, and establishing natural ecosystem functions.

Bioengineered Bank Protection

Banks can be stabilized by revetments, rootwads, or willow waddles, among other methods. These provide resistivity to flow and reduce boundary shear stress by creating greater roughness and redirecting flow away from the bank. Revetments are often composed of rock, and are generally covered with soil and vegetation to create a natural looking bank, while rootwads and willow waddles are made with upended trees and harvested willows, respectively. Bank stabilization projects could include enhancement of existing stabilized banks, by removing concrete rubble, or new protection of eroding banks in critical areas.

Regrading and Revegetation

Regrading and revegetating riparian areas are critical elements for creating a healthy and resilient river corridor, and may include any of the following elements:

- Floodplain benches
- Riparian zone plantings
- Secondary channels and backwater ponds

<u>Floodplain Benches</u>

Floodplain benches are developed by reducing the slope of the bank to form multiple flood zones. These zones enhance river health by providing bank stabilization, redirection of stream flow, removal of pollutants, and other varied environmental benefits. An important ecological function of the floodplain bench is that it creates a connection between the low flow channel and the riparian zone. Floodplain benches are often associated with point bars, but can also occur continuously through straight reaches of the river. These benches can be as narrow as 20 feet, but should be greater than 60 feet in width.

<u>Riparian Zone Plantings</u>

Riparian zones protect stream banks from erosion and attenuate high flows. They also provide habitat for fish and wildlife and help stabilize stream channels. The following plants may be utilized within the riparian zone to increase the diversity and vitality of the vegetation:

- Birch (*Betula* sp.)
- Dogwood (*Cornus* sp.)
- Plains Cottonwood (*Populus* deltoides**)**
- Peach Leaf Willow (*Salix* amygdaloides)
- Diamondleaf Willow (*Salix* planifolia)
- Narrowleaf Willow (*Salix* exigua)
- Alder (*Alnus* sp.)
- Chokecherry (*Prunus* virginiana)
- Hardstem Bulrush (*Schoenoplectus* acutus)
- Baltic Rush (*Juncus* balticus)
- Woolly Sedge (*Carex* pellita)
- Beaked Sedge (*Carex* rostrate)
- Clustered Sedge (*Carex* cumulate)
- Spikerush (*Eleocharis* palustris)
- Streambank Wheatgrass (*Elymus* ianceolatus)
- Switchgrass (*Panicum* virgatum)
- Prairie Cordgrass (*Spartina* pectinate)
- Meadow Brome (*Bromus* biebersteinii)
- Fescue (*Festuca* sp.)

Elevation of plantings of wetland plants should be approximately 0.5 feet above the low-flow water surface elevation, and woody plants should be 2 to 5 feet above the low-flow water surface elevation, depending on the size and root mass of the plants, as well as the local hydrology and soils (**Figure 7-7**).

<u>Secondary Channels and Backwater Ponds</u>

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 can also filter stormwater and attenuate high flows.

Develop Public River Access

Additional river access points on public property could be developed for recreation activities, including fishing and bird watching.

Diversion Structure Modification

Many of the existing diversion structures prevent sediment passage and contribute to channel migration. Structures can be modified to allow for sediment to pass, as well as to allow for fish passage.

7.2 Specific Projects

Implementation of any restoration and/or risk reduction strategies identified are site-specific and take advantage of local conditions in and near the river. Some reaches are 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.

7.2.1 Reach 4 Improvements

Reach 4 encompasses a majority of the river channel adjacent to the City of Fort Morgan (**Figure 7-1**). Colorado State Highway 52 and the "Rainbow Bridge" cross the river parallel to the direction of flow, which caused problems during the 2013 flood and during the extended runoff period in the spring of 2015. Both bridges have multiple piers in the river. Significant debris was entrained on the bridge piers, which limited hydraulic conveyance capacity and reduced sediment transport. A large sand bar has formed upstream of the bridge, crossing along the north bank, which further limited conveyance and sediment transport.

The conceptual projects identified for this reach aim to mitigate the factors that contributed to the flood impacts experienced during the 2013 flood event. The project components are as follows:

- Flow redirection: Installation of river training structures (e.g. spur dikes, weirs, or vanes) to redirect flows to the center of the channel and away from the south bank. River training structures can also be used to shield banks from eroding flows, build up the toe of the bank, and direct flows to create a stable alignment. In this case, the training structures could be installed on the outside (south) bend, upstream and downstream of the bridges, to redirect flow to the north. Redirecting flow to the north would prevent erosion and bank cutting to the south, as well as limit the expansion, and possibly reduce, the size of the sand bar.

- Overflow channel: Grading in a dedicated overflow channel through the sand bar along the north bank would create a dedicated flow path for high flows during spring runoff and flood events. Constructing an overflow channel would also remove sediment along the sand bar, thereby increasing the hydraulic capacity through the bridges. An inlet weir at the upstream end of the overflow channel is recommended to control the flow rate into the channel and limit sedimentation in the channel as a flood hydrograph recedes.

- River Corridor Management: Non-structural management of the river corridor throughout the Fort Morgan reach would help increase flow and sediment capacity through the bridges. River corridor management can be approached through multiple avenues, including removal of debris and sediment, land management, and development/building code consideration for gravel pit operations. The City of Fort Morgan has recognized this need and has ongoing maintenance activities in coordination with CDOT within the river corridor for land management and debris removal. Sediment and debris removal should focus on the Colorado State Highway 52 bridge crossing, where sediment accumulation has exacerbated capacity problems. In addition, the City should work with CDOT on annual inspections prior to the runoff season to perform debris removal along the front (west) face of the bridge piers prior to spring runoff to improve conveyance. Following spring runoff, the piers should be cleared again of debris in advance of summer floods that may occur due to thunderstorms upstream along the South Platte River and its tributaries.

7.2.2 Reach 7 Improvements

Significant flood and sedimentation issues exist in this reach, upstream of Messex, Colorado (**Figure 7-2**), highlighted by impacts from the 2013 and 2015 floods. Morgan County officials identified this reach as a top priority based on damages incurred during these floods. Review of the model results in this area reveals limited options to protect the Morgan County Road 33 bridge and adjacent roadway infrastructure from larger floods. The only tangible solutions to protect up to the 100-year flood would involve bridge reconstruction or relocation. More feasible near-term options include:

- Raising the bridge approaches and adjacent roadway to prevent overtopping up to the 25-year event. Current estimates indicate the bridge is impacted by the events as low as the 10-year flood. Additionally, the roadway embankment within the floodway would require an engineering assessment and, potentially, upgrades to ensure it would not fail or breach during a flood event.

- Increase the active floodplain capacity through land management and sediment removal. This option could be combined with the previous recommendation, and may allow for protection up to the 50-year event without impacting the current bridge deck. Land management activities would need to be coordinated closely with CPW to develop healthy riparian areas for habitat improvement. Removal of downed trees and invasive species is in line with CPW goals and could satisfy multiple stakeholder needs.

- Implement a two-stage channel design from the North Sterling diversion through the Morgan County Road 33 bridge crossing. The North Sterling diversion appears to be passing sediment downstream, but the channel through the Morgan County Road 33 bridge is actively aggrading. A two-stage channel could provide low and high flow sediment flushing capability to reduce future maintenance requirements and maintain higher flow conveyance through this reach.

- Implement additional culvert crossings along the railroad bridge within the northern portion of the floodplain. This would help increase capacity through the crossing and relieve backwater flooding on the upstream side of the bridge. County Road W7 and the railroad tracks to the north were overtopped in 2013 and 2015, which exacerbate downstream flooding issues while also impacting local infrastructure. Increased capacity through the railroad bridge would help to relieve these issues at lower flood recurrence intervals.

This plan recommends a progressive approach to implement these options starting with maintenance activities. Increased capacity and infrastructure resiliency should be considered the highest priorities. Note that replacing the railroad bridge with a new structure that has fewer piers in the river is a long-term recommendation. This solution would involve major structural components, collaboration with outside stakeholders, and would likely take more than twenty years to pursue and implement.

7.2.3 Reach 8 Improvements

The conceptual projects identified for this reach, which encompasses Messex, Colorado (**Figure 7-3**), aim to address each of the major factors that contributed to the flood impacts experienced in the 2013 flood event, as identified in Section 6. The project components are as follows:

- Flow direction berm: A levee is recommended on the west side of the railroad tracks, approximately 0.5 miles southwest of Messex. The recommended levee location is the site of an existing driveway and high point, which can easily be improved and engineered to protect downstream infrastructure up to the 100-year flood water surface elevation, plus freeboard. The levee will tie in to the existing high ground south of the Tetsel Ditch. Based on review of hydraulic model results, the railroad embankment does not overtop during the 100-year event at any point downstream, limiting the required extent of additional flood protection and protecting Messex.

- Flood control works: To prevent uncontrolled flows from the Tetsel Ditch toward Messex, this plan recommends a check-gate and wasteway located southwest of the proposed levee location. The gate will provide a mechanism to control flow that can pass through the Tetsel Ditch to the landward side of the levee during flood events and normal ditch operation. The wasteway provides a drainage network to convey excess water toward the South Platte River. During floods, the conveyance path will be limited by flood backwater, but will prevent the Tetsel Ditch from bypassing the levee protection. During normal operation or smaller flood events, the wasteway ditch will leverage a new culvert structure through the County Road and railroad embankment, which will then follow Washington County Road P toward the South Platte River.

- Drainage improvements: In addition to, or in lieu of, the previous project recommendations, a drainage network should be constructed within Messex. The proposed network would consist of a ditch along Washington County Road 59.5 through Messex to the east, then along Washington County Road P 5/10 to the south through a new culvert under Washington County Road 17.8 and the railroad embankment toward the South Platte River. The main purpose of this drainage system is to allow flood water and seepage to drain out of Messex following a flood event. The culvert would drain to an area outside of the FEMA 100-year floodplain, indicating that backwater from the South Platte River would not prevent drainage from Messex.

7.2.4 Reach 11 Improvements

To better frame recommendations and potential projects associated with this reach, which encompasses Sterling, Colorado (**Figure 7-4**), this plan breaks the recommendations into short-term, mid-term, and long-term recommendations. The short-term solutions are intended to be management and maintenance activities that could be implemented within the next 5 years. The mid-term solutions are broader in scale and would involve structural components, but could be implemented in the next 5 to 20 years, pending the availability of funding sources. The long-term solutions would involve major structural components, collaboration with outside stakeholders, and would likely take more than 20 years to pursue and implement. This tiered set of solutions allows stakeholders to have a highly-inclusive set of projects, with the understanding that a progressive approach will be required.

<u>Sterling Short-Term</u>:

- Flood-proof critical infrastructure: The 2013 flood caused major impacts to the wastewater treatment system and the electrical substation. This plan recommends prioritizing simple flood-proofing measures for each of these systems to ensure uninterrupted function through events up to the 100-year discharge in magnitude.

    - Wastewater Treatment System: The wastewater treatment plant (WWTP) itself is located outside of the floodplain, but the lift station that moves raw sewage from the city to the plant is located well within the floodplain. Due to impending flooding in 2013, the City of Sterling had to shut down the pumps, causing an interruption to the town's sewage operations and a no-flush order for residents. Following the flood, damages were repaired and the system was brought back online, but no steps were taken to protect the infrastructure from a similar future flood event. Based on conversations with the City of Sterling, plans are in place to build an earthen floodwall around the facility. Additionally, Sterling is in the process of revamping their WWTP, and as part of those plans, will rebuild the lift station with submersible pumps that are protected against future flood events. These plans are in line with recommendations developed from this Master Plan. The floodwall around the facility should follow FEMA National Flood Insurance Program (NFIP) guidance, with a minimum finished elevation that is 1foot above the 100-year floodplain. Design requirements can be found in the FEMA floodwall standards guidance document (FEMA 2012).

    - Electrical Substation: The electrical substation is located within the 100-year floodplain northwest of the South Platte River. While the station experienced flooding in 2013, there was not an interruption in service. Based on conversations with the City of Sterling and Xcel Energy, repairs were made and upgrades were implemented to the facility to ensure that critical components were raised above the floodplain. This plan recommends reviewing the latest 100-year floodplain water surface elevations in this area to provide protection up to this event. Based on results from this assessment, emergency action plans should be documented in the City's plan during a flood event to provide protection from impending flood events.

- River Corridor Management: Non-structural management of the river corridor throughout the Sterling reach will help increase flow and sediment capacity and improve ecological habitat. River corridor management can be approached through multiple avenues, including removal of debris and sediment, land management, and development/building code consideration. The City of Sterling has recognized this need and has ongoing maintenance activities within the river corridor for land management and debris removal. Sediment and debris removal should focus on the U.S. Highway 6 bridge crossings, where sediment accumulation has exacerbated capacity problems. Care would need to be taken to prevent impacts to the Lowline diversion downstream of the bridge. A land management plan should aim to increase hydraulic and sediment conveyance capacity and ecological habitat in the project reach through strategic removal of vegetation and debris. Most of the active river corridor in this reach consists of CPW SWAs.

<u>Sterling Mid-Term</u>:

- Stream Restoration Plan: A holistic river restoration conceptual plan has been developed for the Sterling reach to address the major issues related to flood and sediment management for local stakeholders. Building on the short-term management plans, this comprehensive project plan is intended to provide a sustainable set of solutions to improve sediment and flood conveyance, improve diversion infrastructure, protect property and infrastructure adjacent to the active floodplain, and improve river habitat and general river corridor health. Review of hydraulic model results and floodplain mapping in this area, protection up to the 100-year event would require significant modification or reconstruction of the U.S. Highway 6 bridge crossing, falling outside of the intended scope and feasibility of the mid-term project plan. The plan components recommended below are intended to provide maximum flood protection (approximately up to the 25-year event) without a major bridge project. Implementation of any project components requires a detailed hydraulic analysis to ensure feasibility.

    - Channel and Active Floodplain Improvements: Improvements aim to increase flood and sediment conveyance, establish a healthy riparian river corridor, and help protect against migration and avulsion. Improvements include strategic channel realignment, secondary and tertiary high flow channel activation, riparian buffer restoration, and bank protection. Channel realignment is proposed approximately 4,500 feet upstream of the U.S. Highway 6 bridge crossings, leveraging an

CDM Smith

existing high flow path directing the main channel away from an erosional hazard point on the western side of the floodplain. To deter future channel migration, the riparian buffer should be reestablished at the erosional hazard area. The main channel design would utilize a low-flow channel area to allow for consistent low flow sediment passage. Two submerged boulder weir structures are proposed downstream to activate a secondary and tertiary high-flow channel, connecting to the middle and eastern U.S. Highway 6 bridge crossings, respectively. The boulder weirs should be designed to activate these channels at annual to bi-annual flushing flows to reduce future maintenance requirements and help establish healthy riparian habitat areas. Downstream of the U.S. Highway 6 bridge crossing, the western portion of the floodplain should be reclaimed to receive more frequent flows and activate the western railroad crossing.

- Guide Levees: To protect properties, infrastructure, and the U.S. Highway 6 bridge approaches from flooding up to the 25-year event, guide levees should be constructed on the east and west sides of the active floodplain. This level of flood protection was determined to be the highest possible without impacting the low chord of the U.S. Highway 6 bridge crossings, due to an estimated water surface elevation increase of approximately 1 foot. Note that this plan assumed a portion of this water surface elevation increase would be mitigated through floodplain flow capacity improvements. The levee alignment would utilize existing high points in the floodplain. Based on a review of model results and underlying terrain, a 1-foot or less increase in height would be required along the proposed alignment (not including free-board accommodations). A benefit-cost analysis would need to be conducted to confirm feasibility and help guide the project design.

- Henderson-Smith Diversion Improvements: The Henderson-Smith diversion is located approximately 1.6 river miles upstream of the headgate structure at the U.S. Highway 6 bridge crossing, which conveys flow into the canal to the northeast and wastes excess flows back to the South Platte River to the northwest. The diversion is connected to the headgate by an off-chute channel located on the east side of the active floodplain, which requires significant maintenance every year. The diversion uses slide-boards and requires manual operation. Options for improving this diversion include:

    1. Conversion of the water right to Alternate Point of Diversion wells. A portion of this water right has already been converted; converting the remaining portion to wells will decrease maintenance requirements and is a significantly cheaper option than rebuilding the diversion structure.

    2. Relocate the diversion downstream to a more stable location, closer to the headgate structure, and replace the headgate with a structure capable of passing sediment. This would significantly reduce upstream sand dam maintenance, ditch maintenance (moving the diversion closer to the headgate would reduce the length of ditch in the active floodplain), and improve functionality with an upgraded structure. This option is contingent on the decreed point of diversion, which, based on DWR's records is located at the headgate near the U.S. Highway 6 bridge crossing. If the decree ties the point of diversion to the location of the current slide-board structure, this option may not be feasible.

- Lowline Diversion Improvements: The current Lowline diversion is dependent on flows reaching the western U.S. Highway 6 bridge crossing. The project channel improvement and Henderson-Smith project components specified above will address the flow reliability issues for the Lowline diversion. This plan recommends that the diversion structure be replaced with a structure capable of passing sediment.

<u>Sterling Long-Term</u>:

Guide Levee and Bridge Reconstruction: The U.S. Highway 6 bridge crossing is a major emergency access route and a long-term project would provide a solution to increase the flood conveyance at the bridge crossings to prevent impacts and closure up to the 100-year flood event. Based on hydraulic model results, this would require major bridge rehabilitation or complete reconstruction. Additionally, upstream and downstream guide levees would be required to protect bridge approaches, properties, and infrastructure adjacent to the active river floodplain. Project specific details for this long-term option are not provided as part of this plan.

7.2.5 Reach 15 Improvements

The town of Crook is located in a topographically low area relative the adjacent floodplain to the south. Flood events that overtop the Harmony Ditch berm will likely significantly impact the town. Although Crook is completely within the draft CHAMP 100-year FEMA floodplain, the model results indicate that the Harmony Ditch berm only overtops in three to four specific locations upstream and adjacent to the town (**Figure 7-5**). The following are potential project concepts recommended for this reach:

- A FEMA-accredited levee for the entire length of the berm would likely be cost prohibitive and impractical, but strategic improvements to the existing berm could help provide protection up to the 100-year flood event.

- In combination with berm improvements, land and sediment management through the active floodplain would help to improve flood conveyance, and improve riparian habitats. This management would include removal of vegetated sand bars, downed trees, debris, and invasive plant species.

- The north approach to the Colorado State Highway 55A bridge crossing overtops at approximately the 10-year flood event. This plan recommends constructing a high-water bypass to allow flood flows to cross the roadway and limit roadway damage.

- An ongoing CDOT project is evaluating the scour hole on the west side of the Colorado State Highway 55A bridge crossing. The above recommended concepts should consider the components proposed as part of the CDOT plan and integrate project concepts to work in conjunction with the CDOT plan.

7.2.6 Reach 18 Improvements

In 2013, the most significant flood impacts in this reach were caused by backwater through two railroad drainage crossings south of Ovid. This was initially identified as a significant project need through review of the 2013 flood impacts, but based on conversations with Sedgewick County, flap-gates were installed at these crossings following the 2013 floods to prevent similar backwater flooding during future high-flow events in the South Platte River. Development of the other project concepts focused on protecting infrastructure south of the railroad tracks (**Figure 7-6**). The project concepts and recommendations are described as follows:

- WWTP Flood-Proofing: Although the WWTP is within the draft CHAMP 100-year floodplain, review of the model results indicates that the facility is elevated out of the floodplain. This plan recommends an assessment of the facility and the elevations of the critical components to confirm that the flood-proofing is consistent with FEMA regulations.

- Channel Improvements: At approximately 0.5 miles upstream of the Sedgwick County Road 29 bridge crossing, the main channel of the South Platte River is actively avulsing (abandoning the current alignment) at a large meander bend. To protect against channel migration and improve stability, this plan recommends channel realignment by reestablishing the riparian buffer at the avulsing point. This bank should be reinforced to stabilize the new alignment. Downstream of the realignment, a boulder weir should be constructed to activate the southern high-flow channel and deliver consistent low flows to the Liddle point of diversion. The low and high flow channels help increase sediment conveyance through this reach. Additionally, maintenance requirements associated with construction of sand dams for the Liddle diversion will be reduced significantly.

- Liddle Ditch Improvements: This plan recommends upgrading the Liddle diversion structure to a structure that allows sediment passage to reduce maintenance and improve reach-wide sediment conveyance.

7.2.7 Reach 19 Improvements

This is the downstream-most reach in the project area, containing the town of Julesburg, which is elevated outside of the 100-year floodplain. Although minimal damage was reported in Julesburg due to the 2013 flood event, significant flood and geomorphic risks were identified during the risk assessment as part of this plan, warranting recommendations to mitigate risk and increase resiliency (**Figure 7-7**). The specific concepts are described as follows:

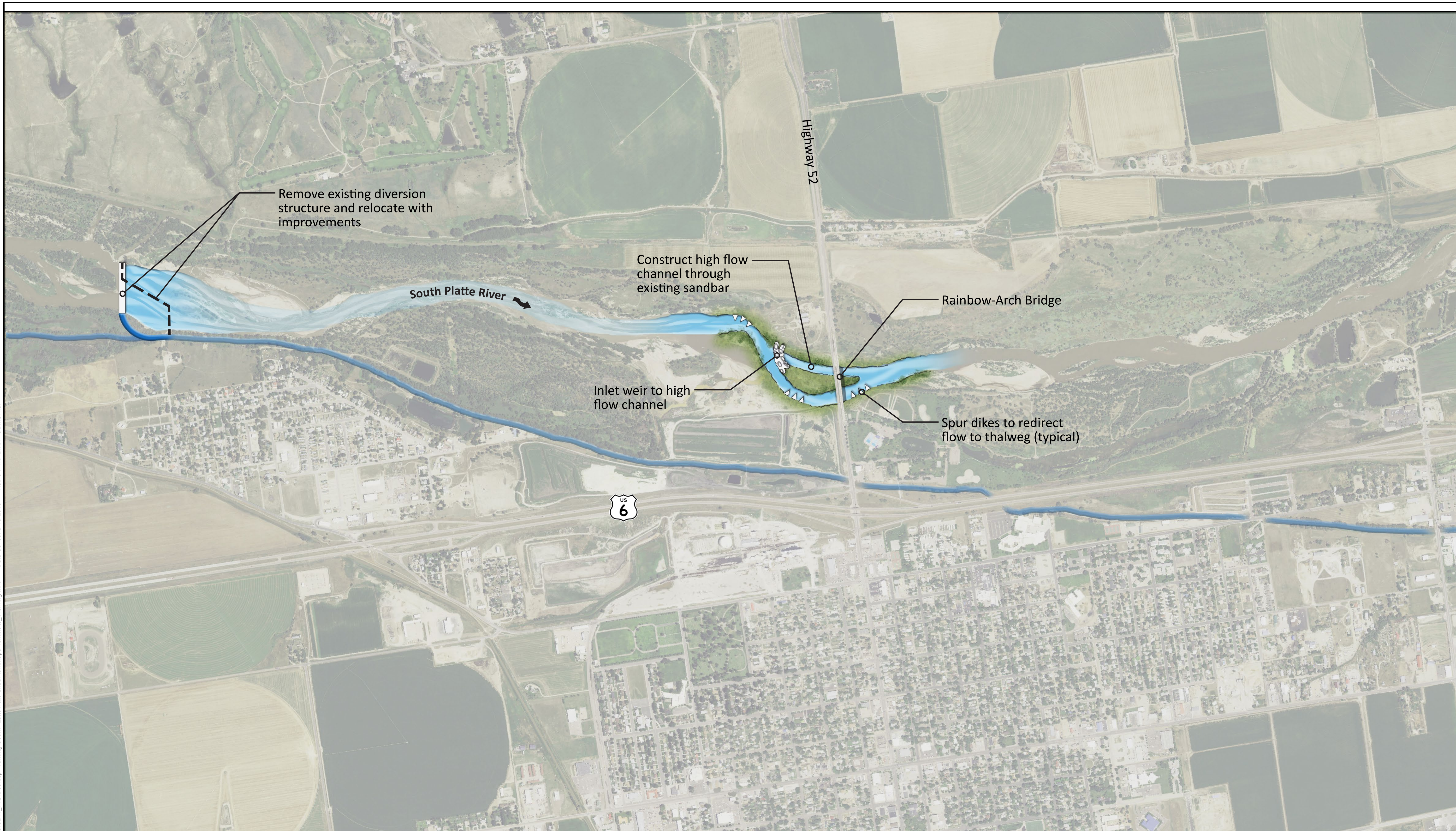
- Channel Realignment: The main stem of the channel currently occupies the southern portion of the floodplain and runs through the southern-most U.S. Highway 385 bridge crossing. The channel poses a significant erosion hazard to adjacent infrastructure south of the floodplain and at the bridge crossing. This concept proposes to realign the main stem of the channel into the typical high-flow channel and through the center crossing by constructing a boulder weir, reestablishing the riparian buffer at the realignment point, and clearing sediment and debris through the new main channel. This channel concept is intended to increase flow and sediment conveyance capacity and provide channel stability to help prevent geomorphic hazards. The boulder weir will direct low flows through the center channel. The southern channel would be activated during moderate to high flow events (starting at approximately the 1-year event) when the boulder weir is overtopped. A riparian buffer should be established at and adjacent to the boulder weir to protect against avulsion and lateral migration into the southern floodplain. An additional boulder weir downstream would allow for activation of the northern channels through the bridge crossings at a designed flow rate to help manage sediment with frequent flushing flows and provide relief to the main channel during high flow events.

- WWTP Flood-Proofing: Although the Julesburg WWTP was not impacted during the 2013 or 2015 event, the Draft CHAMP 100-year model results indicate that the facility may be impacted by flood events as small as the 10-year event. This plan recommends flood-proofing the critical components of the facility to protect against flood events up to the 100-year water surface elevation (WSEL), plus freeboard. The flood-proofing design should follow FEMA guidance. Protection of this facility is considered a critical need for resiliency against impacts from future flood events throughout this reach of the South Platte River.

- Land Management: To increase capacity through the active floodplain and help establish the proposed channel alignment, land management activities should be conducted to remove sediment and debris from the floodplain. Future channel improvements should ease maintenance activities, but large flood events may necessitate additional maintenance activities.

7.2.8 Project-Wide Irrigation Infrastructure Improvements

Recommendations and proposed improvements have been established for all of the active diversion infrastructure throughout the lower South Platte River project reach (**Table 7-1**). These recommendations are based on an extensive inventory that was performed, desktop analysis, site visits, and conversations with stakeholders. Recommended improvements to the diversion structures within the high-priority reaches are discussed above.



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South Platte River Master Plan

Figure 7-1: Proposed Projects near Fort Morgan, Reach 4

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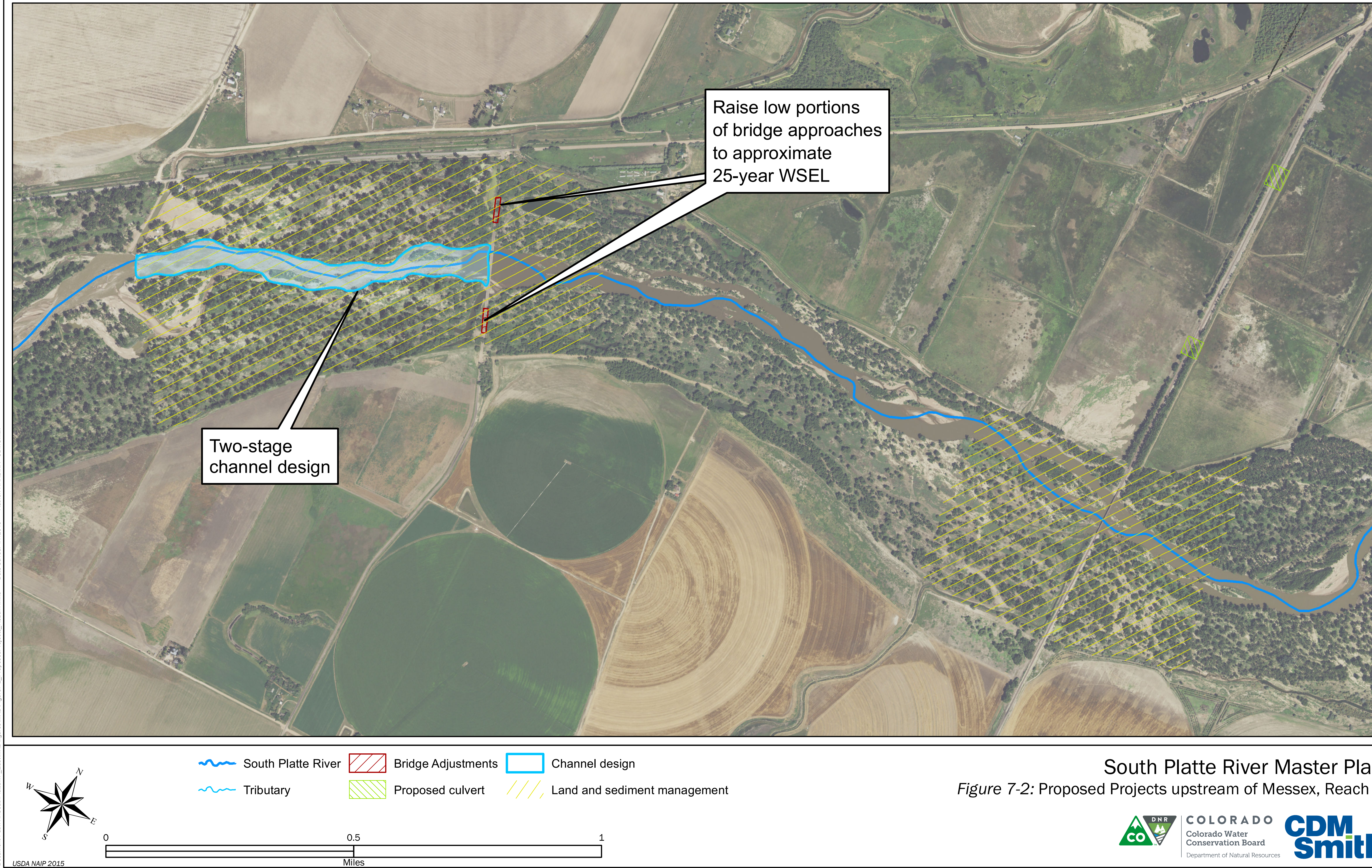

South Platte River Master Plan

Figure 7-2: Proposed Projects upstream of Messex, Reach 7

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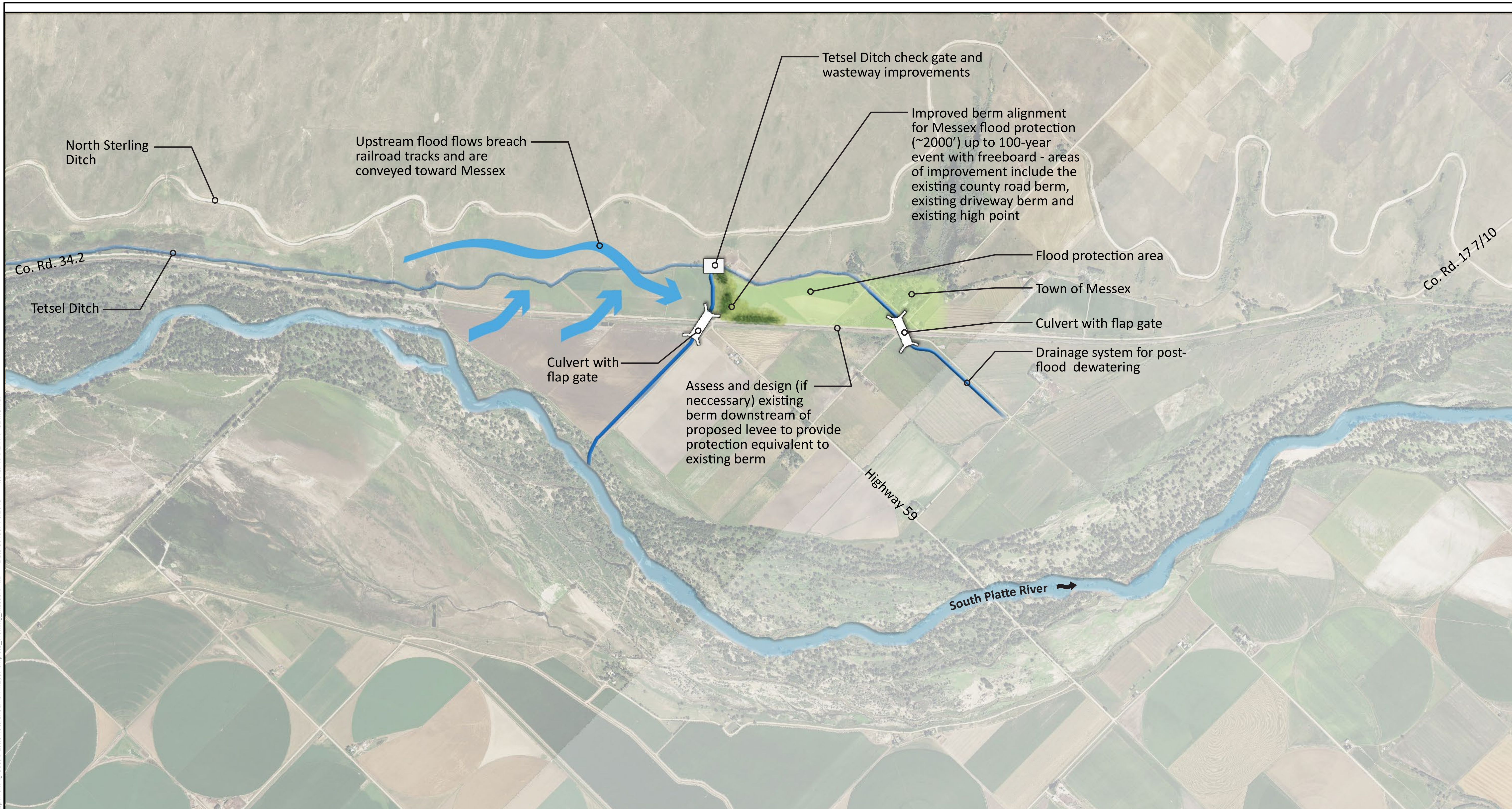

South Platte River Master Plan

Figure 7-3: Proposed Projects near Messex, Reach 8

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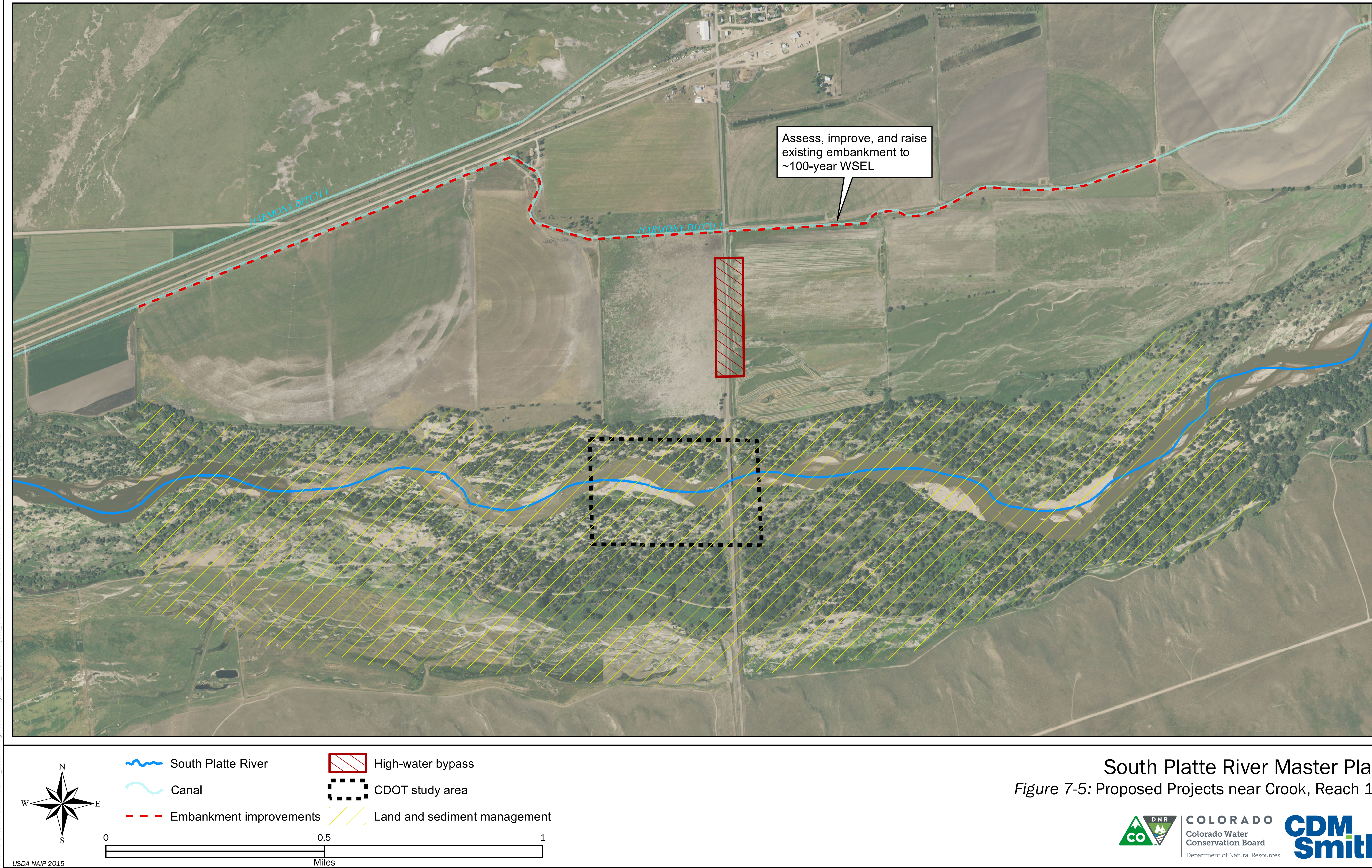
South Platte River Master Plan

Figure 7-4: Proposed Projects near Sterling, Reach 11



South Platte River Master Plan

Figure 7-5: Proposed Projects near Crook, Reach 15

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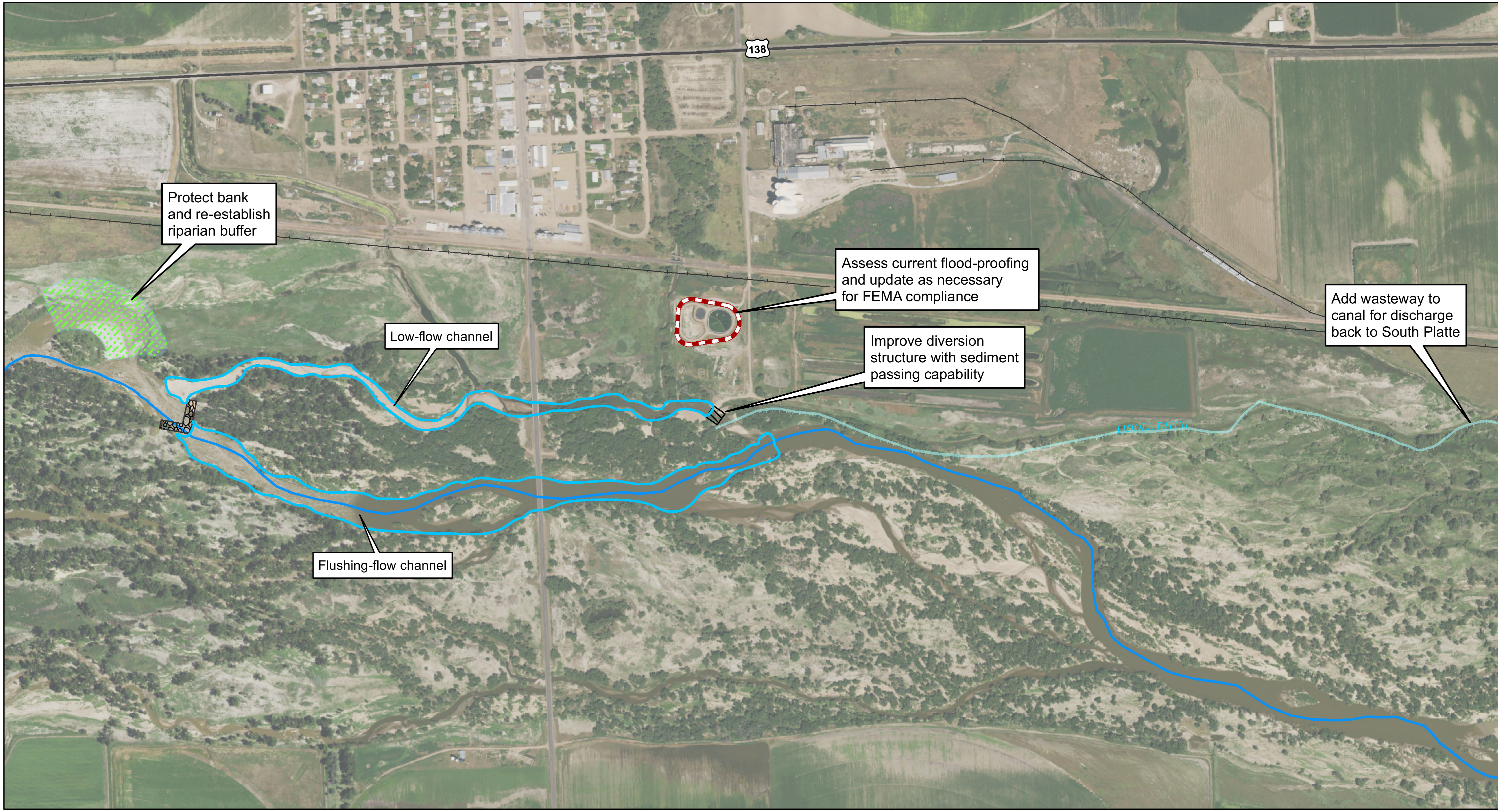

South Platte River
Tributary
Canal
Railroad
Bank Protection
Boulder Weir
Channel Design
Diversion Structure
Flood-proofing

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South Platte River Master Plan

Figure 7-6: Proposed Projects near Ovid, Reach 18

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Department of Natural Resources

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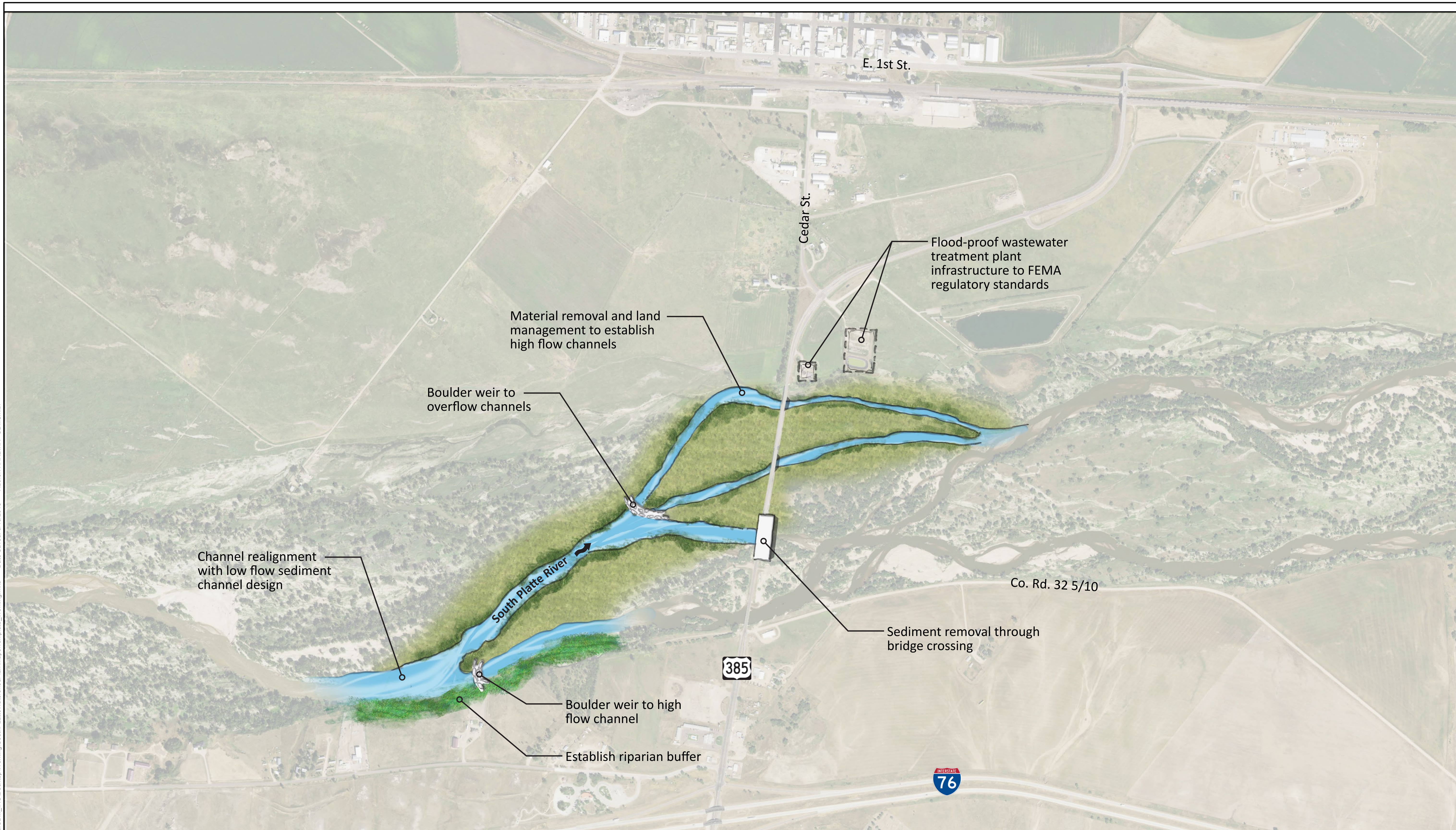

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South Platte River Master Plan

Figure 7-7: Proposed Projects near Julesburg, Reach 19

Table 7-1: Recommended Improvements of Water Diversion Infrastructure

Water Conservation District	Water District No. & Name	County	Study Reach No.	Diversion Name	Canal/Ditch Name	Description of Improvements
	1. South Platte: Greeley to Balzac	Morgan	2	Fort Morgan	Fort Morgan Canal	Could replace left abutment sanddam with a permenant structure. Otherwise no additional improvements recommended.
Lower South Platte			4	Deuel Snyder & Upper Platte Beaver	Deuel & Snyder Canal	Protect left bank sand berm to prevent failure during overtopping. Headgate appears OK. Canal downstream is OK and has existing wasteway. Install sediment passage facility in diversion immediately downstream of headgate.
					Upper Platte Beaver Canal	Improve sediment passage gates. Replace 80 feet of diversion dam to improve river control and sediment passage. Protect around headgate to prevent failure of tie-in banks during overtopping. Install wasteway facility approximately 1,960 feet downstream of headgate.
			5	Tremont & Lower Platte Beaver	Tremont Ditch	Ensure longterm protection of headgate. Possibly reallign canal to minimize sediment deposition.
					Lower Platte Beaver Canal	Install wasteway prior to MCR 25 extended.
			7	North Sterling	North Sterling Canal	Widen diversion dam to allow larger flood & sediment passage thereby lessening the need for rightbank sand dams. Upgrade 0.9 mi Wasteway facility to prevent captured flood flows from continuing down canal. Possible install control gates downstream of 0.9 Wasteway at location of measurement or next downstream bridge.
					Union Ditch	See diversion dam note above.
			8	Tetsel & Prewitt	Tetsel Ditch	Modify Diversion Dam to incorporate sediment passage capabilities.
					Prewitt Inlet Canal	See diversion dam note above.
		Wash-ington	8	South Platte	South Platte Ditch	Modify or replace diversion dam to prevent left abutment scouring and increase sediment passage capabilities. Increase capacity of existing wasteway or add additional wasteways to prevent ditch blow outs. Headgate wasteway/return stucture could incorporate a sediment trap and flushing gate.
	64. South Platte: Balzac to Stateline	Logan	8	Farmers Pawnee	Farmers Pawnee Ditch	None.
			9	Schneider	Schneider Ditch	Possibly relocate diversion and headgate upstream to above sandam location. Possibly locate canal to south/east side of LCR 29. Enlarge capacity of existing wasteway. Otherwise at a minimum install significant sediment passage capabilities in existing diversion dam.
			10	Springerdale	Springdale Ditch	Possibly relocate diversion and headgate upstream to sanddam location with canal located as near to U.S. 6 as possible. New canal would tie back in upstream of existing wasteway.
			10	Sterling No.1	Sterling Irr. Co Ditch 1	Possibly relocate canal north out of active channel zone (will be difficult to cross Pawnee Ck. Rebuild 3.10 mi wasteway (Possibly incorporate into measurement structure). Possibly add passive concrete sill wasteway upstream of LCR 24 to prevent captured 500-year floodwaters from entering Sterling.
			11	Henderson Smith	Henderson Smith Ditch	Alt. #1. Possibly move diversion & headgate upstream approximately 1 mile to a more stable section of river? Alt.#2. Possible candidate to convert to APOD - Wells.
			11	Lowline	Lowline Ditch	Possibly move diversion & add headgate at an upstream more stable section of river: Options 1. At U.S. 6 crossing, or Option 2. Combine with Henderson Smith Diversion (another 2 miles upstream).
			12	Bravo	Bravo&Farmers People's Ditch	Possibly move diversion dam & headgate upstream above sanddams and split flows. Rebuild existing diversion into another wasteway and protect foundation from undermining. Provide erosion protection or abandon existing wasteway facility.
			12	Iliff & Platte	Iliff&Platte Valley Ditch	Possibly replace sanddam diversion with a permenant structure. Siting permenant diversion structure maybe difficult due to presence of local stream (water rights??).
			13	Powel & Blair	Powell & Blair Ditch	Possibly replace sanddam diversion with a permenant structure. Siting permenant diversion structure maybe difficult due to presence of local stream (water rights??).
			14	Ramsey	Ramsey Ditch	Potential candidate to convert to APOD - Well(s)
			14	Harmony	Harmony Ditch #1	Increase sediment passage capabilities (add additional bladder gates) of diversion structure.
		Sedgwick	17	Peterson	Peterson Ditch	None.
			18	South Reservation	South Reservation Ditch	Evaluate relocating diversion dam upstream of the sanddams. At minimum replace existing diversion dam with a structure capable of passing sediment and larger floods. Add a wasteway to ditch system.
			18	Liddle	Liddle Ditch	Replace diversion dam with a structure capable of passing sediment and larger floods. Replace headgate and add wasteway to downstream ditch system.

Section 8

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