Clark Fork River Reach A Phase 2 Preliminary Design Plan

Clark Fork River Operable Unit Milltown Reservoir/Clark Fork River NPL Site Powell, Deer Lodge, Granite and Missoula Counties, Montana

Prepared for:

Montana Department of Environmental Quality

Montana Department of Justice, Natural Resource Damage Program

June 27, 2014

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ACRONYMS

ARCO	Atlantic Richfield Company
ASTM	American Society for Testing Materials
BMP	Best Management Practice
BNSF	Burlington Northern Santa Fe (railroad)
BP	British Petroleum
BT	Brush Trench
CFROU	Clark Fork River Operable Unit
CMZ	Channel Migration Zone
COC	Contaminant of Concern
CQAP	Construction Quality Assurance Plan
CSWBMPP	Construction Stormwater Best Management Practices Plan
D50	The particle diameter exceeded 50 percent of the time
D84	The particle diameter exceeded 84 percent of the time
DEM	Digital Elevation Model
DEQ	Department of Environmental Quality
DVSL	Double Vegetated Soil Lift
EPA	Environmental Protection Agency
FEMA	Federal emergency Management Agency
FWP	Fish, Wildlife and Parks
GIS	Geographic Information System
IWD	Inverse Distance Weighted
LiDAR	Light Detection and Ranging
LLC	Limited Liability Corporation
LP	Limited Partnership
MDT	Montana Department of Transportation
NAD	North American Datum
NAIP	National Agriculture Imagery Program
NAVD	North American Vertical Datum
NRDP	Natural Resource Damage Program
NWI	National Wetland Inventory
PB	Point Bar
PDP	Preliminary Design Plan
PV	Preserve Vegetation
QA	Quality Assurance
QC	Quality Control
RAWP	Remedial Action Work Plan
RipES	Riparian Evaluation System

ROD	Record of Decision
TIN	Triangulated Irregular Network
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WCBB	Willow Cuttings Behind Bank
WSE	Water Surface Elevation

Section 1
Introduction

The Clark Fork River Operable Unit (CFROU) is part of the Milltown Reservoir/Clark Fork River Superfund Site ("Clark Fork Site" or "Site") and includes the uppermost 120 miles of the Clark Fork River (CFR) between Warm Springs Ponds and Missoula, Montana. The Operable Unit is divided into three reaches (A, B, and C) as shown on Figure 1-1.

The Montana Department of Environmental Quality (DEQ), as lead agency, oversees, manages, coordinates, designs, and implements the Remedial Action for the Clark Fork Site in consultation with the U.S. Environmental Protection Agency (USEPA). DEQ coordinates with the State of Montana Natural Resource Damage Program (NRDP) and the U.S. National Park Service (NPS) for the implementation and integration of restoration components into the Work. Four primary functions of consultation and coordination among the agencies for the Clark Fork Site are to 1) understand and receive the information to be collected, 2) understand how that information is to be analyzed, 3) provide review and comment, and 4) maximize the use of the resources available for and the environmental benefits to the Clark Fork Site in the successful and cost-effective completion of the Work.

This Preliminary Design Plan (PDP) presents the scope of the Agencies' intended activities for CFR Reach A, Phase 2, which consists of 1.9 river miles starting from a point immediately downstream of the previously constructed Phase 1 and continuing to Perkins Lane. The Phase 2 Project area, shown on Figure 1-2, consists of the river and its floodplain within these boundaries. The Phase 2 constituent properties are owned by the State of Montana, Logan Ranch, LLC, and Lampert Ranch LP.

This PDP applies design-level factors to site-specific conditions, which, through remedial design/remedial action (RD/RA) allow implementation of Clark Fork River Record of Decision (ROD) requirements, including Performance Standards and Remedial Goals. Considerations include groundwater, riparian vegetation, geomorphic stability, contaminant sampling, ownership, infrastructure, land use, and certain site-specific remedy requirements. The purpose of this PDP is to present pertinent information on site-specific conditions, design criteria, and the basis of the design.. This PDP is accompanied by a preliminary design drawing set showing, among other things, the proposed floodplain grading and streambank treatments.

This PDP has been prepared for the Montana Department of Environmental Quality (DEQ) by the design consultants CDM Smith Inc., (CDM Smith), Applied Geomorphology, Inc., (AGI), and Geum Environmental Consulting, Inc., (Geum).

1.1 Site Description

Heavy metals originating from historic mining activities, milling and smelting processes associated with the Anaconda Company operations in Butte and Anaconda have accumulated on the Clark Fork River stream banks and floodplain over the last century. The primary sources of contamination are tailings and contaminated sediments mixed with soils in the stream banks and floodplains ("tailings /

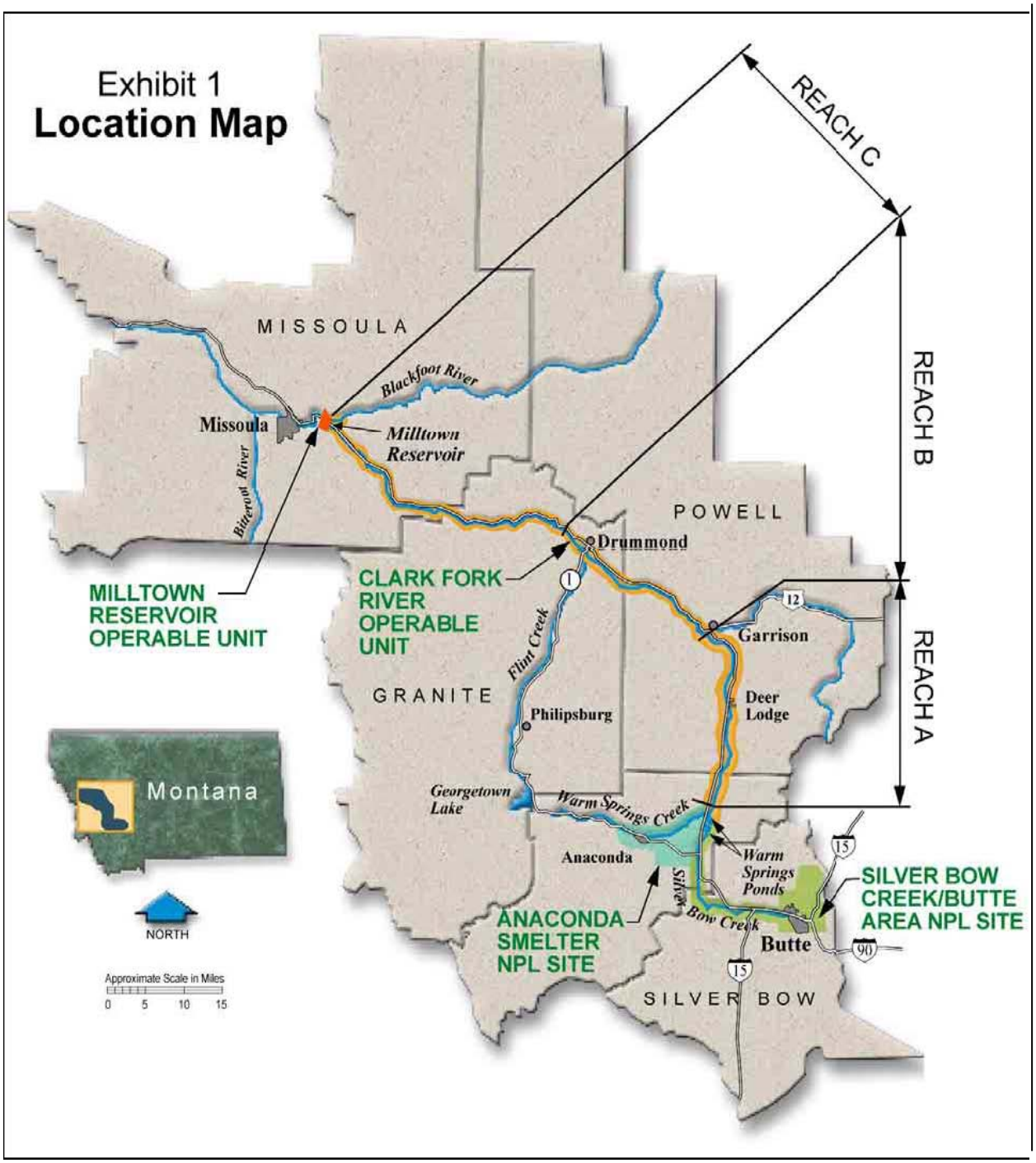

Figure 1-1. Clark Fork River Operable Unit Reaches.

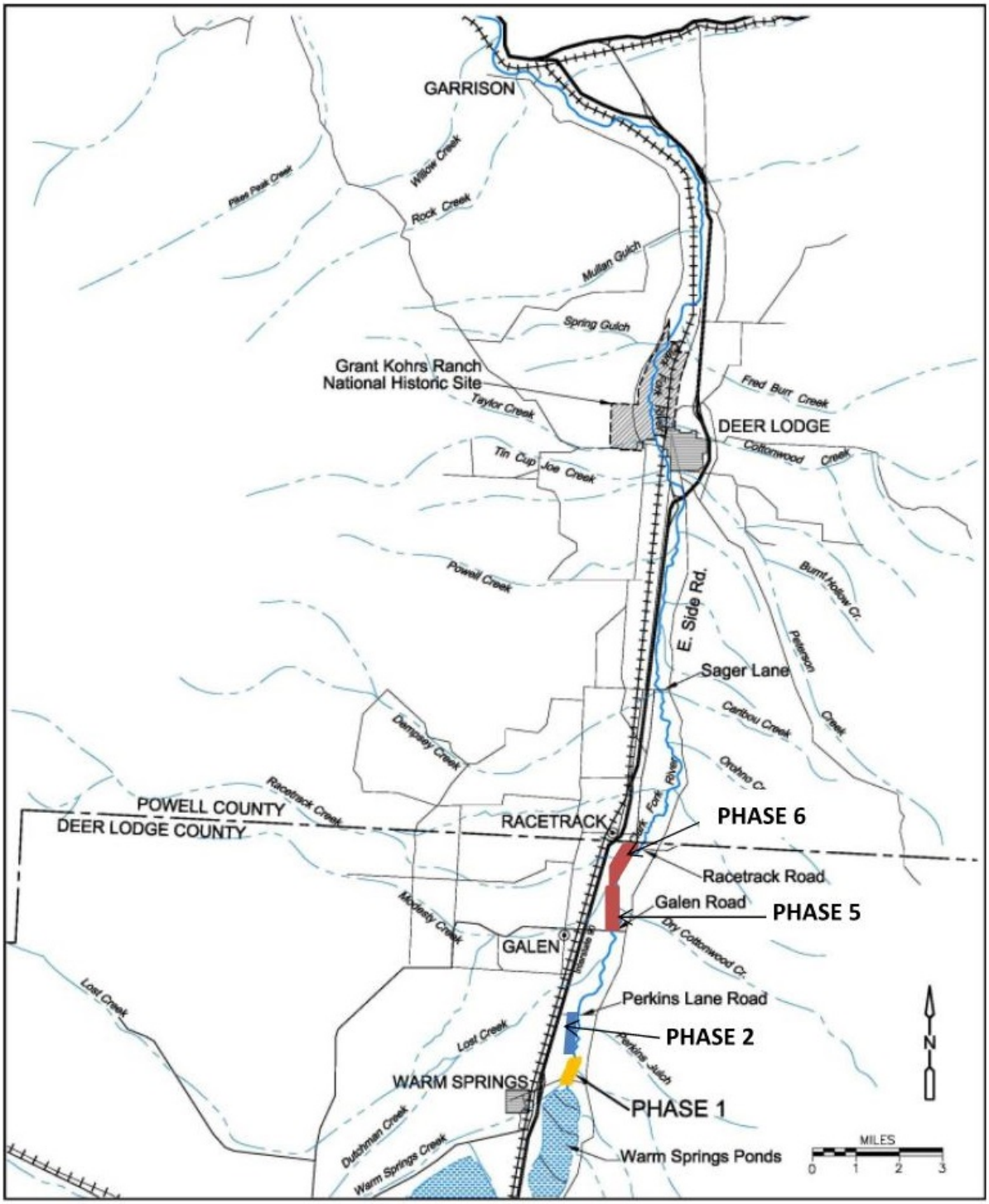

Figure 1-2. Reach A of the Clark Fork River Operable Unit.

impacted soils"), which erode during high flow events and enter the river and other surface waters. In addition to erosion, heavy metals are leached from the contaminated sediments and tailings / impacted soils directly into the groundwater and eventually reach surface water. These contaminant transport pathways result in impacts to terrestrial and aquatic life along the Clark Fork River as described in the ROD for the Site (USEPA/MDEQ, 2004).

The Phase 2 Project area contains floodplain tailings / impacted soils which support plant growth to varying degrees. The vegetated areas consist of grasslands, shrub lands (including dead and living willows as well as water birch) and scattered aspen and cottonwood. In 1990 the Governor's Demonstration Project implemented lime amendment and revegetation techniques in slickens ("severely impacted areas") in the Clark Fork River floodplain and reconstructed some eroding banks in the Phase 2 Project area (Schafer, 1991). The lime amended areas currently support grassland vegetation. Shrubs are beginning to establish in some of the lower elevation portions of these areas.

Figure 1-3 is a vicinity map of the Project area and Figure 1-4 is a map of Phase 2. An oxbow is located in the upstream portion of the site that has been largely cutoff by a very active avulsion. An abandoned railroad grade from the Chicago, Milwaukee Railroad is located near portions of the eastern boundary of Phase 2 and restricts the river to a straight channel for about 400 feet. Lower in Phase 2, a secondary channel splits off to the west before rejoining the mainstem in about 1,000 feet. Just below this junction, a diversion to the Helen Johnson Ditch occurs on the right bank. Below this point an artificially straightened channel conducts the river to Perkins Lane bridge at the downstream boundary of Phase 2.

The floodplain of the Clark Fork River at the Site was raised through deposition of flood-transported tailings on the overbanks over 100 years ago (Smith *et al*., 1998; Smith and Griffin, 2002). This limited access of floodwaters to the floodplain for over 100 years and resulted in significant changes in floodplain vegetation in addition to those caused by metals contamination.

1.2 Purpose

The purpose of this PDP is to outline the scope of remedial activities for design of the remedy in Phase 2 and describe the design basis for the selected design approach. The primary sources of contamination in Reach A are tailings / impacted soil in streambanks and the historic floodplain. These sources directly impact plant and animal life through uptake and ingestion, and also impact humans who come in contact with the soils. Contaminants move from tailings / impacted soils directly into the river through the process of erosion, increasing impacts on aquatic life. Metals also leach directly from the tailings into groundwater and surface water. The lack of typical floodplain vegetation in Phase 2 is caused primarily by acid generation, metals uptake, and disconnection between the aggraded floodplain and underlying groundwater surface. These factors prevent existing vegetation from maintaining the stability of streambanks and the floodplain [1].

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[1] Successful reclamation of land contaminated by mining activities within the Clark Fork River OU is defined as establishing plant communities capable of stabilizing soils against wind and water erosion, reducing transport of COCs to groundwater and surface water, and compliance with ARARs or replacement standards, in perpetuity. Goals of the removal action and plant community establishment are to accomplish the following:

- Minimize direct contact with arsenic, thus reducing the potential risk of human exposure to acceptable riskbased levels.
- Provide geomorphic stability to streambanks, thus minimizing release of COCs to the river.

1.3 Contaminant Processes

Section 2.0 provides information on groundwater, riparian vegetation, geomorphic stability, contaminant sampling, ownership, infrastructure, land use, and **s**ite-specific remedy requirements. As the information makes clear, Phase 2 exhibits extensive contamination within the channel migration zone, dominating the floodplain system. The Phase 2 polygons within the CMZ meet the classification of slickens / severely impacted areas. In addition, certain areas outside the CMZ exhibit extensive contamination where the thickness of tailings / impacted soils is greater than or equal to two feet (tailings and impacted soils extending deeper than 2 feet), also below the 2-year water surface elevation (tailings / impacted soils too wet to effectively treat). These outside the CMZ polygons also meet the classification of severely impacted areas. Lastly, certain discrete areas in addition to these two sets of polygons demonstrate arsenic levels above 620 mg/kg, and are also in the 2-year water surface elevation, and therefore meet the classification of severely impacted areas.

The primary sources of contamination in Reach A are concentrated tailings deposits and tailings mixed with soil along the river banks and on the floodplain. These contaminant sources directly impact plants, terrestrial wildlife, aquatic organisms, and humans through uptake and ingestion. Effects of tailings deposition include but are not limited to degraded vegetation communities, stands of dead willows, and areas devoid of vegetation. These impacts are caused by acid generating potential of tailings during oxidation and phytotoxicity of metals in the soil. In addition to these geochemical impacts, tailings aggraded on the floodplain have physically perched the floodplain above the normal hydrologic regime of the river, causing reduced floodplain inundation frequency and duration, reduced riparian vegetation access to groundwater, and concentrated in-stream flows. Contaminants have been physically recruited into the channel by bank erosion, and some of those reworked contaminants have been deposited within in-channel depositional features such as point bars and low bank-attached bars. In addition to these processes, metals also move through the soil column or are dissolved in the water during fluctuating periods of oxidizing and reducing conditions and can be taken up by plants. Until the contaminants are removed, these conditions will persist within the river system and metals will be available for biologic uptake.

Therefore, to meet the ROD requirements this design for Phase 2 will: 1) remove severely impacted areas, 2) provide geomorphic stability during reestablishment of riparian vegetation after construction, and, ultimately, 3) revegetate through the establishment of plant communities capable of stabilizing soils against wind and water erosion, reducing transport of COCs to groundwater and surface water, and compliance with ARARs or replacement standards, in perpetuity.

- Improve agricultural production by reducing or eliminating phytotoxic conditions, thus providing for multiple land uses.
- Minimize surface water erosion and COC transport to surface water through methods described in the Selected Remedy.
- Minimize transport of COCs to groundwater.
- Minimize wind erosion and movement of contaminated soils onto adjacent lands, thus eliminating human, agricultural, and wildlife exposure.
- Remediate contaminated soils to be compatible with the existing and anticipated future land use with minimal future maintenance activities.

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LEGEND

- PHASE 1 REMOVAL BOUNDARY
- PHASE 2 REMOVAL BOUNDARY
- PROPERTY BOUNDARY
- FO — FIBER OPTIC LINE
- PP — OVERHEAD ELECTRIC LINE
- X — FENCE
- G — GAS LINE
- PH — TELEPHONE LINE
- EXISTING ROAD

N

250 0 500

K:\CFR – PHASE 2\dwg rev dec2013\Figure 2-1 General Site Map.dwg SAVED: 4/3/14 BY: PAFFHAUSENMJ

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Figure No. 1-3
PROJECT VICINITY MAP
APRIL 2014

K:\CFR – PHASE 2\dwg rev dec2013\Figure – Site Map HecRAS.dwg SAVED: 4/3/14 BY: PAFFHAUSENMJ

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Figure No. 1-4
PHASE 2 SITE MAP
APRIL 2014

1.4 Design Concept

This section outlines the general concept for remediation of Phase 2 that is planned to fulfill project objectives. Components of the design are described in detail in later sections of this document.

The design in Phase 2 relies on machine excavation to remove tailings / impacted soil materials from streambanks and the floodplain in the Project area. These contaminated materials will be hauled by truck to the B2.12 cell at Opportunity Ponds. The extent of excavation is determined by the extent of contamination but also considers the channel migration zone, locations of impacted vegetation, and topography. Clean substrates consisting of vegetative backfill and alluvial materials will be used to rebuild streambanks and the floodplain.

The method of floodplain reconstruction depends on the intended land use. Several land uses are anticipated for this Project area including pasture, riparian floodplain, and hay fields. In places the reconstructed floodplain will be lower than the existing floodplain to allow for reconnection with the river. Some bends will be redeveloped as point bars and existing depositional features will be preserved to the extent possible. On State land within the Project area, native vegetation will be reestablished. Microtopography will be developed and coarse woody debris will be imbedded in the floodplain to provide erosion resistance, sediment and seed trapping, micro-sites for plant establishment and a source of organic material. Microtopography is small scale variation in topography of 3 to 10 feet horizontally and about one-foot vertically. For pasture or hay field end uses on the privately owned properties, a largely planar floodplain surface will be built and pasture grasses will be established and interspersed with native woody vegetation. Where riparian areas will be used as pasture, a combination of riparian and pasture vegetation will be established.

Eroding, contaminated stream banks will be rebuilt after removal of contaminated material. Banks with existing robust, woody vegetation will be preserved to the extent possible. Passive margins, which border the stream and are generally not subject to high water velocity, will be preserved or redeveloped as point bars. A suite of bank reconstruction and revegetation treatments will be applied that correspond to the range of bank conditions. Bank treatments use a combination of locally salvaged wood, purchased biodegradable materials such as coir logs and coir fabrics, and live plant material such as willow cuttings, transplanted shrubs, and containerized nursery stock.

Revegetation is closely integrated with floodplain and streambank designs. In areas designed to reestablish native habitats, floodplain surfaces will be constructed to support natural recruitment of willows and other riparian and wetland plants species by using gravel and sand substrate and building surfaces at elevations close to the water table. The entire floodplain will be seeded. Active revegetation, such as planting and placement of vegetation associated with bank construction, will be done in places where plants have a high likelihood of survival. These locations include micro-depressions in the areas where groundwater is near the surface, and within bank structures that have high water-holding capacity due to the absorbent properties of coconut fiber (coir).

Plant communities are designed to correspond closely with geomorphic surfaces; for example, different plant communities will develop on point bar surfaces versus wetlands due to differences in substrate, shear stress, groundwater elevation, and ground surface elevation. Other activities will be conducted in support of the remedial action including dewatering, road construction, borrow area development, and reclamation. Dewatering is needed to facilitate removal of tailings from the floodplain. Temporary roads will be constructed for hauling tailings and borrow materials within Phase 2 and will be reclaimed at the end of the project. Borrow areas will also need to be reclaimed

and revegetated after removal of the borrow materials. Borrow areas will be seeded and planted in conformance with the final land use. Best Management Practices (BMPs) will be implemented to control erosion and minimize increased river turbidity during construction.

Further information on the Phase 2 remedial design is found in the following chapters. Chapter 2, Design Investigation, briefly summarizes investigations which were conducted in 2009 and 2010 to support the design of Phase 2. Chapter 3, Design Criteria, presents the technical criteria that will guide the design of the remedial components in Phase 2. Chapter 4, Proposed Design, develops the elements of the design and provides the justification for these choices. Chapter 5, Supporting Plans, is a summary of documents, either existing or to be prepared, that will guide construction activities such as the Quality Assurance/Quality Control Plan.

Section 2

Design Investigations

Several investigations have been undertaken by DEQ on Phase 2 of the CFROU. The overall objective of these investigations was to support the designs of reconstructed river banks and floodplain modifications necessary for remediation of Phase 2. A 2009 field investigation evaluated the existing geomorphic, hydrologic, and hydraulic characteristics of the Clark Fork River in Phase 2 (CDM Smith and AGI, 2010). An investigation of the geomorphology and hydrology of the entire Reach A was conducted by CDM Smith and AGI in 2012 (CDM Smith and AGI, 2013). A 2010 investigation gathered data concerning the nature and extent of soil contamination within the floodplain and banks of the Clark Fork River (Tetra Tech, 2011). This investigation also collected groundwater level measurements and determined floodplain alluvium gradations.

In 2010, additional studies were conducted by Montana Tech's Geological Engineering Department and Geum. The Montana Tech study (Gordon *et al*., 2010) evaluated groundwater elevations and water quality in the lime-amended portions of Phases 1 and 2 as well as an untreated downstream site at the Clark Fork Coalition Ranch (Phase 5). In July 2010 and September 2012 Geum conducted vegetation mapping and analyzed the data in relation to the water surface elevation (WSE) for the 2-year recurrence probability peak annual flow, tailings thickness, and hydrologic connectivity to help develop a vegetation remediation scenario for Phase 2. A detailed topographic map for Phase 2 was developed using Light Detection and Ranging (LiDAR) in August 2011 (Fugro EarthData, 2011). In November 2012 Geum, CDM Smith and AGI performed a field inventory of the streambanks in Phase 2 intended as a basis for preliminary streambank design. A subsequent site visit was conducted by Geum, CDM Smith and AGI on April 25, 2014 to verify the streambank treatments and investigate the level of bank toe reconstruction needed.

The sections below briefly summarize the results of the investigations. For additional information, refer to the *Data Summary Report – Reach A, Phase 2* (Tetra Tech, 2011); *Part 2, Geomorphic, Hydrologic, and Hydraulic Investigation for Phase 1 Remedial Design/Remedial Action* (CDM and AGI, 2010); and *Monitoring Groundwater in Remediated vs. Unremediated Floodplain Sediments along the Upper Clark Fork River* (Gordon *et al*., 2010).

2.1 Geomorphic Investigation

A geomorphic investigation of Phase 1 and Phase 2 was conducted by AGI in 2009 (CDM Smith and AGI, 2010). The study found that the Clark Fork River is a meandering stream with a sinuosity of about 1.75 along the 1.9 river miles of Phase 2. The average channel gradient is about 0.23 percent (CDM Smith and AGI, 2013). Based on the surveyed channel cross sections that document pre-project conditions, the median bankfull width is approximately 50 feet and the median width to depth ratio is 19. The river has a variably entrenched morphology that disconnects much of the floodplain from frequent inundation. Pool frequency is about 16 pools per mile and the median residual pool depth is about 2.5 ft.

As part of this investigation, a Bank Erosion Hazard Index (BEHI) inventory was performed to assess pre-project erosion extents and severity (Rosgen, 2001). This method classifies bank erosion based on bank height/bankfull depth ratio, rooting depth, rooting density, bank angle, and degree of surface

protection. In Phase 2, about 28 percent of the banklines were mapped as eroding with about half this length classified as having high, very high or extreme erosion severity based on the BEHI criteria.

Bank erosion rates were also estimated based on lateral shift measured on aerial photos taken in 1954 and 2011, and these data were summarized in the Reach A Overview Report (CDM Smith and AGI, 2013). In Phase 2, a total of 58 measurements were collected where bank movement in excess of 20 feet was identified, and the mean migration rate for those measurements was 0.7 feet per year.

Phase 2 has seen some significant changes in planform over the last century. General Land Office Survey (GLO) maps from 1869 show that the course of the river at Perkins Lane was several hundred feet east of the current river course; the river was likely re-routed with the construction of the road and bridge crossing (CDM Smith and AGI, 2013). This relocation resulted in the shortening of the river in the lower portion of Phase 2 by hundreds of feet which may have caused some local downcutting near Perkins Lane Bridge. Upstream at Station 16+00, a large bendway was cut off sometime prior to 1950, abandoning approximately 1,000 feet of channel (CDM and AGI, 2010). This avulsion has resulted in localized channel instability characterized by rapid migration rates and channel lengthening. Beginning at Station 45+00 on the main channel, two distinct meanders have been isolated from the stream corridor by the abandoned Milwaukee Railroad line, which was built in the early part of the 20th century. Although the meander remnants remain separated from the stream corridor by the abandoned rail grade, they contain tailings deposits that meet removal criteria.

Wolman pebble counts were conducted on riffles to assess the coarser fraction of bed material in the system. The median particle size (D_{50}) in Phase 2 was 1.9 inches and the D_{84} was 2.9 inches. Riffle sediment gradations in Phases 1 and 2 show a coarsening trend in the downstream direction (AGI and CDM, 2010).

The geomorphic investigation concluded that Phase 2 currently has limited floodplain access due to floodplain aggradation (CDM and AGI, 2010; 2013). Flood events in the late 1800s and early 1900s deposited several feet of tailings (contaminated soils) on the channel banks and floodplain. In the early part of the 20th century, Warm Spring Ponds were constructed to trap and store contaminated sediment. The ponds not only reduce sediment loading in the river but also attenuate peak flows. Since 1918, when the first pond became operational, rates of channel migration and planform evolution in Phases 1 and 2 appear to have been dampened by the flow attenuation and reduced sediment delivery.

2.2 Hydrologic and Hydraulic Investigation

Site peak flow hydrology for the Clark Fork River and Silver Bow Creek below Warm Springs Ponds was developed to provide understanding of existing river conditions as well as provide a basis for hydraulic design of the remedy (CDM and AGI, 2010). Some of this information was updated in the report *Geomorphology and Hydrology of Reach A* (CDM Smith and AGI, 2013). Hydraulic modeling was conducted to determine the river peak flow behavior under existing conditions in terms of flood elevations, velocities and shear stresses.

2.2.1 Project Area Hydrology

Several drainage basins contribute runoff to Reach A of the Clark Fork River. Silver Bow Creek flows into the extensive Warm Springs Ponds, which attenuate peak flows. The ponds' discharge joins with Willow Creek/Mill Creek bypass and continues around abandoned Pond 1 for 0.8 miles through a man-made channel to join the original Clark Fork River channel. This confluence is the upstream end

of the CFROU. Eleven-hundred feet downstream of this point, Warm Springs Creek joins the Clark Fork River. For the first four miles of the Clark Fork River, there are no significant tributaries other than Warm Springs Creek.

2.2.2 Flood Hydrology Analysis

Peak flow estimates for Phase 2 of the Clark Fork River design were determined using regression equation methods and gage records analysis. A flood insurance study of the Clark Fork River in the Site area was completed for the federal flood insurance program in 1980. Since the study relied on peak flows determined prior to the installation of most gages on Reach A of the Clark Fork River, its results were not used in this analysis. United States Geological Survey (USGS) gage no. 12323800 (Clark Fork River near Galen) is located at Perkins Lane Bridge, the downstream boundary of Phase 2. Because no significant tributaries enter the river in Phase 2, the flows measured at this gage are appropriate for the entire Project area. Table 2-1 summarizes the estimated peak annual flows for Phase 2 at this gage (CDM Smith and AGI, 2013).

To predict the less frequent peak flows at the Clark Fork River Galen gage, which only had 24 years of record, correlations with the Clark Fork at Deer Lodge, Montana gage (USGS station #12324200) and the Middle Fork Rock Creek gage (USGS station #12332000) were used to extend the record to 75 years. For details of this analysis, see the report *Geomorphology and Hydrology of Reach A* (CDM Smith and AGI, 2013).

Table 2-1. Peak Flow Summary

Recurrence Interval (yrs)	Clark Fork River near Galen, MT USGS 12323800
1.5	441
2	584
5	961
10	1,216
25	1,535
50	1,757
100	1,893

Note: For the Clark Fork River near Galen, the 2, 5, 10 and 25- year peak flows are predicted directly from the 24 years of record; the 50 and 100-year peak flows are predicted from the 75 year extended record

2.2.3 Hydraulic Modeling

U.S. Army Corp of Engineers HEC-RAS model version 4.1 (USACE, 2008) was employed to predict the hydraulic characteristics of the Clark Fork River under peak flow conditions. A model developed in 2010 addresses existing conditions on Phases 1 and 2, and provides a baseline for comparison with the design conditions. Different model versions were developed to evaluate the different peak flow events because assumptions on overbank flooding differed with different peak flows. The model development and input parameters are described in *Part 2 – Geomorphic, Hydrologic, and Hydraulic Investigation for Phase 1 Remedial Design/Remedial Action* (CDM and AGI, 2010). Reach averaged hydraulic depth, main channel velocity, and energy slope were calculated for Phases 1 and 2 for 2, 5, 10, 25, 50 and 100-year flow events.

Hydraulic modeling of existing conditions shows that the Clark Fork River channel in Phase 2 generally contains the 10-year flow event, and even the 100-year flow event has limited access to the

floodplain. Limited flooding occurs during the 100-year event in the upstream portion of Phase 2, but flooding is confined close to the channel in the channelized reach between the Helen Johnson Irrigation Ditch diversion structure and Perkins Lane.

2.3 Streambank Investigation

Streambanks in Phase 2 were evaluated to determine the need for stabilization and treatment. Short term planform stability is necessary so floodplain vegetation has enough time to establish and provide erosion resistance and roughness during flood events. After this establishment period, which is approximately 3 to 7 years, increased lateral bank movement is acceptable to achieve the long term project objective of a dynamic river and floodplain environment that supports a shifting mosaic of geomorphic features and associated riparian vegetation communities. Streambanks were evaluated in November 2012 for planform stability through observations of existing vegetation and bank material. Information on bank erosion rates generated during the geomorphic investigation are described in Section 2.1. Streambanks were grouped according to like characteristics to determine the type of streambank treatment required. Streambanks are described below by streambank treatment group.

2.3.1 Group 1 Streambanks

Group 1 streambanks are located on the passive margins, in particular on inside bends, where shear stress is low. In Phase 2, inside bends exhibit various elevations and vegetation densities. Geomorphic position and low levels of shear stress are the characteristics that categorize a streambank as Group 1. Figure 2-1 is a photograph of an existing Group 1 streambank in Phase 2. The following are typical characteristics of Group 1 streambanks in the Project area:

- Located in passive geomorphic positions such as inside bends, where deposition frequently occurs.
- Located in areas of low shear stress.
- Vegetation often consists of scattered herbaceous vegetation consisting of wetland herbaceous species and young willows consistent with the mapped vegetation community “Vegetated Bar” described in Section 2.7.
- There is often a lower, unvegetated alluvial bar below vegetation.
- Occasionally support dense herbaceous vegetation and young willows that have colonized recent deposition.
- Contamination is present.

Group 1 treatments include:

- Point bar/brush trench (PB/BT)
- Lateral bar/brush trench (LB/BT)

Figure 2-1. Examples of Group 1 streambanks in Phase 2.

2.3.2 Group 2 Streambanks

Group 2 streambanks are located on straight or outer banks with low migration rates. Group 2 streambanks typically support mature, well-rooted woody vegetation growing between base flow and the 2-year WSE or the existing top of bank. Figure 2-2 is a photograph of an existing Group 2 streambank in Phase 2. The following are typical characteristics of Group 2 streambanks in the Project area:

Figure 2-2. Example of a Group 2 streambank in Phase 2.

- Geomorphic position varies between straight reaches and outside meander bends.
- Migration rates are low.
- Toe material varies, consisting of gravel, cobble or clay.
- Vegetation typically consists of mature woody riparian species such as willow or birch consistent with the mapped vegetation community "Willow Birch" described in Section 2.7.
- Woody vegetation density varies but typically extends from baseflow to the 2-year WSE or existing top of bank.
- Often support undercut banks.
- Contamination is present either in the streambank or in the adjacent floodplain.

Group 2 treatments include:

- Preserve Vegetation (PV)
- Willow Cuttings Behind Bank (WCBB)

2.3.3 Group 3 Streambanks

Group 3 streambanks are typically located on outside meander bends with moderate to high rates of erosion or on straight reaches supporting little to no mature woody riparian vegetation. Vegetation is often sparse. Figure 2-3 has photographs of existing Group 3 streambank in Phase 2. The following are typical characteristics of Group 3 streambanks in the Project area:

Figure 2-3. Examples of a Group 3 streambanks Phase 2.

- Geomorphic position varies between straight reaches and outside meander bends.
- Migration rates are moderate to high and erosion is typically visible.
- Toe material varies, consisting of gravel, cobble or clay.
- Homogenous fine-grained alluvial deposits are present throughout the bank.
- Vegetation typically herbaceous vegetation consistent with the mapped vegetation community "Upland Herbaceous" described in Section 2.7.
- Mature woody vegetation is occasionally present but density is low, or vegetation is not well rooted or growing lower in the bank profile (i.e., does not extend to baseflow).
- Contamination is present in the streambank and the adjacent floodplain and is often visible in the upper portion of the bank.

Group 3 treatments include:

- Double Vegetated Soil Lift (DVSL)—Native Toe
- Double Vegetated Soil Lift (DVSL) – Reconstructed Toe

2.3.4 No Treatment Streambanks

No Treatment streambanks are those banks with no contamination present within or behind the bank. Uncontaminated streambanks are typically those that were too high for historical flood inundation and tailings deposition to occur. In Phase 2 there are only a few occurrences of uncontaminated streambanks. Where they occur, these banks are typically actively eroding or heavily armored, and located on the margin of the active stream corridor. Uncontaminated banks are generally too high to support dense riparian vegetation and are typically dominated by herbaceous vegetation and upland areas behind support upland grasses and shrubs. Where heavily armored, banks support sporadic mature woody vegetation in the lower and mid-bank area. Figure 2-4 shows photographs of existing No Treatment streambanks in Phase 2.

Figure 2-4. Streambanks in Phase 2 with no contamination (heavily armored in top photo and actively eroding in bottom photo).

The following are typical characteristics of No Treatment streambanks in the Project area:

- Geomorphic position varies between straight reaches and outside meander bends.
- Typically on the margin of the active stream corridor.
- Migration rates vary from low to high.
- Vegetation varies between herbaceous types on actively eroding banks (consistent with "Upland Herbaceous" vegetation community described in Section 2.7) to sporadic mature riparian shrubs such as willow and birch on armored banks.
- Contamination is not present.

2.4 Bank Toe Material Investigation

As part of the work performed by Tetra Tech in 2010, test pits were excavated near streambanks to investigate the presence and character of materials at the elevation of the bank toes on Phase 2 of the Clark Fork River (Tetra Tech, 2011). Stability of banks is dependent upon having a suitable bank toe material, particularly at banks in high shear stress locations such as outer bends. In this section, the term "bank toe material" means the material that extends beneath and supports the bank at an elevation below the reconstructed bank elevation. It includes the grade break at the base of the bank slope where it meets the streambed.

The toe material is especially critical because shear stresses increase with depth and are highest at the toe of the bank. Therefore, the bank toe is the most likely portion of a bank to fail under high flow conditions if it is not designed to withstand the shear stress anticipated at this depth. Generally, in natural alluvial river systems, the bank toe material consists of sand, gravels and cobbles that provide resistance to high shear stresses and slowly erode or deform under high flows. If less resistant materials are present at the bank toe elevation, streambanks tend to migrate rapidly and bank collapse commonly occurs.

Test pits along streambanks were opened and evaluated at 19 locations in the Project area. The objectives of this portion of the study were:

- Determine the vertical position of the suitable bank materials in relation to the bank toe elevations,
- Analyze gradations of the bank toe materials, and
- Estimate the frequency of occurrence and approximate locations of unsuitable bank toe materials to determine where bank toes may be needed during bank reconstruction.

For this analysis suitable in place materials for toes included sands and gravels, as well as those materials with a Universal Soil Classification System classification of sand, if there was a significant presence of gravels as indicated by at least 40% of the material retained on the No. 4 screen (0.187 inches). Clay in thick dense layers was also considered a suitable toe material and was found in two test pits. These clay layers are highly cohesive and resistant to erosion.

The material gradation analysis found that in the bank toe environments (base of pits) the median particle size (D_{50}) was 0.9 inches and the D_{84} was 2.4 inches. In comparison, active stream bed gravels

measured in riffles are notably coarser, with a D_{50} and D_{84} of 1.9 and 2.9 inches, respectively. This reflects the winnowing of fine sediment from riffle environments, and provides some indication of the overall coarse bedload gradation for Phase 2. In general, the results indicate that the alluvial materials that are available as an in-situ bank toe reflect native Clark Fork River alluvium, and will mobilize under certain events, allowing for long-term deformability of the banks. The gradations present are useable, however, as they are coarse enough to preclude significant transport at flows less than a 10-year flood event.

Two test pit locations were eliminated from the original 19 planned; one because bank materials were uncontaminated and therefore no bank treatment would take place, and the other because it was outside the reconstructed bank design due to channel realignment. Of the 17 test pit locations analyzed, only one did not contain suitable toe materials within the excavated depth. For the remaining test pits, toe material elevations were compared to base of DVSL design elevations for each location (Figure 2-5). This was done to determine if the native toe would meet the requirements for the bank protection strategy. The DVSL base design elevation is approximately 2 feet below the design top of bank, and establishes the platform upon which the lifts are built. Toe material elevations relative to this platform height ranged from 2.75 feet to -1.94 feet, where negative values indicate elevation above the DVSL base. Table 2- 2 summarizes the results of the bank toe investigation.

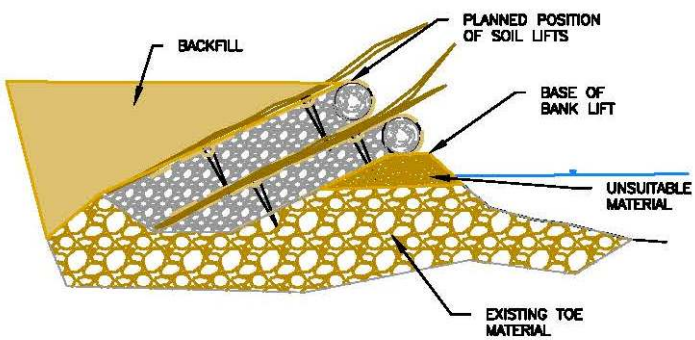

Figure 2-5. Hypothetical diagram of bank toe requirements.

For design purposes, toe material will be needed where the native toe is greater than 0.5 feet below the DVSL base elevation. Test pit data suggests that 13 percent of DVSL banks had no suitable existing bank toe material, 62 percent will require an average of 2 feet of material, and the remaining 25 percent had suitable material. Suitable bank toe material can be either coarse gravels or clay. Banks with unsuitable bank toe material composition are likely to erode and collapse, especially at locations such as outside bends.

The test pit investigations of bank toes showed that about 25 percent of the locations excavated had suitable bank toe material close to the desired elevation. The remaining test pits either had no suitable bank toe material (13 percent) or it was found at too low an elevation to provide the necessary protection for the bank (62 percent). For this last class of banks, the average depth of toe material that would need to be constructed was 2.0 feet.

Table 2-2. Summary of Bank Toe Elevation Calculations

Station	Test Pit Surface Elevation (ft)	Pit ID	Proposed Bank Elevation (ft)	SoilType	Top of Toe Material Elevation (ft)	Depth to Top of Toe Material (in)	Elevation of Bottom Lift (ft)	Bottom of Lift - Top of Toe Material (ft)
Left								
2+03	4780.90	02-401	4779.98	SP	4776.00	60	4777.98	1.98
13+20	4779.81	02-403	4776.74	GP	4772.50	90	4774.74	2.24
26+16	4776.28	02-406	4774.26	SP-SM	4770.00	72	4772.26	2.26
46+12	4772.77	02-409	4770.49	SP-SM	4767.50	66	4768.49	0.99
57+26	4770.02	02-411	4768.75	SP-SM	4764.00	60	4766.75	2.75
63+43	4768.03	02-412	4767.7	CL	4764.50	42	4765.70	1.20
73+76	4766.31	02-413	4765.17	GP	4760.00	72	4763.17	3.17
Right								
6+06	4781.18	02-402	4779.38		4775	78	4777.38	2.38
22+61	4775.62	02-405	4774.71	CL	4770.50	66	4772.71	2.21
31+57	4775.98	02-407	4773.69	SP-SM	4768.98	84	4771.69	2.71
50+52	4770.71	02-410	4770.05		4767.71	36	4768.05	0.34
68+78	4768.20	02-414	4766.23	GP	4763.70	54	4764.23	0.53
78+59	4765.41	02-415	4764.30	GP	4761.41	48	4762.30	0.89
84+17	4765.70	02-416	4762.70	GP	4760.70	60	4760.70	0.00
89+34	4767.60	02-417	4760.00	GP	4757.10	126	4758.00	0.90
92+62	4763.01	02-418	4759.57	GP	4759.51	42	4757.57	-1.94

To support these conclusions with additional field evidence, bank toes located at planned DVSL locations were probed during the April 25, 2014 site visit. A long stick was used to probe the toe material, and a judgment was made as to type of toe material present at each location. Although locations were not systematically tested, estimates were made as to the percentage of each DVSL that might require bank toe construction. The percentages for all DVSL streambanks in the Project area were averaged and an estimate that 60% of the bank length would require bank toe construction was determined. This is less than the 75% estimate from the test pit investigation, but confirms that well over half the DVSL length in the Project area will require bank toe construction.

2.5 Contaminant Characterization

The purpose of the CFROU Phase 2 contaminant characterization investigation was to collect and identify design level data concerning the nature and extent of soil contamination. A Project area specific contaminant characterization of Phase 2 was completed between September 13, 2010 and October 14, 2010. The investigation included opening test pits, logging and sampling the soil profile, screening of the samples using a field X-ray fluorescence (XRF) spectrometer, and measuring depth to groundwater. Select samples expected to bracket the depth of contamination were sent to a laboratory for analysis of concentrations of contaminants of concern (Tetra Tech, 2011).

A track-mounted excavator was employed to excavate test pits to an average depth of approximately five feet. Soil samples were collected from one pit wall which was cleaned of potential cross

contamination from excavation and then sampled. Test pit documentation included locations of soil horizons, visual interpretation of the depth of contamination, depth to groundwater, and a soil log of the test pit sidewall.

In general, test pit locations were spaced on a north-south – east-west grid pattern with 125-foot centers. Additional sample locations were identified within and outside of the grid pattern in areas where the grid did not adequately capture data needed to characterize soil impacts, such as historic channels or old oxbows. The preliminary plan set, Sheets C3 and C4, Existing Conditions and Test Pit Locations display the test pit locations, depth to contamination and removal elevation for Phase 2.

2.6 Groundwater Investigations

During the period October 2009 through September 2010, students from the Montana Tech Geological Engineering Department conducted a groundwater investigation along portions of the Upper Clark Fork River (Gordon *et al.*, 2010). In Phase 2, three new 2-inch diameter monitoring wells were installed to a depth of 10 feet. An existing well (WS-1) of unknown origin located very near the river was also monitored. All of these wells were in areas that had been subject to lime amendment during the Governor's Demonstration Project.

During the investigation period, depth to water was measured manually on a monthly basis. One well (ML-2) was equipped with a pressure transducer from February through June 2010 to record hourly water levels. Based on the new well data, monthly depth to water below ground surface ranged from 0.8 feet in June to 4.0 feet in December suggesting that groundwater is near the surface in some areas within the floodplain during high water periods.. A ground water gradient towards the river was found in all seasons except summer suggesting the Clark Fork River is a gaining stream on its west side through most of the year in this area.

As part of the Montana Tech study, groundwater samples were collected three times during the investigation period (November 2009, February 2010, and May 2010). Samples were analyzed for routine field parameters, alkalinity, common ions, nutrients, and trace dissolved metals. Samples from the vicinity of Phase 2 indicate a near-neutral pH, calcium-bicarbonate type water that is low in dissolved oxygen and nutrients. However, sodium is also relatively high in the Phase 2 wells compared to the Phase 1 wells. The water in the ML wells has high conductivity, typically 1,000 to 2,000 micro Siemens per centimeter (µs/cm), and a moderately-high alkalinity of 200 to 300 milligrams per liter (mg/L). Dissolved trace metals were below human health standards, but cadmium, copper and zinc results were ambiguous and may have occasionally exceeded surface water aquatic life standards.

The soil test pit investigation completed by Tetra Tech in September and October 2010 (Tetra Tech, 2011) provides some additional information on groundwater conditions throughout Phase 2. Depth to water in test pits ranged from 1 foot below ground surface to 8 feet. The average depth to ground water was 3.4 feet indicating that ground water levels are near the base of tailings on the average in late season. However, based on the seasonal well data of Gordon *et al*. (2010), large portions of the tailings to be removed may be saturated during the late spring and early summer high water period.

2.7 Vegetation Investigations

This section describes vegetation within the Phase 2 area, including previous vegetation assessments, historical vegetation, and existing vegetation. Vegetation patterns observed in the Project area were used to support design criteria and vegetation design.

2.7.1 Previous Assessments

Vegetation assessments for portions of the CFROU, including Phase 2, have been completed by various agencies and researchers to assist with remediation efforts. Smith *et al*. (1998) evaluated vegetation establishment after the 1908 flood of record. This study showed that vegetation along the Clark Fork River is variable and states that, while some streambanks and floodplain areas are covered by phytotoxic slickens and lack woody vegetation, willows (*Salix* spp.) re-grew after the 1908 flood in areas where tailings have been covered by levy sands. Smith and Griffin (2002) examined the density and distribution of floodplain vegetation to assess the vulnerability of floodplains to erosion during overbank flow events. The results of their analysis showed that 74 percent of the floodplain tabs (floodplain areas between meander bends) have less than 40 percent of their surface covered by shrub canopy, with an average shrub canopy cover of 29 percent. According to Griffin and Smith (2002) tailings and historical grazing practices have suppressed vegetation development, and few younger age classes of shrubs are present.

Wetland and riparian areas were mapped in the Upper Clark Fork watershed as part of the U.S. Fish and Wildlife Service (USFWS) National Wetlands Inventory (NWI) (USFWS, 2005). This effort classified wetlands using the Cowardin classification system (Cowardin *et al*., 1979) and riparian areas using the USFWS riparian classification system (USFWS, 2005). The NWI data set was used to identify the location and extent of wetland and riparian areas in Phase 2 to better guide vegetation community mapping.

To support development of the ROD, EPA assessed vegetation and wetlands. This effort included: distinguishing tree- and shrub-dominated areas as polygons; mapping jurisdictional wetlands to be used as a baseline for evaluating wetland credits that may become available as part of remedial activities; and distinguishing and mapping three broad categories of vegetation condition using the Clark Fork River Riparian Evaluation System (RipES) (CH2M Hill, 2008) with the thought that plant community composition and structure might correlate with degree of contamination (EPA, 2004). This latter mapping effort provided a basis for remedial actions anticipated by the ROD. Results from these assessments are in the form of GIS data layers developed by EPA and its contractors as part of development of the ROD.

Consultation between State and Federal agencies will continue for this Project as remedial design goes forward to ensure “no net loss” of wetlands through implementation of the Remedy in Reach A and limited areas of Reach B, where cleanup is proposed. It is likely that there will be a net increase in wetland value within the CFR OU through implementation of the Remedy because not all material removed from the floodplain will be replaced, leading to the development of additional wetlands, and increased wetlands function of existing wetlands. “No net loss” is a performance standard measured on an operable unit wide basis in the Clark Fork River Basin (rather than a requirement that applies to and must be documented during construction phase by phase). The Geomorphology and Vegetation Monitoring Plan for Phase 2 includes tracking of wetlands. Wetland monitoring will continue (consistent with the Phase 1 plan) in CFR Reach A, Phases 2 and future phases. DEQ proposes to complete Step 4 (final wetland inventory) for the entire CFROU in a ten year period following remedial construction completion, consistent with the timeframe we agreed to for this process under the SST OU Consent Decree.

2.7.2 Historical Vegetation

Historical reports of the vegetation and Clark Fork River channel within the Deer Lodge Valley indicate that the channel was narrow and deep with densely vegetated streambanks (Smith *et al*., 1998). Historical vegetation communities and variable topography within the floodplain may have been influenced by beaver dams (Smith *et al*., 1998). Both springs and beaver impoundments would have supported a much wetter floodplain that included dense willow thickets, sloughs, marshes, and aspen swamps (BLM, 2012). Prolonged saturation from beaver dams may explain peat development observed in some areas along the Clark Fork River.

Smith and Griffin (2002) suggest that the historical conditions, including variable topography and densely vegetated streambanks and floodplain, influenced the distribution of deposited tailings following large flood events in the early 1900s. Dense vegetation on the channel margin would have slowed overbank flows and promoted deposition on the channel edges, creating natural levees that slope away from the channel. Conveyance of flood flows over these natural levees into the adjacent floodplain drove deposition of suspended material as flow velocities slowed on the floodplain surface. Variations in tailings thickness reflect the variability of deposition on topographically irregular ground. For example, tailings are typically deepest in areas that were depressions prior to the early 1900s flood events (areas such as oxbows, side channels, backwaters, and other low elevation floodplain areas).

The deposition of up to several feet of tailings on the Clark Fork River floodplain in the early 1900s resulted in the formation of elevated streambanks and reduced floodplain access (Smith *et al*., 1998; Smith and Griffin, 2002). While stream channel entrenchment is commonly the result of channel incision, in this case entrenchment was caused by rapid floodplain aggradation resulting from tailings deposition prior to the activation of Warm Springs Ponds as a sediment trap.

2.7.3 Existing Vegetation

To support preliminary design and refine Remedial Actions, Project area-specific vegetation assessments were completed and the results compared with contamination data from soil pits and geomorphic features identifiable from detailed topography provided by LiDAR (Light Detection and Ranging) elevation data.

Existing vegetation communities were evaluated using two methods. Field mapping first identified the composition and location of existing vegetation communities within Phase 2. Later, spatial analyses of the resulting vegetation community mapping combined additional data layers to further characterize and determine patterns of vegetation establishment. Existing vegetation communities were mapped by Geum during the 2010 growing season, and were refined in 2012. Vegetation communities were mapped in the field using the following spatial data for reference:

- 2009 National Agriculture Imagery Program (NAIP) imagery (USDA FSA, 2009).
- 2011 aerial photography (Microsoft, 2011).
- National Wetlands Inventory mapping including wetlands and riparian areas (USFWS, 2005).
- Deer Lodge County Area Soil Survey (USDA NRCS, 2012).
- Modeled water surface elevations prepared by CDM Smith.

- Elevations relative to the 2-year water WSE using processed LiDAR data collected between August 6, 2011, and August 11, 2011, by Fugro EarthData, Inc. (2011) and post processed with DJ&A, P.C.

During field mapping, the extents of distinct vegetation communities were delineated over aerial photographs of the Project area. Vegetation communities were distinguished according to dominant plant species composition and life forms, geomorphic position, elevation relative to river hydrology, and land use criteria as shown in Table 2-3. Information obtained from field mapping of the vegetation communities was later used to digitize a spatial data layer using ArcMap 10.1 (ESRI, 2011), that could be combined with other Project area spatial data, such as depth of contamination and LiDAR elevation data for further analysis.

A total of 14 vegetation communities were mapped in and around the Phase 2 Project area. Approximately 175 acres were mapped. The soil pit investigation area is approximately 115 acres so approximately 60 additional acres of vegetation were mapped outside of this area (Table 2-3, Figure 2-6). The most extensive vegetation communities within Phase 2 are Upland Herbaceous (53.2 acres), Willow/Birch (26.9 acres) and Low Shrub (14.3 acres).

The elevation of each vegetation community relative to the 2-year WSE was evaluated to determine the range of elevations needed to support the desirable vegetation communities. Each vegetation community was also evaluated for depth of contaminated soils present. Soil pit data were interpolated using an inverse distance weighted (IDW) method in ArcMap 10 (ESRI, 2011) to generate a raster representing the depth of contamination, where the summed concentration of Contaminants of Concern (COCs) equals or exceeds 1,400 mg/kg throughout the Project area. The ArcMap tool "Zonal Statistics by Table" was used to determine the minimum, maximum, and average elevation of each plant community relative to the 2-year WSE, and the minimum, maximum, and average depth of tailings contamination by vegetation community. This tool "…summarizes the values of a raster within the zones of another data set" (ESRI, 2011). In this case, the raster values used were elevations relative to the 2-year WSE and the depth of contamination, and the zones used to summarize these data were the vegetation communities.

Figure 2-7 and Table 2-3 show the results of the analysis comparing vegetation communities with the 2-year WSE. Vegetation communities with average elevations at or below the 2-year WSE include: Vegetated Bar (0 ft), Distichlis (-0.4 feet), Depositional (-1.2 feet), and Emergent Marsh (-1 feet). All other vegetation communities have average elevations above the 2-year WSE, ranging from 0.3 feet for the Willow/Birch -Depression community to 5.5 feet for the Cottonwood Stand community.

Table 2-3 provides the results of the analysis overlaying vegetation communities with soil contamination thickness. The Agricultural and Willow/Birch-Depression vegetation communities had the greatest average depth of contamination (both 2.4 feet) followed by Depositional (2.1 feet) and Upland Herbaceous and Vegetated Bar (both 1.9 feet). The Vegetated Bar and Depositional communities generally are present on meander tabs and point bars where deposition of eroded contaminated bank material occurs. The Willow/Birch-Depression community is generally present in old oxbows where deposition of sediments transported via flood waters is likely to have occurred. The Agricultural and Upland Herbaceous communities are generally present at higher elevations, but are occasionally found on low meander tabs. The Agricultural community may have been irrigated with water from the channel containing metal particulates or dissolved metals which may have contributed to the higher contamination depths.

Each vegetation community was also evaluated for hydrologic connectivity with the Clark Fork River. Hydrologic connectivity is defined as occurring at an elevation that is half a foot above the 2-year WSE or lower. Based on previous floodplain projects and observed natural conditions, this elevation corresponds with conditions and processes required to establish and sustain riparian vegetation such as soil moisture, nutrient transport, scour and deposition, and seed availability. As such, half a foot above the 2-year WSE is estimated to be a reasonable maximum elevation corresponding to locations with sufficient hydrologic connectivity to sustain native riparian plant communities. These areas either receive frequent overland flow from the channel or have groundwater present in the rooting zone during significant portions of the growing season. To quantify existing floodplain hydrologic connection, the area of surfaces at or below half a foot above the 2-year WSE was calculated for each mapped vegetation community to indicate those areas that are currently connected to river hydrology (Figure 2-8).

This analysis indicates that only 7.7 acres (6.7 percent) of the mapped vegetation communities within the Project area are hydrologically connected to the Clark Fork River. This is reflected in the area being largely dominated by drier vegetation communities such as Upland Herbaceous (53.2 acres, 46.4 percent of mapped vegetation communities) and Low Shrub (14.3 acres, 12.5 percent of mapped vegetation communities). Dominant vegetation communities including Willow/Birch, Upland Herbaceous, and Low Shrub only have a small percentage of area considered hydrologically connected to the river. Other vegetation such as the Vegetated Bar, Depositional, Emergent Marsh, and Willow/Birch-Depression communities only occur on lower elevation geomorphic features, and therefore a higher proportion of their total area is within the elevation range corresponding with hydrologic connectivity. Historically, Willow/Birch areas were likely hydrologically connected to the river channel, but tailings deposition caused these areas of the floodplain to aggrade and become hydrologically disconnected, with only 1.6 acres (6.0 percent of the mapped Willow/Birch community) hydrologically connected. Existing willows and birches are likely the result of vegetative regrowth from live roots and branches buried under depoSited tailings. New willow and cottonwood are unable to colonize many of these areas from seed because of the lack of river flows to scour and deposit substrate.

Floodplain aggradation has resulted in a floodplain that is largely disconnected from the river channel, affecting the composition and structure of vegetation communities compared to historical conditions. Areas that are presently connected to river hydrology, such as Vegetated Bar, Depositional, Emergent Marsh and Willow/Birch-Depression are able to perform ecological functions including sediment and nutrient transport and storage, flood water storage, food web support, and supporting aquatic habitat. These areas provide higher levels of ecological function despite also having greater depth of contamination. Areas not connected to the river channel are unable to provide similar ecological functions. Removing tailings to increase areas of hydrologically connected floodplain will make it possible to sustain a range of native riparian and wetland plant communities and related floodplain functions.

Variations in plant community composition and structure appear to be driven partly by contamination but more strongly by geomorphic position, elevation relative to river-influenced hydrology, and land use. Very few patterns were apparent that linked the composition and structure of existing vegetation communities to depth of contaminated soils; however, there are relationships between vegetation community structure and composition, geomorphic position, hydrology relative to the river channel, and land use.

Table 2-3. Existing Vegetation Community Descriptions.

Vegetation Community Type (Acres)	Vegetation Community Type Description	Elevation (feet) Relative to 2-year WSE			Depth of Contamination >1,400 mg/kg (feet)			Hydrologically Connected Area[1] (acres)	Geomorphic Feature	Land Management Effects
		Min	Max	Ave	Min	Max	Ave			
Upland Herbaceous (53.2 acres)	Dominated by upland species such as wild rye, redtop, and wheat grasses. Lacks shrubs and trees. Weed species often present.	-2.5	11.0	2.4	0	5.0	1.9	2.5	Outer meanders and high terraces; occasionally elevated areas on meander tabs	Often hayed or grazed
Willow/Birch (26.9 acres)	Willow and/or birch dominated canopy. Understory can include upland vegetation such as gooseberry and rose, or wetland herbaceous vegetation such as sedges.	-2.8	9.9	2.5	0	4.8	1.7	1.6	Generally within the meander belt width; meander tabs, along side channels or low areas in the floodplain; along ditches; occasionally small patches further from the channel	Often impacted by cattle, some shrubs heavily browsed and some areas with soil pugging
Low Shrub (14.3 acres)	Dense low growing shrubs including snowberry, Wood's rose, and currant. Limited herbaceous understory. Lacks willow/birch in the overstory.	-1.9	5.5	3.0	0	4.9	1.0	0.0	Variable, only on west side of channel	Often grazed

Table 2-3. Existing Vegetation Community Descriptions.

Vegetation Community Type (Acres)	Vegetation Community Type Description	Elevation (feet) Relative to 2-year WSE			Depth of Contamination >1,400 mg/kg (feet)			Hydrologically Connected Area[1] (acres)	Geomorphic Feature	Land Management Effects
		Min	Max	Ave	Min	Max	Ave			
Agriculture (12 acres)	Cultivated land including a mix of native and pasture grasses and alfalfa.	-0.8	9.9	2.3	0	5.0	2.4	1.1	Throughout floodplain and historic floodplain	Hayed or grazed
Wet Meadow (2.9 acres)	Dominated primarily by wetland species and temporarily or seasonally flooded wetlands.	-1.9	4.4	2.0	0	3.0	1.4	0.1	Abandoned meander channels and low elevation areas in floodplain	Often hayed or grazed
Vegetated Bar (1.7 acres)	Recently deposited sediment vegetated with wetland plants and colonizing willows.	-3.1	2.8	0.0	0.0	4.8	1.9	1.1	Point bars and low areas along the Clark Fork River	Often grazed

Table 2-3. Existing Vegetation Community Descriptions.

Vegetation Community Type (Acres)	Vegetation Community Type Description	Elevation (feet) Relative to 2-year WSE			Depth of Contamination >1,400 mg/kg (feet)			Hydrologically Connected Area[1] (acres)	Geomorphic Feature	Land Management Effects
		Min	Max	Ave	Min	Max	Ave			
Willow/Birch – Depression (1.5 acres)	Willow and/or birch dominated canopy. Understory dominated by wetland species such as sedges.	-1.7	5.5	0.3	0	3.5	2.4	0.9	Floodplain depressions and along abandoned oxbow features	Occasionally grazed
Cottonwood Stand (0.8 acres)	Black cottonwood stand with an understory dominated by upland herbaceous vegetation.	1.2	10.1	5.5	0	3	1.5	0	Along an ephemeral tributary channel on the east side of the floodplain	Heavily grazed
Willow/Birch – Decadent (0.8 acres)	High percentage of decadent willows and/or birch.	-1.2	2.8	1.3	0.0	2.3	1.1	0.1	Throughout the floodplain	None observed
Open Water (0.2 acres)	Ponded or flowing water with no or some aquatic vegetation.	-1.9	4.0	0.8	N/A	N/A	N/A		Ditches and stock ponds	Often man-made and maintained
Depositional (0.2)	No vegetation, fine to coarse substrate recently deposited.	-2.8	-0.2	-1.2	1.4	3.5	2.1	0.1	Point bars and mid-channel islands	None observed
Distichlis (0.05 acres)	Salt grass is dominant vegetative cover.	-2.2	0.9	-0.4	1.0	1.2	1.1	0.0	Limited distribution located on outside meander bend	Grazed

Table 2-3. Existing Vegetation Community Descriptions.

Vegetation Community Type (Acres)	Vegetation Community Type Description	Elevation (feet) Relative to 2-year WSE			Depth of Contamination >1,400 mg/kg (feet)			Hydrologically Connected Area[1] (acres)	Geomorphic Feature	Land Management Effects
		Min	Max	Ave	Min	Max	Ave			
Emergent Marsh (0.1 acres)	Dominated by wetland species and typically semi-permanently to permanently flooded wetlands.	-1.8	0.2	-1.0	0.6	1.0	0.8	0.1	Low areas of the floodplain, along abandoned oxbow, along open water features	Occasionally grazed
Greasewood Stand (0.3 acres)	Greasewood Stand	-0.4	1.2	-1.0	0.6	1.0	0.8	0.1	Floodplain	Grazed

[1] Areas located at or below 0.5 feet above the 2-year water surface elevation are considered hydrologically connected to the Clark Fork River.

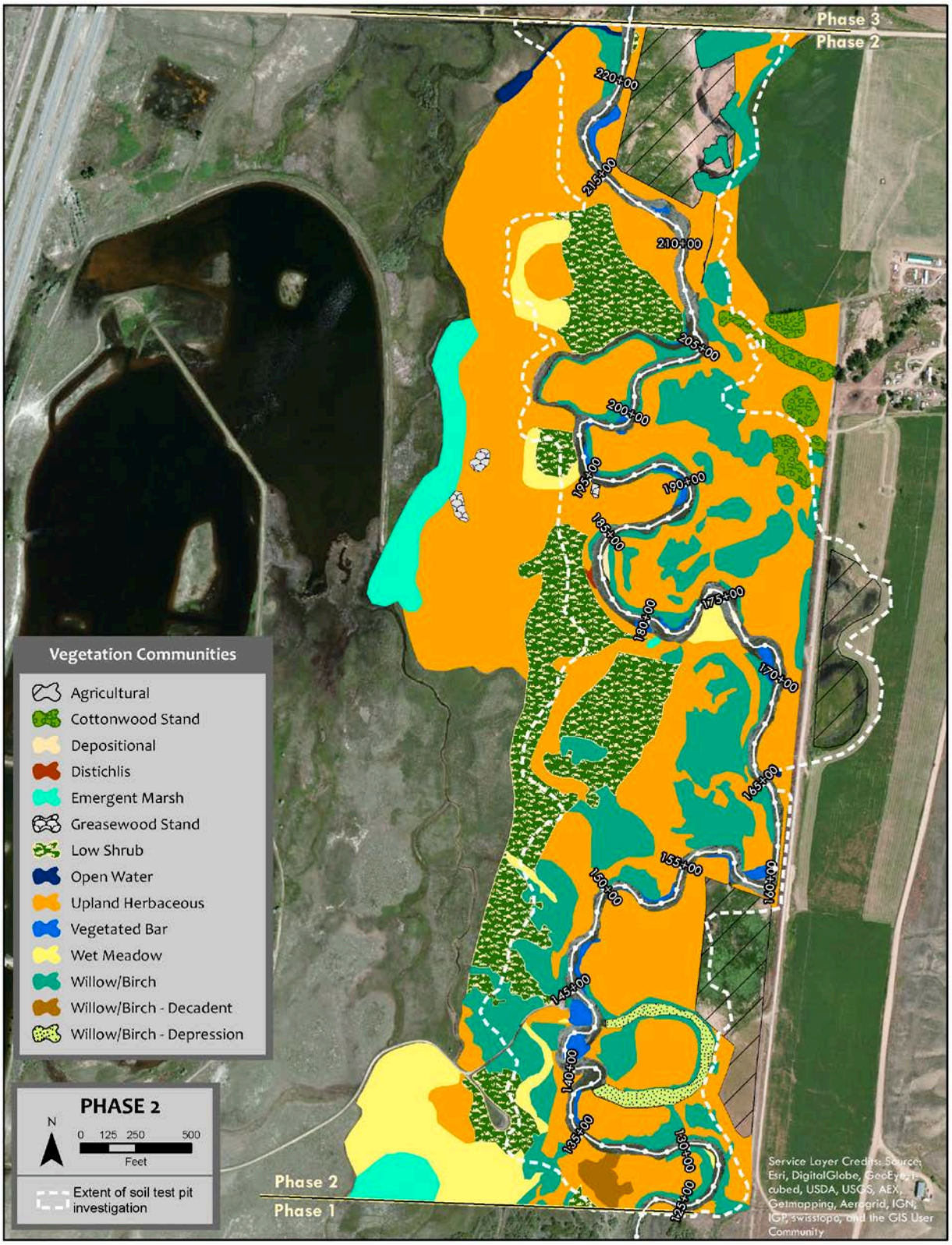

Figure 2-6. Phase 2 Vegetation Community Distribution.

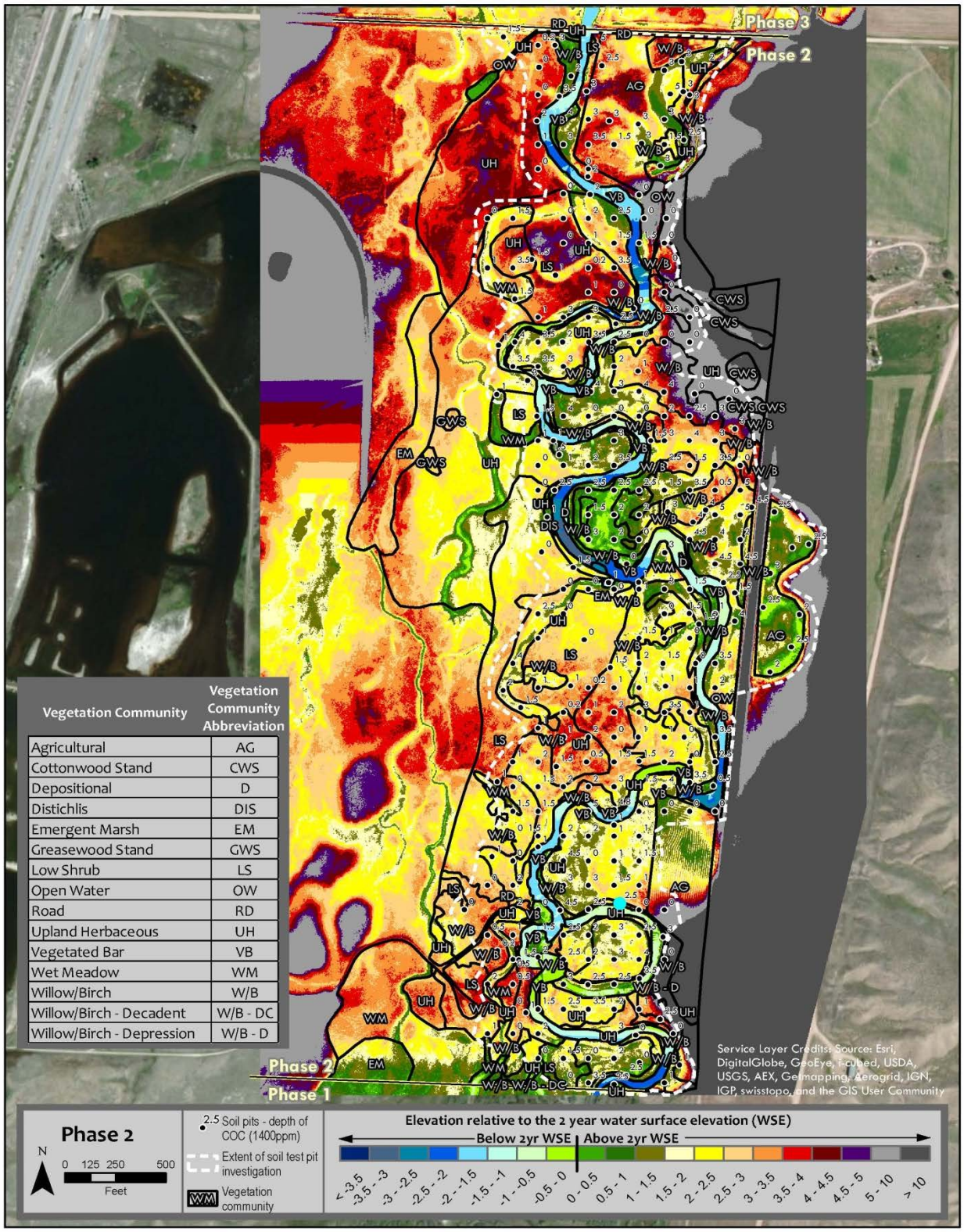

Figure 2-7. Vegetation Communities, Existing Ground Elevation Relative to the 2-Year Water Surface Elevation and Soil Test Pits with Depth of Contamination in feet.

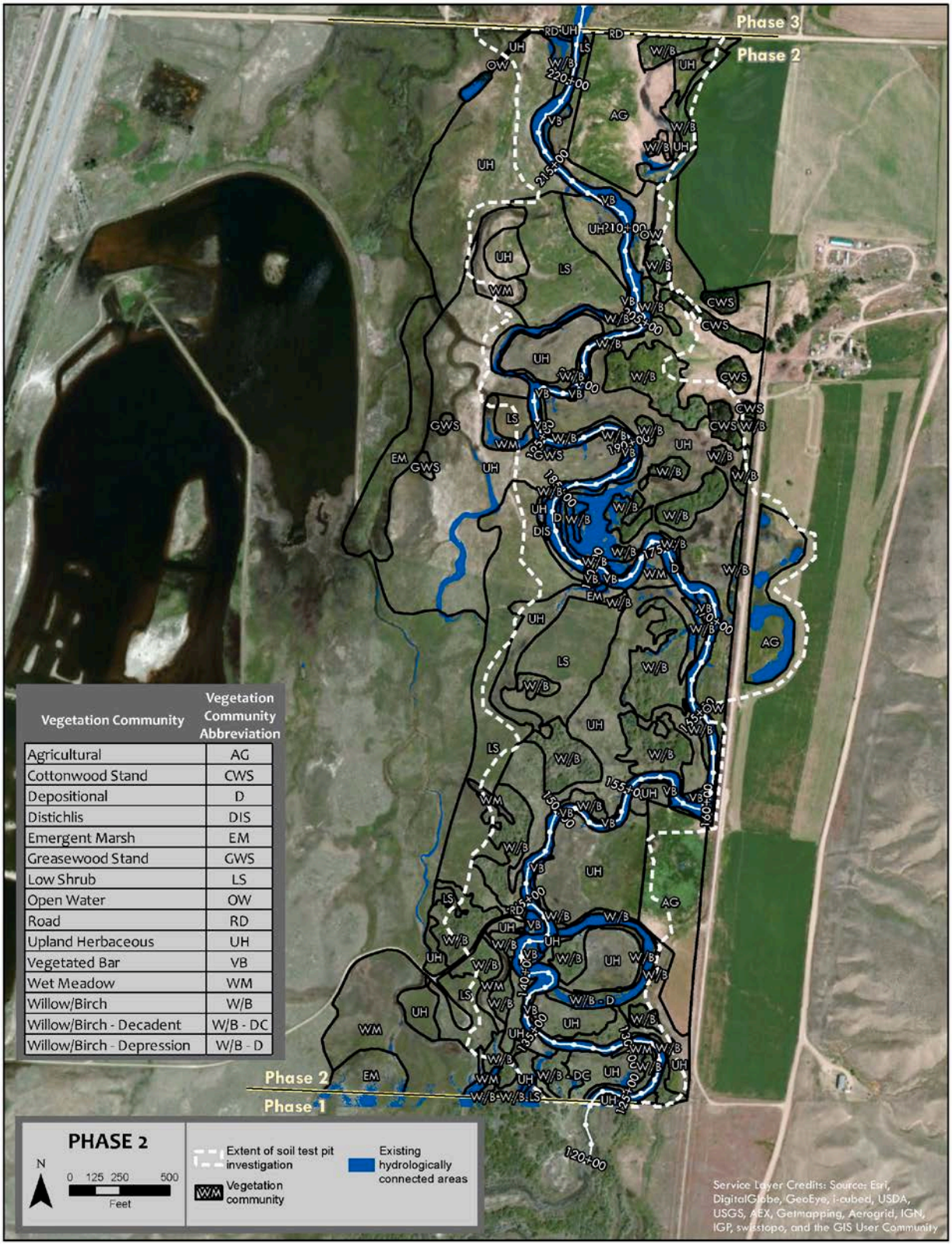

Figure 2-8. Phase 2 Floodplain Areas Connected to River Hydrology.

2.8 Aerial Mapping

DEQ contracted with DJ&A consultants of Missoula, MT, for aerial mapping services on Reach A of the Site. Fugro EarthData, Inc., performed a LiDAR and aerial photography flight over Reach A on August 7-10, 2011(Fugro EarthData, 2011). Data were processed by Fugro EarthData and converted to Montana State Plane Coordinates (NAD 1983) and NAVD88 Geoid 2009, US survey feet. DJ&A delivered bare-earth point files, key point, and a digital elevation model (DEM) bare earth files to DEQ. The DEM had a grid interval of 3 feet.

Consultants working with the delivered data found that the addition of hydrographic and bank breaklines to the LiDAR models would enhance the accuracy of the data in the vicinity of the banks. In January 2013, DJ&A supplied the requested breaklines for the mainstem, tributary streams and drainage features greater than 0.5 miles long. This deliverable included point files with reduced coverage in the area of the banks of the river. For Phase 2, the consultants determined that the best definition of banks could be achieved by using the 2011 point file (key points) in combination with the bank and break lines delivered in 2013. A new triangulated irregular network (TIN) was developed from this information, and the TIN was cleaned of extraneous or incorrect lines in the vicinity of the banks.

2.9 Present and Projected Land Uses

Phase 2 is comprised of three land ownerships: Lampert Ranch, Logan Ranch, LLC, and the State of Montana. The State of Montana land on the southwestern portion of the Project area in Section 7 is administered by the Montana Department of Fish, Wildlife, and Parks (FWP). The Lampert Ranch is north of the state land in Section 7 and extends to Perkins Lane. The Logan Ranch is east of these two properties in Section 8 and extends from Perkins Lane (the northern line of Section 8) to the southern line of Section 8. Discussions were held between members of the design team and Lamperts on their current and projected land uses on October 9, 23, and 27, 2013. The design team met with the Logans on October 9 and 30, 2013. DEQ and NRDP met with FWP on November 7, 2013 to determine their concerns and wishes for the southern portion of Section 7. Figure 2-9 shows current land ownership and land use.

2.9.1 Lampert Ranch

The Lampert Ranch property within the Project area is used for pasturing cattle, primarily bulls and was part of the Governor's project. Heifers are kept north of Perkins Lane where the largest portion of the grazing land is located. The Lamperts formerly hayed the high ground east of the river near Perkins Lane, but the land did not support a hay operation presumably due to contamination in this area. This area had been lime amended during the Governor's Demonstration Project in 1990. The Montana Department of Transportation (MDT) has a permanent lease on a portion of the Lampert pastures lying west of the Project area. This lease area is currently fenced and not grazed. No disturbance is planned for the leased area. The Lamperts use water from the Helen Johnson irrigation ditch located on the eastern edge of the property but they only apply this water north of Perkins Lane, downstream of the Project area.

The Lamperts plan to continue their current land use for the foreseeable future. They intend to continue grazing bulls in the pasture areas after vegetation is reestablished. Management of their land would be enhanced if the island formed by a secondary channel is permanently accessible through installation of a crossing. The Lamperts are in agreement to the concept of a lower riparian corridor

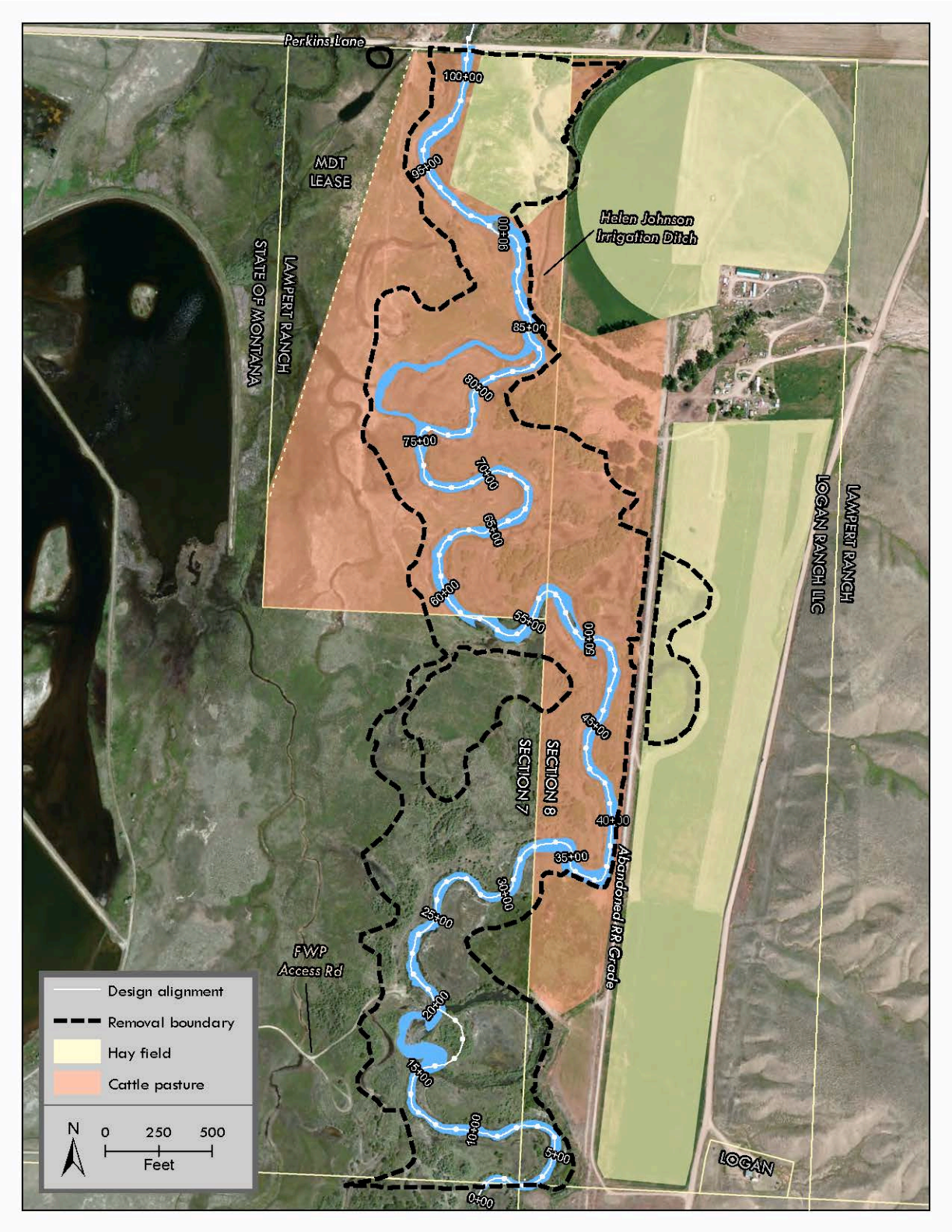

Figure 2-9. Land ownership and land use in Phase 2.

along the river provided that water gaps are constructed to allow cattle to access the river and provided that most of the area will be available for grazing in the future.

The Lamperts intend to reestablish their hay field east of the river after the area is remediated. They requested that this area be reestablished at approximately its current elevation. development. This area will accordingly be reconstructed to approximate the present elevation.

2.9.2 Logan Ranch LLC.

The Logan Ranch property within the Project area is used for hay production and winter/spring pasture. A pivot irrigates the northern hay field on their ranch and a wheel line is used to irrigate the southern hay field. Both are planted with alfalfa. Winter pasture for cattle is primarily on the east side of the river and west of the abandoned railroad grade. A section of pasture west of the river is accessed by a river crossing at river section 51+00. There is also a small pasture near Perkins Lane located between the Helen Johnson irrigation ditch and the Lamperts' property. Most of the pasture is located within the contaminant removal boundary. The hay fields are outside the removal boundary with the exception of about three acres in the southern hay field.

The Logans plan to continue ranching on their property as they have in the past. They eventually hope to replace the wheel lines in the southern hay field with pivots with private funding. They requested the remediated area in the southern hayfield regraded to drain to a culvert near the north end of the contaminated ground to minimize flooding. They are concerned with the poor growth of grasses on their existing pastures and welcome the improvement expected after remediation. They requested that the main pasture on the east side of the river be maintained at its present elevation or higher because it is currently inundated during floods. They also requested that this pasture not be planted with trees except in the southeast section because they may install sprinkler systems over the norther portion of the pasture. The Logans stated that there is a pipeline and an electric line serving the irrigation pump located in the southern portion of this pasture.

Two potential vegetative borrow sites have been investigated by CDM Smith and Geum on the south end of the ranch. The sites are on either side of the abandoned railroad grade. If either site is used, the Logans would like the land rebuilt at a flatter slope to accommodate any future irrigation pivots. If developed, the west side borrow area would be replanted as pasture and the east side would be replanted with alfalfa.

2.9.3 State Land

DEQ and NRDP met with Dave Dziak and Jason Lindstrom representing FWP about present and future land use of the state parcel in the southern portion of Section 7. The parcel is currently accessed by a road from the wildlife ponds located near Interstate 90. Recreationalists, primarily fishermen, access the Clark Fork River at the end of this road. Some hunting for game birds, waterfowl, and big game occurs on this parcel as well.

FWP is supportive of the remediation that will take place on this parcel. However, they are concerned with the lengthy period that access will be restricted (about five years) and would like to see remediation accelerated if possible. They would like access to the river reestablished as quickly as possible after construction is complete.

Section 3

Design Criteria

This section presents the design criteria for Phase 2 of the Clark Fork Site on which the Remedial Design is based. The Record of Decision (ROD) provides for the removal or treatment of tailings contamination and stabilization of streambanks and the floodplain by the establishment of permanent vegetative cover to lessen the high rate of erosion and contaminant input into the Clark Fork River. The Record of Decision defines areas of impacted soils and vegetation. The ROD determined that slickens ("severely impacted areas") would be removed, but assumed that in most instances, areas of impacted soils and vegetation would be treated in place, using careful lime addition and other amendment as appropriate, soil mixing, and re-vegetation. Removal would be required where the depth or saturation of the contamination prevents adequate and effective treatment in place or where arsenic levels would not be reduced below the human health level for current or reasonably anticipated land use.

This Preliminary Design Plan (PDP) applies a number of design-level considerations to site-specific conditions. These considerations are necessary to meet ROD requirements, including Performance Standards and Remedial Goals, and include groundwater, riparian vegetation, geomorphic stability, contaminant sampling, ownership, infrastructure, land use, and certain other site-specific remedy requirements.

To maintain consistency with the selected remedy described in the Record of Decision for the CFROU (USEPA/DEQ, 2004), strategies were developed to address the various impacts in Phase 2. Those strategies include stabilizing eroding, contaminated streambanks and the adjacent floodplain; removal of tailings and contaminated soils to a central disposal area and replacing with clean soils; and revegetation of the riparian corridor and other removal areas.

In order to achieve these general goals, design objectives were developed. These objectives include the removal of tailings and contaminated soils within the 100-year floodplain greater than 24-inches thick and reconstruction of the floodplain to an elevation supportive of the desired land use. Another important objective is the reconstruction of contaminated banks that are eroding or have inadequate native woody vegetation to maintain desired stability while maintaining the banks with healthy vegetation and deep, binding root mass. Establishing healthy native vegetation communities on the reconstructed banks and floodplain as land uses allow is equally important to achieve project goals.

In order to accomplish the above objectives, the Remedial Design relies on a combination of the following remedial strategies:

1. To offset and reduce the impacts from the tailing / impacted soils contamination:

   - Remove the severely impacted areas from the floodplain
   - Dispose at the B2.12 cell at Opportunity Ponds.

2. To provide system stability during reestablishment of the floodplain after removal:

- Topographically reconnect the floodplain and river, allowing for increased groundwater access surface that will support a permanent vegetative cover including robust woody riparian and wetland species, and increased frequency and duration of floodplain inundation.
- Reinforce floodplain areas that are at a higher risk of erosion using specific substrate gradations, bank treatments, and topographic grading strategies.
- Preserve those streambanks that are at a lower risk of accelerated erosion.
- Stabilize actively eroding streambanks as necessary with bioengineered treatments designed to manage erosion and bankline migration during the period of floodplain vegetation establishment.

In the long term, these strategies are intended to collectively meet the following requirements:

- Prevent or reduce unacceptable risk to ecological (including agricultural, aquatic, and terrestrial) systems degraded by tailings / impacted soils.
- Minimize direct contact with arsenic, thus reducing the potential risk of human exposure to acceptable risk-based levels.
- Prevent or inhibit ingestion of arsenic in tailings / impacted soil where ingestion or contact would pose an unacceptable health risk.
- Remediate tailings / impacted soils to be compatible with the existing and anticipated future land use with minimal future maintenance activities.
- Improve agricultural production by reducing or eliminating phytotoxic conditions, thus providing for multiple land uses.
- Minimize wind erosion and movement of contaminated soils onto adjacent lands, thus eliminating human, agricultural, and wildlife exposure.
- Provide geomorphic stability to streambanks, thus minimizing release of COCs to the river.
- Minimize surface water erosion and COC transport to surface water through methods described in the ROD.
- Comply with surface water standards
- Minimize transport of COCs to groundwater.
- Return contaminated shallow groundwater to its beneficial use within a reasonable time frame.
- Comply with State groundwater standards, including nondegradation standards.
- Prevent groundwater discharge containing arsenic and metals that would degrade surface waters.

In Phase 2, studies have shown that most mine waste deposits are greater than 24-inches deep (Sheets C3 and C4; Tetra Tech, 2011). Because it is not technically feasible to incorporate lime at depths greater than 24-inches, these areas will require excavation of the tailings or contaminated soils and removal to the B2.12 cell at BP/ARCO Waste Management Area.

According to the contaminant characterization data (Tetra Tech, 2011) and further groundwater studies performed by Montana Tech (Gordon, et al., 2010), approximately 95 percent of the total area of tailings / impacted soils within Phase 2 is saturated or potentially saturated during high water periods. The fact that added lime will not remain in place under saturated conditions but will dissolve and move with groundwater further supports the removal of tailings / impacted soils in Phase 2.

In this context, these design criteria address contamination, removal of contamination, floodplain reconstruction, streambank reconstruction, borrow sources and backfill, and vegetation design.

3.1 Contaminant Removal Design Criteria

Although tailings / impacted soils tend to have a distinct boundary with native materials, there are areas where contaminants may be mixed with soil and therefore are not readily identified. Accordingly, the design criteria for determining if mixed tailings / impacted soils are contaminated require a chemical component.

The ROD provides for the removal or treatment of tailings contamination and stabilization of streambanks and the floodplain by the establishment of permanent vegetative cover to lessen the high rate of erosion and contaminant input into the Clark Fork River. A remedial assumption is applied to remedial design considerations to assist with identifying the presence of tailings / impacted soils contaminated by mining activities and, when combined with other Remedial Design considerations, determining the severity of such impacts (e.g., severely impacted, impacted or slightly impacted). This numeric threshold will be used on a site-specific basis to judge the adequacy and appropriateness of removal when applying the other design criteria. This Remedial Design Assumption is based on phytotoxicity, a key to meeting remedial action objectives and performance standards.

Design Assumption: Tailings / impacted soils are contaminated when the sum of the Contaminants of Concern (COCs) (As, Cd, Cu, Pb, Zn) exceeds 1,400 mg/kg (parts per million). The 1,400 number is not used as a risk-based screening level or cleanup level. Instead, the sum of the COC's > 1,400 number is used as a Remedial Design Assumption in the design process to help identify areas of contamination in site-specific locations. Levels of contamination will be used alongside additional contamination criteria, such as the severity of contamination; thickness of contamination; likelihood of contamination to be re-entrained via bank erosion or avulsion; and the capability the vegetation to hold the contamination in place. The use of 1,400 as a Remedial Design Assumption of contamination will not be viewed in isolation, but in conjunction with other Design Criteria.[1]

Criteria for removing contaminated soils are based on a combination of several factors, including: the presence and depth of contaminated tailings, the channel migration zone, patches of vegetation that could be preserved, and opportunities to reconnect the floodplain by removing tailings. Tailings or contaminated soil will be removed under the following conditions:

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[1] EPA's Montana office uses a numeric criteria for the horizontal and vertical removal criteria used to guide the remedial design and develop anticipated removal limits of 1,000 mg/kg Cu for remedial work on nearby Warm Springs Creek. See Remedial Action Work Plan – RDU 10 Warm Springs Creek, Anaconda Regional Water, Waste & Soil Operable Unit.

1. Arsenic levels exceed the human health standard in the surface interval as discussed below.
2. The sum of COCs (As, Cd, Cu, Pb, Zn) exceeds 1,400 mg/kg (parts per million) and any of the following:
   - The lowest contaminated interval of metals is deeper than 24 inches, or
   - The contamination lies within the Channel Migration Zone (CMZ).
3. Limited areas where contaminated material is shallower than 24 inches but are contiguous to removal areas will be removed to promote floodplain connectivity or construction efficiency.
4. In areas where removal occurs, six inches of material below the base of tailings as defined by the removal criteria will be excavated to ensure sufficient removal of contaminants.

3.1.1 Human Health Based Removals

The Baseline Human Health Risk Assessment (USEPA, 1998) documented the risks to human receptors based on various land use scenarios. The land use and corresponding maximum arsenic concentrations that would require remedial action are shown in Table 3-1.

Table 3-1. Maximum Arsenic Concentrations by Land Use

Land Use	Concentration Limits
Residential	150 ppm
Recreational	680 ppm (children at Arrowstone Park and other recreational scenarios)
	1,600 ppm for fishermen, swimmers and tubers along the river
Rancher/Farmer	620 ppm

Areas with arsenic concentration greater than the appropriate concentration limit will be removed. These are generally surficial removals unless total metals concentrations exceed 1,400 ppm in the deeper intervals. The rancher/farmer limit applies to the private land in Phase 2; the recreational level applies to the State land. To provide a uniform application of the design, the lower rancher/farmer limit (620 ppm) has been applied to all of Phase 2.

3.1.2 Channel Migration Zone Based Removals

As mentioned in removal criterion No. 2 above, the CMZ (buffer zone) is a key criterion for contaminant removal. This section describes the development of the CMZ for Phase 2.

Fluvial entrainment of contaminants on the Clark Fork River has been documented by Swanson (2002) and CDM Smith and AGI (2013). Since 2006, approximately 32.9 acres mapped as impacted soils and 0.71 acres mapped as slickens (CH2M Hill, 2008) were recruited through bank erosion in Reach A (CDM Smith and AGI, 2013). In order to assess the risk of continued direct entrainment of contaminants by fluvial processes, an evaluation of historic rates of channel migration was used to develop a modified CMZ for Phase 2. The CMZ was modified by limiting the CMZ developed from the historic migration rates to areas of contamination. The historic CMZ was developed by evaluating measured migration rates in geomorphic subreaches and applying an erosion buffer to the 2011 digitized banklines. This zone was then reshaped to exclude higher elevation areas such as terraces and colluvial deposits that do not show contamination based on test pit data. The intent of the CMZ is

to identify a contaminant removal corridor that empirically addresses direct tailings entrainment hazards.

To develop the CMZ, migration was measured on all banklines that displayed in excess of 20 feet of movement since 1955. Vectors were collected at approximately 20 feet station frequencies on eroding banks to capture the range of migration distances expressed at a given site. The results are summarized in Table 3-2. In developing a buffer, a migration rate reflecting the 90th percentile measurement was selected and extrapolated to a 100-year erosion buffer. This buffer was applied to the digitized 2011 banklines on both banks to allow for future channel movement including bendway migration, bendway compression, and stochastic processes such as woody debris lodging and associated channel movement. The CMZ buffer applied in Phase 2 is 117 feet (Table 3-2). Based on the historic analysis, this buffer is anticipated to accommodate the vast majority of channel movement over the next century, thus effectively addressing the risk of entrainment due to channel migration.

Table 3-2. Results of Migration Rate Analysis

Station		**Phase 2**
Number of Measurements		58
1954-2011 Migration Distance (ft)	Mean	40
	90th Percentile	67
	Maximum	107
1954-2011 Migration Rate (ft/yr)	Mean	0.7
	90th Percentile	1.2
	Maximum	1.9
100-Yr Migration Distance (ft)	Mean	70
	90th Percentile	117
	Maximum	188
Basis of Buffer Selection		**Minimal Buffer Width (ft)**
100-Year Migration Buffer		117

In addition to channel migration, tailings recruitment by the river can occur due to channel avulsion, or a rapid relocation of the channel into a new thread. Avulsions are most common across bendway cores where the channel is elongated through a bend, the meander tab is low and floodplain channels are present that provide an efficient cutoff path. One large bendway at Station 1+00 was identified as an avulsion risk and added to the CMZ. All other high risk avulsion hazards are accommodated by the 117-foot wide CMZ buffer. Once the CMZ was developed, areas where test pits showed no contamination were clipped from the boundary to develop an initial removal boundary based on the demonstrated risk of direct tailings entrainment over the next century. The CMZ derived removal corridor is shown in Figure 3-1.

3.1.3 Floodplain Connectivity and Riparian Vegetation

In some cases, the removal boundary may be adjusted to increase floodplain connectivity or preserve wetland or rare vegetation as well as low depositional areas along the channel. For purposes of identifying the tailings removal extents, a connected floodplain surface is defined as the area that is 0.5 feet above the 2-year WSE or lower. This elevation is used to determine those areas low enough to be regularly inundated by surface flows or saturated by groundwater within the rooting zone. This

range of elevations typically supports native riparian and wetland vegetation. Removal may occur in areas that are not currently connected, but would be connected if removing tailings plus 0.5 feet of over excavation would result in the surface being 0.5 feet above the 2-year WSE or lower. This would result in floodplain elevations that are similar to adjacent to areas where tailings/impacted soils are being removed as part of remedial activities.

Some areas having patches of uncommon native vegetation, such as mature cottonwoods (*Populus balsamifera ssp. trichocarpa)*, will be preserved regardless of contamination depth and location relative to the CMZ. Cottonwoods are rare in the Clark Fork River floodplain in Reach A and provide habitat and seed sources, so preservation is consistent with remedial objectives.

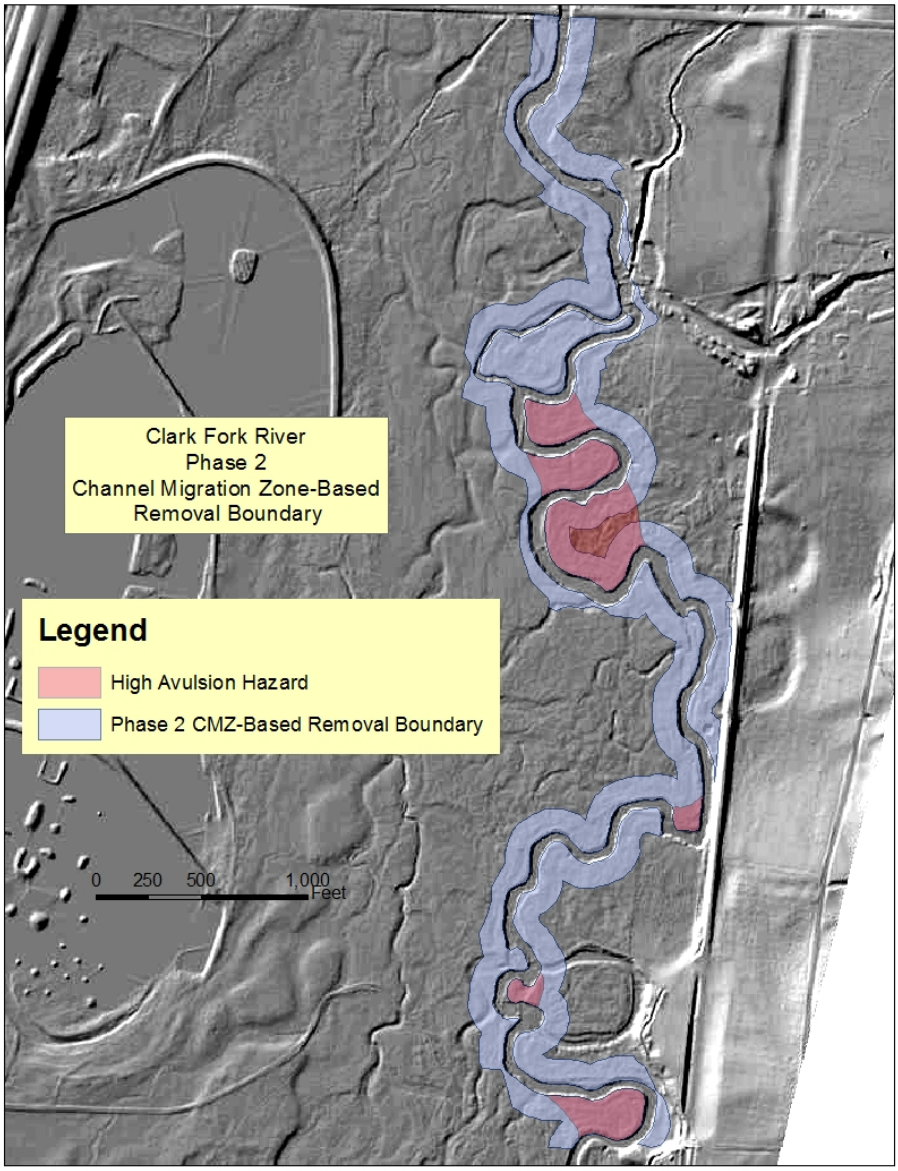


Figure 3-1. Channel Migration Zone-based removal boundary, Phase 2.

3.1.4 Excavation Boundary Design Criteria

The extent of the excavation boundary is determined by a number of factors including the CMZ, the presence of surficial arsenic, the presence and depth of tailings, connectivity to groundwater, and the presence of high value vegetation. The removal of tailings creates an opportunity to reestablish a functioning floodplain by partially backfilling the excavation and leaving an inset floodplain. This inset floodplain will allow out-of-bank flows during high flow periods and provide floodplain vegetation with more direct access to groundwater while minimizing the need for backfill. Landowners' needs were also considered in determining the excavation boundary, such as retaining flat areas for grazing and hay production (floodplain design criteria are discussed in Section 3.2).

The excavation boundary therefore is determined by several criteria that can modify the contamination removal criteria presented above:

1. At a minimum, the excavation boundary will include a zone large enough to remove contamination that is demonstrably at risk of entrainment over the next century (CMZ).
2. The excavation boundary will be expanded beyond the CMZ margin to include areas with over 24 inches of contamination.
3. The boundaries of healthy vegetation communities may be used to modify the extent of excavation in areas where tailings are less than 24 inches deep.
4. The existing topography can be used to aid interpretation of boundaries.

These excavation boundary criteria together with the contamination removal criteria in this section are considered collectively in the definition of the floodplain boundary presented in Section 4, Proposed Design.

3.2 Floodplain Design Criteria

Design criteria for reconstruction of the floodplain are guided primarily by land use determined by the landowners. Three main types of land use have been identified:

- Pasture –This land will be rebuilt either to the approximate existing elevation or lower. This land will be left relatively flat with no surface roughness features. However, planting belts of willows or other shrubs may be included where appropriate.
- Hay field – These areas will be rebuilt to the approximate existing elevation and planted for hay production.
- Riparian floodplain – This land will be rebuilt to an elevation that on average floods at a 2-year recurrence frequency and is adjacent to the river. Portions of the riparian floodplain will be left with a rough, hummocky surface, and pieces of brush salvaged from brush clearing piles will be buried into the surface and scattered over the surface to enhance floodplain roughness and provide microenvironments that enhance plant establishment. Wetlands and secondary channels may be constructed in riparian floodplains when consistent with land use. Small depressions, approximately 30 feet wide, 20 feet long and 2 feet deep will also be constructed in riparian floodplain areas. Riparian floodplain areas will be revegetated with native riparian species. Some riparian floodplain may be grazed after vegetation is established and special consideration will be given to plants species suitable for forage in these areas.

Currently, the Clark Fork River floodplain in Phase 2 is elevated above the stream to a degree that rarely allows overbank flows and greatly reduces suitable conditions for riparian vegetation (CDM and AGI, 2010). The objective of rebuilding a lower floodplain is to provide connection of the stream with the floodplain and thereby promote the recovery of a robust, self-sustaining riparian corridor, a condition precedent to meet remedial vegetative performance standards. This configuration will also allow the river to migrate in a more natural manner, recruit woody debris, and support geomorphic complexity and stability on the floodplain including wetland areas, secondary channels etc. This dynamic interaction between the river and its floodplain also results in improved aquatic and terrestrial habitat as well as improved sediment transport and other fluvial functions.

3.2.1 Floodplain Excavation and Backfill Design Criteria

Removal of tailings from the Phase 2 floodplain provides an opportunity to hydrologically reconnect the floodplain to the river, which has benefits for river function and revegetation. The elevation of the reconstructed floodplain should be low enough to allow regular, though not necessarily annual inundation during high flow periods. There are a number of methods of arriving at the preferred channel capacity including effective discharge, bankfull discharge, and the return-interval discharge. The advantages and disadvantages of these different approaches are discussed in *Channel Forming Discharge Selection in River Restoration Design* (Doyle *et al.,* 2007). For this design, the return-interval method is applied to provide the desired access frequency of out-of-bank flows to the floodplain.

Bankfull discharge has often been associated with a flood-recurrence interval. This method has some validity when applied to stable alluvial streams and a recurrence flood in the range of 1 to 2.5 years is often found (Copeland *et al.,* 2000; Shields *et al.*, 2003). However, the range of recurrence floods can be wider than this as discussed by Williams (1978). Selection of the 2-year interval for the Clark Fork River falls within the conservative end of this typical range yet provides a 50 percent probability of floodplain inundation in any year, and is therefore a logical recurrence interval to use to cause occasional access by floods to the floodplain. Selection of a more frequent interval would increase the frequency of out-of-bank events and increase the width to depth ratio on the resulting smaller channel, both of which are undesirable consequences during the period of establishment of floodplain and bank vegetation. It also allows greater channel capacity should the Warm Springs Ponds be removed from the system and peak flows increase.

Because the floodplain will be reconstructed below its existing elevation in many locations, special consideration must be given to excavation and backfill during construction. These considerations include overexcavation in certain areas to ensure sufficient depth for placement of appropriate backfill and disposition of the overexcavated material. The design criteria for floodplain excavation and backfill are as follows:

1. The final floodplain will be reconstructed at an elevation that is appropriate for the final land use.

2. In excavated areas where the removal depth is too high to accommodate the planned backfill required for vegetation establishment or other design purpose, additional material will be removed and used as general backfill in the floodplain.

3. In excavated areas that require fill to meet the final floodplain elevation, uncontaminated sources of fill that meet the specifications for the desired substrate will be imported.

4. The transition from the edge of the rebuilt floodplain to the existing grade at the excavation boundary should be no steeper than 3H:1V.

3.2.2 Design Criteria to Minimize Avulsion

When floods of significant depth access the floodplain, the force of the water flowing across the floodplain can cause new channels to form. If these new channels are large enough that they retain a major portion of the streamflow after the flood subsides, they are called avulsions. Avulsion is a river-forming process that is expected to occur over time in a naturally functioning, meandering river system. For example, when a meander bend becomes so long and low gradient that it can no longer transport sediment, an avulsion is likely to form during an out-of-bank event. This cuts off the over-long bend, establishes a straighter channel with a steeper grade, and reestablishes sediment transport. However, avulsions are not desirable while the floodplain is in a vulnerable condition before woody vegetation is well established. If an avulsion forms prior to establishment of floodplain vegetation, it will cause a large amount of erosion over a short period of time, which will adversely affect local grade stability, riparian recovery, and aquatic species.

Research has shown that a common cause of avulsion is the reduction in channel slope (Sc) through channel lengthening (meandering) to a point where the slope of the avulsion path (Sa) is markedly steeper than that of the channel (Jones and Schumm, 1999). Slingerman and Smith (1998) showed that avulsions are common on sandy systems when the ratio of avulsion path slope to channel slope (Sa/Sc) exceeds a value of approximately five. On the Clark Fork River, this value has been used as a rough guide since the system is coarser grained, and because of the lack of reinforcing vegetation immediately post-construction. Five bends have been identified as having a Sa/Sc ratio in excess of 4, and these bends have all been categorized as having a high avulsion hazard. Another bend at Station 38+00 was categorized as a high hazard due to the anomalously steep avulsion path slope where the river abuts the right valley wall. These sites are summarized in Table 3-3 and Figure 3-2.

Because avulsions are undesirable during the period of vegetation establishment, several design criteria have been developed to minimize the formation of avulsions on bendway identified as high hazard. These criteria address both the potential for bendway cutoff as well as creation and/or enlargement of secondary channels on the floodplain.

- To reduce the potential for avulsion on bends identified as prone, a subtle topographic high will be constructed through the bendway core to reduce the risk of immediate avulsion.
- This high ground will take the form of a broad berm with minimal height (typically about 0.5 feet). Meander cores and other potential avulsion paths will be treated with roughness elements (e.g., buried wood) and planted with shrubs through the anticipated avulsion pathway.
- Outside bends may be elevated up to 0.5 feet above the 2-year water surface elevation, and inside bends may be lowered up to 0.5 feet below the 2-year water surface elevation to minimize risk of avulsion paths forming on the outside of bends (see Figure 3-3).
- Secondary channel banks should not be set at a lower elevation than the corresponding main channel banks in a cross-valley direction to avoid becoming preferential flow paths during major floods.

Table 3-3. Identified Avulsion Hazards, Phase 2.

Station	*Channel Length (ft)*	*Avulsion Path Length (ft)*	*Channel Slope*	*Avulsion Path Slope*	*Sa/Sc*	*Risk*	*Comment*
5+00	743	157	0.25%	1.17%	4.7	High	Transitioning from Phase 1
18+00	335	62	0.35%	1.90%	5.4	High	~1950 meander cutoff adjustment
27+00	454	254	0.04%	0.07%	1.8	Low	Very low gradient section
30+00	417	241	0.07%	0.12%	1.7	Low	Low gradient
33+00	500	244	0.18%	0.37%	2.0	Low	Low gradient
38+00	401	152	0.41%	1.08%	*2.6*	High	Profile indicates anomalously steep slope here as channel approaches right valley wall.
53+00	500	227	0.16%	0.36%	2.2	Mod	Low Radius of Curvature/Width ratio (~1.4), some deposition within upstream limb.
61+00	1285	311	0.25%	1.04%	4.1	High	Low Radius of Curvature/Width ratio on upstream meander
68+00	1000	210	0.12%	0.57%	4.8	High	Within removal boundary; Sa/Sc approaching 5
74+00	800	189	0.21%	0.90%	4.2	High	Overflow return point is split flow segment; avulsion would cause channel enlargement

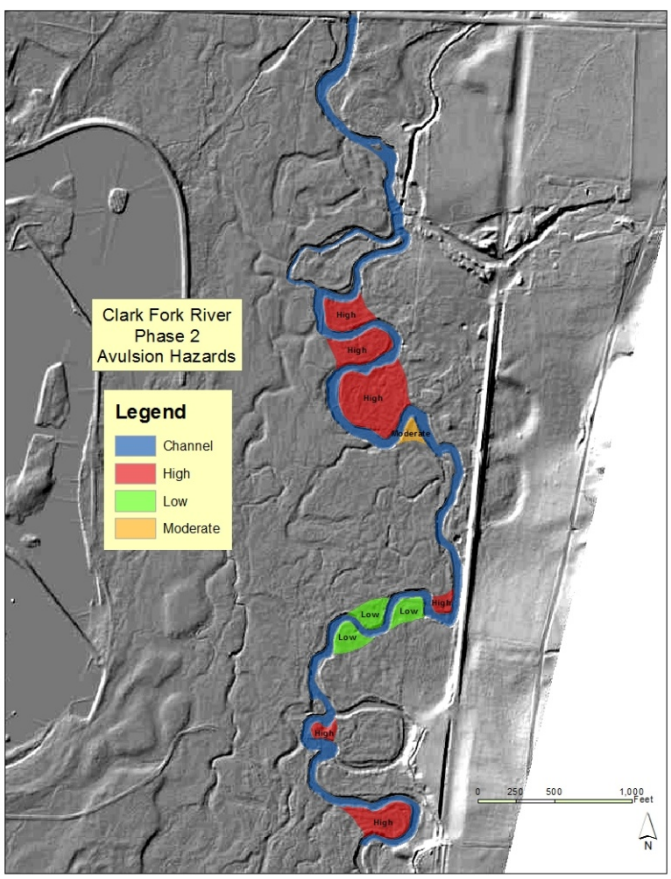
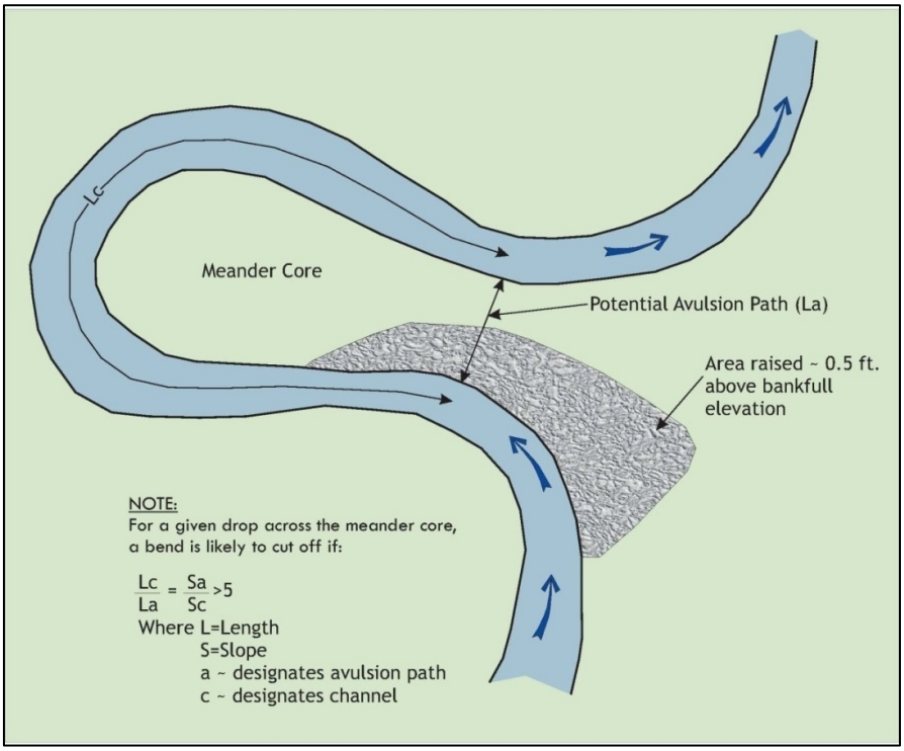


Figure 3-2. Mapped areas at risk of avulsion showing relative risk, Phase 2.

Figure 3-3. Schematic example of avulsion protection on meander bend.



- The secondary channel length will be no less than 75 percent of the adjacent primary channel length. The floodplain backfill gradation will be designed to withstand similar shear stresses to those of the channel to minimize floodplain erosion and new channel formation (Section 3.4.2).
- Wetlands should be set back at least 50 feet from the main channel to avoid being easily accessed during out-of-bank flows and potentially developing into avulsions, and should be spaced so as to minimize the potential to form new channels during floods. Wetlands should also be placed away from other potential avulsion paths such as those across meander cores.

3.2.3 Floodplain Grading Design Criteria

The objective of floodplain grading is to establish a surface that supports the expected land use. Three land uses are anticipated in Phase 2, pasture land, hay fields, and riparian floodplain.

Pasture

The objective of pasture floodplain grading is to develop a relatively smooth surface that is easily planted with suitable forage for grazing. The following design criteria apply to grading for pastures:

1. This land will be rebuilt either to the approximate existing elevation or lower. The final 0.5 feet of cover will be vegetative backfill.
2. Materials used to build subgrade will be non-impacted material or alluvial backfill. In higher areas of the floodplain where the finished grade will be at least 0.5 feet higher than the adjacent bank height, the subgrade can be built with general fill.

3. This land will be left relatively flat with no surface roughness features. However, planting belts of cottonwoods, willows or other shrubs may be included to provide livestock shelter, and these features may be graded lower than the typical floodplain surface to promote growth. Side slopes of these depression features shall be a maximum of 4H:1V.

Hay Field

Areas used for hay production will be rebuilt to the approximate existing elevation and planted with hay. The following design criteria apply to grading for hay fields:

1. The final surface will be set at the elevation desired by the landowner but no higher than the existing elevation.

2. The final surface will be graded to be smooth and relatively flat but with enough slope for drainage (0.5% to 2% slope).

3. Backfill of the uppermost 1.5 feet will be vegetative backfill. Subgrade will be constructed of general backfill with minimal coarse fragments.

Riparian Floodplain

In areas where a riparian floodplain is designed, the objective is to develop a complex surface, generally close to or in contact with groundwater that supports diverse riparian vegetation. This surface will also support secondary channels and wetlands when consistent with land use. Some riparian floodplain will be grazed and special consideration for landowner needs will be given to designs in these areas. The following design criteria apply to grading for riparian floodplain areas:

1. The target elevation for the riparian floodplain areas is approximately the 2-year WSE.

2. Point bar features will be incorporated into the riparian floodplain areas. Point bars occur at the inside of bends and can have significant width compared to their length. Point bars occupy elevations between base flow and the 2-year WSE. Design criteria for point bar slopes strike a balance between providing depositional areas where willows and cottonwoods can establish, and creating sufficient hydraulic compression through pools and outer bend features necessary to drive sediment transport.

3. Lateral bars are low features that occur on straighter reaches between base flow and the 2-year WSE. They are generally set higher than point bars and appear as low benches rather than uniformly sloping features. They are included in the design to preserve existing low features on the floodplain.

4. Backfill of the uppermost 0.5 feet of riparian areas, excepting point bars, will be vegetative backfill. Subgrade will be constructed of non-impacted or alluvial material.

5. Low features such as wetlands and secondary channels, when consistent with land use, will be located where risks of avulsions developing are minimal. These features will be designed to provide topographic variability and habitat variety on the floodplain surface.

6. The existing secondary channel from river station 75+70 to 84+50 will be preserved. Any new secondary channels will be designed to start flowing at a flood magnitude less than the 2-year recurrence events. Secondary channels will contain no more than 10 percent of the 2-year flow during the 2-year flood event. Secondary channels will have irregular margins and

variability of bank elevation to promote infiltration and vegetative recovery on the floodplain surface. Secondary channels will intersect the primary thread at areas of low channel velocity. The channels will reconnect with the main river at the invert grade, creating backwater conditions at the downstream end of the side channel.

7. Wetlands should range from 0.25 to one acre in size. Maximum side slopes should be 10H:1V with more gradual slopes preferred. Depths should be great enough to intersect the groundwater table for at least part of the year (assumed to be 2 feet lower than the 2-year WSE). Wetlands and other low features (other than designed channels) should be bounded by higher ground in the down-valley direction to prevent avulsions during flood events. Wetlands should be located a minimum of 50 feet from streambanks specially if near an avulsion risk area. Backfill of the uppermost 1 foot will be vegetative backfill in wetland features.

8. Wetlands can imitate oxbow bends on an abandoned channel. These wetlands can be connected by shallow, broad channels that flow during wet periods.

9. Microtopography (small swales, ridges) will be included throughout the riparian floodplain with variation of up to one vertical foot from the grading plan. Larger swales (30 to 60 feet long by 15 to 50 feet wide by 1.5 to 2.5 feet deep with target elevation of 2 feet below the 2-year WSE) should also be constructed to promote reestablishment of vegetation by improving access to the groundwater table. These swales should not be placed within 50 feet of the main channel or in meander cores with high or moderate risk of avulsion. Woody debris as well as plants should be incorporated in the swales to increase floodplain roughness.

10. Woody debris will be scattered across and partially buried into the surface of the riparian floodplain. This will reduce velocities at the soil/water interface on the floodplain and increase stability and complexity of reconstructed floodplain surface. Woody debris will consist of willow and birch salvaged during clearing and grubbing activities within the excavation boundary.

3.3 Streambank Reconstruction Design Criteria

The ROD requires that contaminated eroding banks be addressed during remediation (USEPA/MDEQ, 2004). When an eroding bank must be reconstructed, the preference is for stabilization using natural materials. However, in accordance with the ROD, banks that may be contaminated but already have deep, binding, woody vegetation will not be rebuilt. Most banks in Phase 2 will be reconstructed at a lower elevation than existing banks whether they require full reconstruction or not. The purpose of lowering banks is to allow more frequent overbank flooding events and to tie in to the floodplain elevation. Reconstructed banks will have a top bank elevation equivalent to the elevation of the 2-year WSE plus or minus 0.5 feet as described in Section 3.2.2. The following design criteria guide the identification of banks that need reconstruction and determine how the banks are rebuilt.

If contaminated sediments are not present in the adjacent floodplain, no streambank treatment is required. For those banks that require treatment due to presence of erosion, banks were classified in three general categories: point bar reconstruction (Group 1), banks that are not at high risk of erosion, are capable of supporting short-term planform stability, but require some reconstruction (Group 2), and banks that are at high risk of erosion, are not capable of supporting short-term planform stability, and need to be rebuilt in their entirety (Group 3). In addition to these three groups,

which cover most streambank treatment scenarios, some banks require special treatment to protect infrastructure, some areas have split flow conditions, and other areas require no treatment. Figure 3-4 is a flow chart that summarizes the decision process for determining the type of bank treatment needed at specific locations.

3.3.1 Streambank Treatment Design Criteria

Design criteria for bank treatments reflect the desires to maintain banks that are well vegetated with woody vegetation because they support short-term planform stability. Some of these banks have tailings present and removal of tailings is expected to occur behind the banks, but there is a clear preference in the ROD for maintaining these well vegetated banks. The following design criteria apply to bank treatments:

1. Uncontaminated banks without tailings deposits behind them will not be reconstructed unless geomorphic considerations require reconstruction

2. If infrastructure is present, adjacent banks or banks approaching infrastructure (particularly bridges) will be treated to provide stability as needed. This may require a higher level of protection such as riprap. Typical infrastructure needing protection includes irrigation diversions, roads, bridges, or utility crossings.

3. Locations with risk of avulsion should be treated with Group 3 methods both at the likely point of departure of the avulsion path and the return of the avulsion path.

4. Native, desirable woody vegetation will be preserved wherever possible between the typical low water elevation and the 2-year WSE. If native woody vegetation is present and the bank is supporting short-term planform stability, the bank is assigned a Group 2 treatment. If the bank is not supporting short-term planform stability, the bank is assigned a Group 3 treatment.

5. Group 2 bank treatments are determined according to whether stabilizing woody vegetation is present on the bank. Stabilizing woody vegetation is defined as at least 50 percent cover of willow or birches growing from between base flow and the 2 year WSE, with gaps less than 10 feet between woody vegetation along the bank.

6. Group 3 bank treatments are determined according to whether stable toe materials are present (stable toe materials are able to withstand forces associated with a 10-year flow). If existing toe materials are stable, the upper bank is constructed on these existing materials; otherwise, a stable toe is constructed as part of the bank treatment.

7. Banks located at split flow locations, such as an island or entrance to a secondary channel, may receive a bifurcation treatment.

8. Point bars and other passive margins with native, desirable vegetation do not require reconstruction if tailings are not present and these features are at the desired elevation. If tailings are present, inside margins of bends may be reconstructed as point bars with appropriately sized alluvial rock (Group 1).

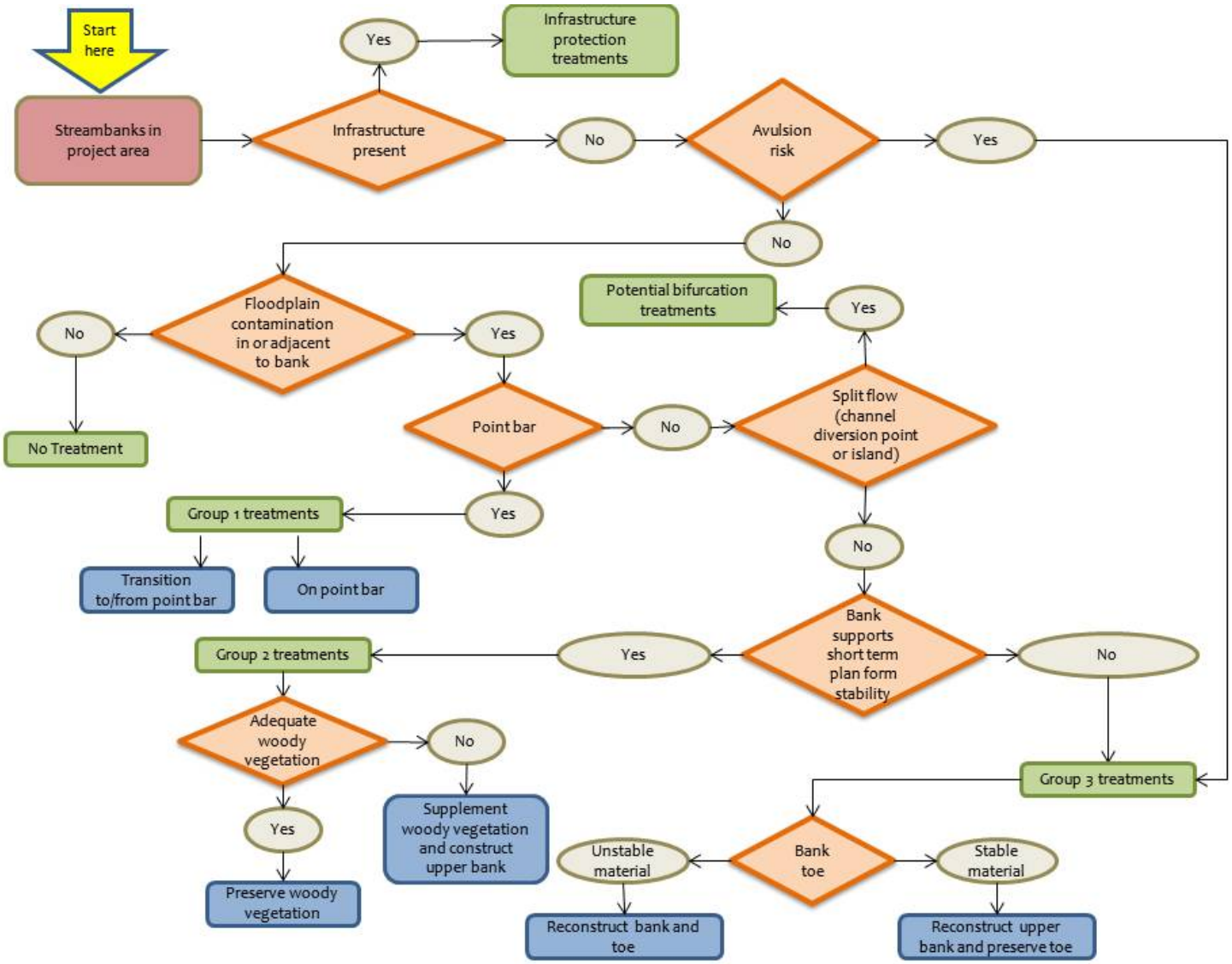


Figure 3-4. Decision process for streambank reconstruction.

3.3.2 Design Criteria for Streambank Reconstruction

Where land use allows, banks will be reconstructed at an elevation that allows frequent access of floodwaters to the floodplain. If the landowner has requested that the floodplain remains high in an area, banks will still be constructed to the design elevation but the land behind them will rapidly slope up to the desired grade. In addition to the criterion for frequent access of floodwaters to the floodplain, the reconstructed bank designs will meet the following stability criteria:

1. Reconstructed banks will be designed to withstand the 10-year flood event at the time of installation.
2. Reconstructed banks for protection of infrastructure will be designed to withstand the 100-year flood event.
3. Streambank designs should use native vegetation and organic materials to the extent practicable.
4. Where native, desirable woody bank vegetation below the design floodplain elevation exists (Group 2 treatments), excavation of the bank will only extend to the top of bank elevation.

3.3.3 Design Criteria for Streambank Toe Construction

The bank toe investigation described in Section 2.4 showed that about 25 percent of the locations excavated had suitable bank toe material close to the desired elevation. The remaining locations would require construction of bank toes to provide stability for reconstructed banks. Bank toe construction for Group 3 banks will meet the following design criteria:

1. Bank excavation will continue until suitable bank toe material is encountered or the expected scour depth is reached.
2. If the bank toe area is excavated, it will be rebuilt up to the elevation where the upper bank protection begins.
3. Rock used in reconstruction of banks other than for infrastructure protection should be sized based on incipient motion calculations and should be fluvial in origin. The D_{50} of the toe gravel should not be mobile under the 10-year recurrence flow at that location.

3.4 Design Criteria for Channel Realignment

Channel reconstruction or realignment was not contemplated in the ROD, but may be necessary in some areas. Upstream in Phase 1, a 450 foot length of channel was diverted and reconstructed to allow excavation of a deep tailings deposit in this area. Another situation that may require channel reconstruction is where locally extreme shear stress conditions drive severe bank erosion. When channel hydraulic conditions are especially severe and banks are eroding rapidly, slowing erosion with bioengineered banks may not be optimal due to the inherent site instability. Factors that contribute to these high shear stresses are over steepened channel segments, areas under rapid adjustment due to meander cutoff, very tight bend radii, and highly irregular bank scalloping. Rather than installing hardened banks to lessen the erosion rate, it is more consistent with project goals and the protection of Bull Trout to realign the channel in a manner that reduces the local site instability. Indicators that a Clark Fork River channel may need realignment to permit construction of bioengineered banks are:

- Radius of curvature to width ratios (R_C/W) of 2 or less,
- Channel slope of 0.0025 or greater, and
- Unvegetated and severely eroding banks.

If at least two of these conditions exist, realignment should be considered when planning streambank remediation. Design criteria for channel realignment are as follows:

- Realign channels so R_C/W is at least 2.5,
- Channel gradient should be less than 0.0033 to avoid mobilizing the streambed in the 10-year recurrence flow.
- Maintain typical bank widths for this reach of river.
- Design pool, riffle and run sections consistent with the bends.
- Use the typical riffle particle gradation to reconstruct the riffle sections.
- Use typical floodplain alluvium gradation to reconstruct the pool and run sections.

3.5 Design Criteria for Backfill Materials

Backfill materials will be needed to reconstruct the floodplain in Phase 2. Vegetative backfill and coarse materials, including various alluvial gradations, will be required. Vegetative backfill requirements are consistent with those in the ROD, and coarse material specifications are based on site specific requirements for floodplain stability. In addition, a general backfill specification will be developed for use in the subgrade outside the CMZ.

3.5.1 Vegetative Backfill

Vegetative backfill is relatively fine grained material that is suitable, when properly amended, for plant growth including grasses, forbs, shrubs and trees. Vegetative backfill design criteria include:

- Vegetative backfill will not have phytotoxic concentrations of metals or be acidic.
- Vegetative backfill will have a texture suitable for a growth medium and coarse fragments should be limited.
- Vegetative backfill will not be too saline for growth of appropriate native species.
- Vegetative backfill will be free of noxious weeds and not contain noxious weed seeds.
- Vegetative backfill will have organic matter concentrations suitable for a growth medium.

Numeric criteria for vegetative backfill are found in the ROD and documented in Table 3-4.

Nutrient or organic matter requirements are described in Section 3.6.

Table 3-4. Chemical and Physical Criteria for Vegetative Backfill

Parameter	Value
pH	6.5 to 8.5
Arsenic (As)	<30 ppm
Cadmium (Cd)	<4 ppm
Copper (Cu)	<100 ppm
Lead (Pb)	<100 ppm
Zinc (Zn)	<250 ppm
Texture:	Sandy loam or finer; no clay
Coarse fragments (>2 mm diameter)	< 45% by volume
Maximum size	6 in.
Specific conductance	<4.0 dS/m
No weeds or weed seeds	

Notes: ppm – parts per million
dS/m – deciSiemens per meter
mm – millimeters

3.5.2 Alluvial Gravel Design Criteria

Alluvial gravel is needed for construction of bank toes, point bars, constructed streambeds, and the floodplain. The alluvial gravel is expected to have a significant soil component in addition to gravel and cobbles. The following design criteria apply to alluvial gravel:

1. The soil portion of the alluvial material will meet metals criteria for vegetative backfill.
2. Gravel and cobble fractions will be rounded and not crushed.
3. The D_{50} of the bank toe material will not be mobilized at flows less than the 10-year recurrence event in the river channel.
4. The floodplain and bank toe material will have sufficient soil fraction to allow compaction.
5. The point bar material will have a D_{50} of about one inch with cobble sizes no larger than six inches. It shall have a soil fraction less than 10 percent.
6. Constructed streambeds will use alluvium with a gradation similar to the gravel and cobble fraction of floodplain alluvium.

3.5.3 General Backfill Design Criteria

In some upland areas, it is unlikely that post-remediation erosion will occur over the next several centuries. For these areas, the subgrade material does not have to be floodplain alluvium and a variety of soils could be used instead of alluvium. One location where such material could be used is beneath the Lampert hayfield, an area that is currently up to five feet above the 2-year WSE. The requirements for general fill are:

- General backfill will not have phytotoxic concentrations of metals or be acidic.

- The texture of general backfill under ASTM D2487 shall be classified as GW, GP, GM, GC, SW, SP, SM, or SC with fine fraction less than 12% and be free from roots and other organic matter, trash, debris, frozen materials, and stones larger than 6 inches in any dimension.
- General backfill will not be too saline to prevent root growth of desired species.
- General backfill will be free of noxious weeds and not contain noxious weed seeds.

3.6 Floodplain Vegetation Design Criteria

As described in Section 3.2, three types of land use have been identified for the Phase 2 project area: pasture, hay field and riparian floodplain. Within pasture and hay field areas, vegetation design criteria focus on establishing conditions necessary to support grazing and hay production operations. Within the riparian floodplain areas, the vegetation design emphasizes creating a self-sustaining mosaic of riparian and wetland plant communities on a floodplain surface that is hydrologically connected to the CFR. The design acknowledges that sediment transport and deposition, distribution of woody debris, flood events, water storage, and nutrient regimes all play a role in floodplain plant community development. Each design plant community (cover type) within the riparian floodplain area represents a starting point for the development of a dynamic riparian system that has the ability to respond to interconnected factors at both the local and watershed scales. Local factors that influence vegetation community development and succession in the floodplain include groundwater, woody debris accumulation, sediment distribution, and accumulation of organic matter or litter. Landscape-scale factors that influence vegetation development include flood regimes, climate patterns, valley type, and surface water-groundwater interactions. These communities are not meant to be static, but are intended to develop and change over time in response to natural floodplain processes.

Because several plant communities can occur on similar geomorphic features, plant communities are grouped into broader floodplain cover types for the purposes of developing vegetation design criteria and treatments. For Phase 2, floodplain cover types include:

- Land use cover types:
  - Pasture
  - Hay field
- Riparian floodplain cover types:
  - Exposed Depositional (non-vegetated)
  - Colonizing Depositional (vegetated)
  - Emergent Wetland
  - Riparian Wetland
  - Floodplain Riparian Shrub
  - Outer Bank Riparian Shrub
  - Upland Transition

Design criteria for each floodplain cover type were developed based on the following physical factors that influence the development of plant communities:

- Future land use.
- Geomorphic feature: the location of the cover type within the floodplain.
- Flood dynamic: the anticipated return interval for overbank flooding within the cover type.
- Estimated depth to groundwater.
- Elevation relative to the 2-year WSE.
- Soil texture: Range of soil textures that can support development of desired plant communities within the cover type.
- Soil depth: depth of soil before alluvium is reached.

Table 3-5 provides ranges for each of these design criteria by floodplain cover type. Design criteria for vegetation are closely tied to floodplain design criteria (Section 3.2), streambank reconstruction design criteria (Section 3.3), and design criteria for backfill materials (Section 3.5). The following discussion explains some of the rationale for vegetation design criteria within the project area for Phase 2.

Creating hydrologic connectivity between the channel and floodplain is necessary for floodplain cover types and related plant communities to develop so they can provide a wide range of floodplain functions and processes. Reconstructing the floodplain at the range of elevations specified in the design will result in this degree of hydrologic connectivity between the floodplain and channel. As a result, flows exceeding the 2-year return flow will deposit nutrients, sediment, and seeds on the floodplain, thereby creating and sustaining riparian vegetation. Floodplain topography that is part of this design also allows for surface connection to groundwater that transports additional nutrients to floodplain vegetation and develops complex food webs below ground. Diverse topography will also support a wide range of plant communities in the floodplain.

As with other natural floodplain processes, riparian soil development and related nutrient exchange also depends on the floodplain and channel being hydrologically connected. Riparian systems generally receive nutrients from allochthonous sources such as dead leaves and woody debris brought from upstream (Vannote *et al*., 1980). Topographic diversity in the form of oxbows, connected side channels, wetlands, and smaller depressions provides pathways and sinks for allochthonous inputs of organic matter and promotes soil development. A significant portion of organic matter and nutrients is also delivered to the floodplain during flood events (Tabacchi *et al*., 1998). A high proportion of fine sediment in floodplain soils consists of soil particles or mineral sediments originating from the stream channel where they were coated with organics (Gregory *et al*., 1991).

The appropriate substrate to support vegetation development includes cobble, gravel, and sand (alluvium) on exposed depositional and colonizing surfaces, and sandy loam to finer textured soils (vegetative growth media) on higher elevation floodplain surfaces and within wetlands. Vegetative backfill depth will be 6 inches within most cover types, which reflects the typically shallow soils found on western Montana alluvial floodplains, where most fine-textured soil that accumulates on alluvium is made up of sediment trapped by established woody vegetation. The organic component of these

Table 3-5. Design Criteria for Floodplain Cover Types

Floodplain Cover Type	Geomorphic Design Feature(s)	Flood Dynamic (flood return interval)	Distance to Groundwater (feet)	Elevation Relative to 2-year WSE (feet)	Soil Texture	Vegetative Backfill (inches to subgrade)
Pasture	Higher terrace			-1 to 2	Silt loam to sandy loam (vegetative backfill)	6
Hay field	Higher terraces	>2 year		0 to 5	Silt loam to sandy loam (vegetative backfill)	18
Exposed Depositional (Non-vegetated)	Non-vegetated portion of point bars	< 1 year	0 to 3	-2.5 to -1.0	Sand, fine to coarse gravel or cobble (alluvium)	0
Colonizing Depositional (Vegetated)	Vegetated portion of point bars	1 to 2 years	0 to 3	-1.0 to 0	Sand, fine to coarse gravel or cobble (alluvium)	0
Emergent Wetland	Passive margins along channel; wetlands, oxbows, and backwater areas	< 1 year	0 to 3	-2.5 to -1.0	Silt to sandy loam (vegetative backfill)	12
Riparian Wetland	Bankfull floodplain in backwater areas; edge of emergent wetlands and oxbows	1 to 2 years	0 to 3	-1.0 to 0	Silt to sandy loam (vegetative backfill) overlying gravel or cobble (alluvium)	6
Floodplain Riparian Shrub	Bankfull floodplain; low terrace	2 to 50 years	2 to 4	-0.5 to 2.5	Silt loam to sandy loam (vegetative backfill) overlying alluvium	6
Outer Bank Riparian Shrub	Streambanks along outer meanders	1 to 10 years	2 to 4	0 to 2.0	Silt loam to sandy loam (vegetative backfill)	6
Upland Transition	Slope transitions to higher terraces; high inclusions within CMZ	10+ years	3 +	2.0 +	Silt loam to sandy loam (vegetative backfill)	6

soils is typically low (1.5 to 2.5 percent) because most organics are derived from either litter that has accumulated over a relatively short time frame or organics that have moved in through the water column. Deeper vegetative growth media will be placed in wetland depressions because depressions with no outlets trap more sediment, resulting in a deeper mineral soil layer. Anaerobic conditions within these constantly-saturated features also result in relatively rapid accumulation of organic matter in soils because the organics do not decompose rapidly. Within designed wetlands, organic matter content in soils will likely trend toward 5 percent or greater over time. Deeper vegetative growth media will also be placed in hay field cover types to allow for long term management of these areas.

3.6.1 Integration with Floodplain Grading

The floodplain grading plan references modeled WSEs for key flows, including the 2-year WSE for creating connected floodplain surfaces and setting bank heights, and the 10-year flow for short-term streambank and floodplain stability. Much of the design floodplain will be constructed between 1 foot above the base flow elevation and 0.5 feet above the 2-year WSE. Floodplain surfaces 0.5 feet above the 2-year WSE and lower are considered to be connected to the river hydrology and able to support riparian and wetland plant communities. The floodplain grading plan development process is closely tied to the process of assigning floodplain cover types for revegetation. Some floodplain locations, such as streambanks on outer meander bends, require specific elevations to maintain the channel and floodplain and support specific vegetation communities, namely the Outer Bank Riparian Shrub cover type. Other floodplain locations allow for more variable elevations that will support the mosaic of riparian and wetland vegetation communities typically found in connected floodplains. Pasture and hayfield elevations also require specific elevations to minimize damage from flooding and support land management goals.

3.7 Restoration in lieu of Remedy

No State Restoration in lieu of Remedy is included in the design.

3.8 Restoration Components

DEQ has coordinated with NRDP regarding implementation and integration of restoration components into the Work. The design reflects the addition of certain specific wetlands which are restoration components. The information regarding these additional restoration wetlands, including the identification of the limited areas and expected additional wetland vegetation needed, is being provided by NRDP under separate cover. Quantities and any additional costs will be delineated in the Remedial Action Work Plan / Bid Package as restoration components.

Section 4

Proposed Design

This section presents the design basis for the Phase 2 Remedial Design. Major elements of the design are developed and presented with respect to the design criteria and project objectives. Design assumptions are explained and references are made to supporting documents. The major elements of the design include:

- Contaminant removal,
- Floodplain reconstruction,
- Streambank reconstruction,
- Channel reconstruction,
- Borrow and backfill, and
- Vegetation.

Besides these major elements, supporting design elements such as dewatering and transportation are discussed. Finally, construction sequencing and construction BMPs are presented for the Phase 2 Remedial Action.

within the removal boundary. Table 4-1 summarizes the calculation of the excavation volume estimate. The total excavated volume is estimated at 389,000 cubic yards.

Table 4-1. Summary of Excavation Volume for Phase 2.

Excavation Area	88.64 Acres
Tailings Volume	318,000 CY
Average Tailings Depth	2.22 ft.
Over Excavation Volume (0.5 ft.)	71,000CY
Total Excavation	389,000 CY
Average Removal Depth	2.72 ft.

Note: CY – cubic yards

4.1.2 Contaminant Removal Excavation Boundary

A determination of the excavation boundary depends upon a combination of several factors, including: the presence and depth of contaminated tailings, the channel migration zone, , and opportunities to increase streambank and floodplain stability by reconnecting the floodplain vegetation with surface flows and groundwater. Tailings / impacted soils will be removed under the following conditions:

1. Arsenic levels exceed the human health standard in the surface interval as discussed below.

2. The sum of contaminants of concern (COCs) (As, Cd, Cu, Pb, Zn) exceeds 1,400 mg/kg (parts per million) and either of the following:

- The lowest contaminated interval of metals is deeper than 24 inches, or

- The contamination lies within the Channel Migration Zone (CMZ).

3. Limited areas where contaminated material is shallower than 24 inches, but that are is contiguous to removal areas, will be removed to promote floodplain connectivity or construction efficiency.

4. In areas where removal occurs, six inches of material below the base of tailings as defined by the removal criteria will be excavated to ensure sufficient removal of contaminants.

Removing tailings and rebuilding a lower floodplain will increase areas of hydrologically connected floodplain and provide a shallower water table. This will make it possible to sustain a range of riparian and wetland plant communities and floodplain functions, which will in turn provide the necessary stability to the floodplain and stream banks.

4.2 Floodplain Design

The objective of the floodplain design is to reconstruct the floodplain in accordance with the existing land use. This allows for uses such as pasture, hay fields, and riparian floodplain, some of which may be subject to grazing after vegetation is established. In areas where landowner use permits, the floodplain will be lowered to the approximate 2-year WSE. To meet this objective and the design criteria that derive from it, numerous features were incorporated in the floodplain design. This section discusses the floodplain backfill concept, means of minimizing risk of avulsions, and details of the floodplain grading plan.

4.2.1 Floodplain Excavation and Backfill Design

Uncontaminated backfill will be used to establish the new floodplain at the appropriate elevation for the land use. As discussed in Section 4.1, tailings will be removed to a depth based on the sum of metals concentration plus a six-inch over excavation depth. Floodplain design will also affect the excavation depth at some locations. In some locations it may be necessary to excavate to a lower elevation to accommodate sufficient backfill to establish appropriate vegetation. An obvious location for additional excavation would be the deeper portions of wetlands. In these cases, the over-excavated material may be placed in areas of the floodplain requiring more fill but should not be substituted for final surface materials such as vegetative backfill.

Pasture and hay fields will generally be established at higher elevations than the riparian floodplain to avoid frequent flooding of these areas. Transition slopes will be needed to gain elevation to these higher terrace-like areas. These transition slopes should be no steeper than 4H:1V to allow vegetation to establish but should be less steep where conditions permit. Transition slopes that occur close to the banks may need additional erosion protection such as coir fabric to protect them while vegetation establishes. In areas where the riparian floodplain extends to the excavation boundary, a slope is required to tie the lowered floodplain surface into existing ground outside of the excavation boundary. To permit revegetation of the slope resulting at the boundary, however, backfill will be placed at no steeper than 3H: 1V slope at the boundary.

4.2.2 Minimizing Risk of Avulsion

As discussed in Section 3.2.2, bends with avulsion paths that are significantly steeper than the channel path are susceptible to channel relocation through the steeper route. At each of these potential cutoff paths, a broad, low elevation berm was designed along the upstream portion of the core of the bend to reduce frequency of meander core overflow. At most locations this broad berm was blended with a raised outer bank on the bend normally found upstream of the meander core (Figure 3-3). This results in a broad section of elevated ground across the potential avulsion path. The outside bank elevation was raised up to 0.5 feet on the upstream end of bends identified as avulsion paths. To reduce the stress on the outer bank in these situations, the inner bank was also lowered about 0.5 feet, which permits the flow to spread out on the floodplain on the inside of the bend.

In areas of potential avulsion, the floodplain should be roughened to provide more initial resistance to flow, thus reducing velocities and providing resistance to erosion. Initially this roughness can be provided by topographic shaping and addition of wood to the substrate. Eventually, planted woody vegetation should provide the needed resistance and floodplain stability, but a period of years will be needed to establish this vegetation. In the interim period, roughness can be added by grading microtopography and inserting woody materials such as small trees and branches in the floodplain backfill. Drawing D6 shows an example of microtopography and coarse woody debris placement on the floodplain surface. Equally important is maintaining a coarse substrate through potential avulsion paths. Floodplain alluvium, which is primarily gravel with cobbles up to 6-inches in diameter, should be placed as backfill and compacted in areas of potential avulsion. This material includes a significant soil fraction which allows compaction of the material. Section 3.4.3 discusses the specifications for floodplain alluvium, which are based on materials observed deep in the existing floodplain.

The process of avulsion commonly involves downstream to upstream headcutting through a meander core. Steep re-entry of floodplain flows into the channel on the downstream limb of meander bends results in floodplain erosion, headcut formation, and potentially up-valley headcut migration through

the meander. To reduce the potential for such headcutting, the banklines most prone to steep overflow returns (the downstream end of mapped avulsion paths) will receive Group 3 bank treatments where appropriate to reinforce those banks during floods.

Secondary channels and wetlands are planned as part of the floodplain design described later in this section. These features pose some risk of avulsion because they are low areas in the floodplain that could serve as pilot channels for avulsions. Therefore, the design of these features considers their potential to develop into avulsion paths as well as their habitat functions. Secondary channels and wetlands are included in the design to provide diverse conditions for vegetation communities to establish, which also provides habitat for a wide range of aquatic and terrestrial species. Secondary channels should be designed so that bankfull elevation is similar to the main channel when compared in the cross-valley direction. If the secondary channel is lower than the main channel in the cross valley direction, water depths will be high in the secondary channel during overbank flows potentially causing the secondary channel to erode into a larger channel. In the extreme case, the secondary channel could actually become the main channel. Therefore, considerable attention was given to the elevation of the secondary channel compared to the main channel during floodplain design. Among other criteria presented in Section 3.2.2 to minimize risk of avulsion, the secondary channel length should be no less than 75 percent of the adjacent primary channel length. In one case, from station 26+50 to station 57+00, a planned secondary channel was not designed because of the inability to meet this criterion. Instead, a series of wetlands connected by linear swales was designed in this area, and connection to the main channel was avoided at the originally planned upstream end.

Avulsion paths were also considered in determining the location of wetlands. Although wetlands are not continuous linear features, they are low areas that could facilitate avulsion. Therefore, wetlands were not situated within 50 feet of the main channel and were not placed near potential avulsion paths such as meander cores.

4.2.3 Riparian Floodplain Grading Design

The riparian portions of the floodplain are designed to provide access for out-of bank flows and to allow vegetation access to groundwater to the maximum extent possible. Reconnection is necessary to meet remedial goals and vegetation performance standards. These design goals are balanced against the need to minimize the risk of avulsion and allow flood water to return to the main channel. Considerations for preventing avulsions have been discussed, and this section presents other design considerations for secondary channels, wetlands, wetland ponds and microtopographic features. A general design goal for all riparian floodplain features is to provide increased complexity in the floodplain resulting in increased roughness to minimize floodplain erosion as well as a variety of habitats.

As discussed above, secondary channels have been included in the design to provide diverse conditions for vegetative communities to establish, and also provide additional aquatic habitat of a type not found in the main channel.

Several channel types have been identified in this design in addition to the main channel. There is an existing secondary channel that splits from the main channel on its left bank at station 75+70 and rejoins the main channel at 84+50. This channel will not be altered and will carry approximately the same flows after remediation as before. A largely inactive oxbow channel is found between stations 16+30 and 19+50 on the right side of the main channel. The topographic expression of this oxbow will be removed during tailings removal because the tailings depths on either side extend below the

base of the oxbow. During floodplain reconstruction the oxbow will be rebuilt in approximately the same alignment except that its apex will be shifted westward, so that the whole oxbow feature will be on State land. The channel will be built to the approximate dimensions of the existing oxbow and the thalweg elevations will be similar as well. This design will replicate the deep pools currently found in the oxbow.

A secondary channel that is not currently active will be partially reactivated. This channel will not be connected to the river at its upstream end but will originate in a wetland near the western border of the excavation and join the river on the left bank at station 57+00. This channel is designed to carry flows less than 10 cfs and will connect a chain of created wetlands along its path. It will be built according to Detail F as shown on Drawing D3 as a simple cobble bed without bank treatments.

Designed wetlands are typically 0.25 to 1 acre in size and are irregular in shape and variable in depth. Wetlands are designed to have variable depths with some of the area low enough to have seasonal low groundwater within the vegetation rooting zone. This ensures that the wetlands will be largely inundated during seasonal high groundwater, which is typically about 2.5 feet higher than low water (Gordon *et al.,* 2010).

Small depression features called floodplain swales are included throughout the floodplain to promote establishment of vegetation by decreasing the depth from the planting surface to groundwater. These features are about 30 to 60 feet long and 15 to 50 feet wide. These features will serve to facilitate floodplain revegetation and trap sediment, nutrients and organic matter. These floodplain swales will also increase floodplain roughness along with other microtopographic features and will contain buried wood as well as plants. In the long-term, and as vegetation establishes, these features will fill with sediment and debris and become less pronounced, eventually returning the floodplain to a more natural appearance.

The design incorporates microtopography (small depressions and ridges) across the floodplain. The purpose of these features is to provide microhabitats for plant establishment as well as additional floodplain roughness. These features typically change the local height of the floodplain by ±0.5 feet. The floodplain roughness created by this microtopography will reduce overbank flow velocities and help control erosion while vegetation is establishing. Woody debris is incorporated in the floodplain as well to provide additional microhabitats and roughness.

4.2.4 Floodplain Hydraulic Model

A hydraulic model of the design condition was developed using HEC-RAS (USACE, 2008). The purpose of the design hydraulic model was to determine bank-full elevations, floodplain inundation, and velocities and shear stresses for channel evaluation. The model was built using the same surveyed stream cross–sections used for the existing conditions model with the exception of the new channel to be constructed from 14+30 to 20+80 where design sections are inserted. The final grading surface was used to develop the overbank portions of the cross sections. Manning's n values for the channel remained the river channel (0.036), but Manning's n for the overbank surfaces varied depending on the desired land use. Pasture lands were assigned an n of 0.035, whereas riparian areas were assigned an n of 0.11 assuming the fully developed land use includes numerous clumps of shrubs.

The model was run as a steady state program with the 2-year peak flow of 584 cfs and the 10-year peak flow of 1,216 cfs (Table 2-1). A low flow estimated from late summer gage records at the Galen gage at 86 cfs was also modeled. The model boundary condition was based on a normal depth

calculation at the lowest survey cross-section located about 600 feet downstream of Perkins Lane bridge. The flow remained subcritical throughout the modeled length. Two spit flows were modeled; one at the oxbow and one at the secondary channel. Table 4-2 summarizes the flows in these channels and the mainstem. Model section locations are in Appendix A as well as model outputs for the 2-year and 10-year peak flow events.

Table 4-2. Results of Split Flow Analysis for Phase 2 Stream Reaches.

	Low Flow (cfs)	2-Year Peak Flow (cfs)	10-year Peak Flow (cfs)
Combined Reaches	86	584	1,216
Oxbow Reach - Main Channel	86	500	992
Oxbow	0	84	224
Secondary Channel Reach – Main Channel	86	418	803
Secondary Channel	0	166	413

A floodplain inundation verification was performed for the 2-year and 10-year recurrence events. Figures showing the inundation surfaces are in Appendix A, and results of the inundation modeling are summarized in Table 4-3. The reconstructed bank height is set at the 2-year flood elevation to promote flow expansion onto the floodplain beginning at this event. The inundation map shows that under project conditions, the two-year event is sometimes within the banks and sometimes outside the banks, generally meeting this criterion. In addition, it shows that the design will promote inundation of both the oxbow and the partially reactivated secondary channel at the 2-year event (Appendix A). The floodplain inundation that occurs at the downstream end of Phase 1 is due to use of a higher 2-year flow for Phase 2 (584 cfs) than in Phase 1 (522 cfs). Analysis of recent peak annual flows increased the estimated 2-year flow for this reach. The 10-year flow will inundate 71% of the reconstructed floodplain indicating that considerable floodplain connectivity has been achieved.

Table 4-3. Inundation areas for 2-year and 10-year Flow Events

	2-yr. Flow	10-yr. Flow
Reconstructed Floodplain Area (acres)	81.2	81.2
Inundated Area (acres)	9.1	57.6
Percent Inundation	11%	71%

Note: Calculations exclude area of river channel.

4.3 Streambank Design

Streambank elevations in Phase 2 will be lowered in most locations as tailings / impacted soils are removed. As discussed in the floodplain design (Section 4.2), the design elevation for the reduced bank height is generally the elevation of the 2-year recurrence event. Below this level native, woody vegetation will be preserved to the extent possible. Passive margins that are vegetated with native, desirable vegetation will also be preserved if they do not require contaminant removal. Where inside bends require reconstruction, they will be constructed in a point bar configuration with appropriately sized alluvial gravel. This lowering of inside bend elevations will reduce outer bank stress during high flow events.

Design criteria require protection of infrastructure, which can require hard bank protection to ensure no bank movement at the design flood. No banks are required to be built to protect infrastructure in Phase 2. The only infrastructure on-stream at this site are the intake to Logan's irrigation pump on

the right bank at station 42+20, where existing riprap will be left in place, the intake to the Helen Johnson ditch where streambanks will be left in place, and the entrance to Perkins Lane Bridge where existing protection will be left in place around the USGS gaging station.

4.3.1 Upper Bank Design

After streambank elevations are lowered to the floodplain elevation, the height of the bank from typical base flow elevation to the floodplain will average 2.1 feet with a minimum height of 1.2 feet and a maximum height of 2.8 feet. Reconstructed banks are designed to resist the 10-year recurrence (10 percent annual frequency). Higher design flows are not desirable because they could result in formation of a minimally deformable channel that will not support natural geomorphic processes. The 10-year recurrence event is estimated to be 1,216 cfs (CDM Smith and AGI, 2013).

Shear stress is a key parameter that affects the stability of streambanks. Shear stress is a calculated parameter that is standard output from the HEC RAS hydraulic model (USACE, 2008). Channel shear stress is calculated by the model as the average value across the wetted perimeter of a cross section, although in actuality it varies from its highest value on the stream bed to its lowest value at the top of the bank. Modeling of the proposed conditions found that the average channel shear stress during the 10-year recurrence event on Phase 2 was 0.50 lb/ft^2 and the maximum value was 1.15 lb/ft^2 (Appendix A). Coir fabrics will be used in the upper bank construction as part of soil lifts that provide short-term bank reinforcement while vegetation establishes. The strongest coir fabrics (e.g,, KoirMat 700 or 900) have shear strengths of 2.25 lb/ft^2 when properly installed and therefore will meet the requirement of initial bank stability during a 10-year event (Fischenich, 2001).

There are some banks in Phase 2 that will not be treated because the bank and materials behind the bank (typically hillslope colluvium or terrace) are not contaminated. There is a short reach of no treatment from Station 2+50 to 3+70 on the right bank, where a high bank of uncontaminated colluvium forms the right bank of the river. Downstream between Station 35+80 and 41+00 the stream abuts the right valley margin; the material has been characterized as uncontaminated and no treatment is required. The downstream portion of this reach follows the abandoned Milwaukee Railroad embankment, which is well armored with large riprap. From Station 42+10 to 42+60 there is riprap on the right bank to protect the intake for Logan's irrigation system and this will remain in place.

Several approaches are taken to bank treatment in Phase 2. No bank treatment will be applied in areas where contamination is absent or where existing bank protection will be preserved. In all other areas, the following bank treatments are applied, listed in order of increasing bank strength:

- **Group 1 Bank Treatments** are applied in areas of low shear stress and include regrading inside meanders into point bar configurations and/or the installation of brush trenches.
- **Group 2 Bank Treatments** include preserving existing bank vegetation or bank material and in some areas adding willow cuttings behind the bank or brush mattresses on the face of the bank to reinforce bank material and vegetation.
- **Group 3 Bank Treatments** employ double layer soil lifts to protect the upper bank where it requires greater protection from shear stress. These treatments are applied in straight runs and outsides of bends where higher shear stresses are expected.

All of these bank treatments that involve reconstruction make use of dormant woody cuttings to provide the binding root mass needed to increase bank strength.

Group 1 Bank Treatments (Point Bar/Lateral Bar Regrading / Brush Trench)

Passive margins, such as insides of bends (point bars/lateral bars) and other low velocity depositional areas will be left untreated or regraded into a point bar/lateral bar configurations and/or treated with a simple brush trench consisting of dormant woody cuttings. These treatments, referred to as Group 1 bank treatments, are shown on Drawing D3. There are a number of ways these passive margins may be treated depending on local topography, presence of robust vegetation on the margin, and desired geomorphic form. Examples of these unique cases are described below:

- Bends with large central angles will be reconfigured as point bars with a gently sloping bar beginning at the base flow elevation. Brush trenches will be installed at the 2-year recurrence flow elevation to indicate the landward extent of these bars although the brush trench may not be continuous on the longer point bars.
- Bends with smaller central angles and existing lateral bars that are contaminated will be reconfigured or rebuilt with steps at the water's edge (low flow) and at the tie in point with the brush trench. This configuration will allow for a relatively flat cross-slope on the bar as shown on Drawing D3.
- Well vegetated passive margins that are not contaminated, such as bank attached bar platforms and that are at an appropriate elevation will be preserved. These areas will be left undisturbed with the potential for installing a brush trench on the landward side of the feature.

Group 2 Bank Treatments (Preserve Vegetation, Vegetation Reinforcement, Gap Treatments)

Group 2 bank treatments preserve existing vegetation or bank material on the face of the bank below the design bank elevation. Some Group 2 banks may have gaps in the vegetation or areas of weakness in the vegetation that require reinforcement. Gaps can be treated with brush mattresses consisting of branches and rocks layered together as shown on Drawings D2 and D3. Where bank material alone is preserved, additional vegetation is added by inserting willow cuttings behind the bank as shown on Drawing D2. These banks are only appropriate in areas with moderate shear stresses such a straight runs.

Group 3 Bank Treatments (Double Vegetated Soil Lifts)

If the bank face does not have sufficiently reinforcing native woody vegetation at the appropriate level, that portion of the bank will be removed and rebuilt with the vegetated soil lifts. In general, areas on outsides of bends, where shear stresses are highest, will be rebuilt with Group 3 treatments.

Group 3 bank treatments contain two soil wrapped lifts with cuttings placed above, below, and between them as shown on Drawings D2 and D3. Floodplain alluvium should be placed and compacted.

Plantings will also be installed behind some Group 3 bank treatments with an option of additional cuttings installation about ten feet behind the bank as shown in Drawing D2. The vegetation design for banks is described in more detail in Section 4.6.

4.3.2 Bank Toe Design

Analysis by CDM Smith of the bank toe materials described in the test pit investigation carried out by Tetra Tech found that alluvial gravel was present below the upper bank in 25% of the investigated locations. For purposes of this design, the upper bank is defined as the upper two feet of the reconstructed bank where soil lifts will be placed. Bank toe material, when dominated by gravels and cobbles, supports the upper bank and minimizes the effects of scour beneath the bank, thereby maintaining bank stability. Dense clay at the position of the bank toe can also fulfill the same purpose. If suitable bank toe material is not present, a bank is likely to collapse especially at erosive locations such as outsides of bends.

For streambanks assigned a Group 3 bank treatment, the contractor should verify that suitable bank toe material is present before rebuilding the bank. Suitable bank toe material in Phase 2 is alluvial material that generally meets the gradation for floodplain alluvium described in Section 4.4.2 (Table 4-8). If suitable bank toe material is not present, the bank toe should be constructed as shown on Detail C of Drawing D3. Based on the test pit investigation, this is expected to occur at approximately 75 percent of the Group 3 bank treatment locations. In some cases, suitable material is present at a deeper elevation than the bank toe, and the bank toe will only need to be constructed down to this elevation. If no suitable bank toe material is encountered, bank toe construction should be extended to the scour depth. The scour depth for a 10-year event has been calculated to range from about two feet below the bank toe for straight reaches to 5 feet below the bank toe for outsides of tight bends (Maynord, 1996). If bank toe material must be installed to the scour depth, the scour depth should be calculated using geometric and hydraulic data for that location.

Most locations where Group 3 bank treatments will be built in Phase 2 are on the outside of bends where shear stresses can be high due to the deflection of the flow by the bend. Bends with small radii of curvature that required Group 3 bank treatments were selected and analyzed for critical shear stress using Shield's Equation (Shield, 1936) under the 10-year peak flow. Table 4-4 shows the calculated increase in shear caused by bendway shape as defined by the ratio of Bend Radius to Width (Rc/W). The Rc/W correction coefficient increases the particle size mobilized (critical D_{50}) with the exception of the bend at Cross Section 91, all of the calculated critical D_{50} values are greater than the average D_{50} for alluvium of 1.2 inches. Processing of the floodplain alluvium will be needed to produce suitable bank toe at these locations if the existing toe material is not suitable. Suitable bank toe material in Phase 2 is alluvial material that generally meets the gradation for floodplain alluvium described in Section 4.4.2 (Table 4-8). If suitable bank toe material is not available at these sections, a gradation with the D_{50} in Table 4-4 should be installed. One additional exception is Cross Section 80, where the bank will be preserved and no toe will be built.

The bank toe should be constructed of floodplain alluvium as shown in Drawing D3. The gradation for floodplain alluvium is given in Table 4-8 and is applicable for the toe reconstruction at all locations except for those four locations previously identified in Table 4-4. Because excavation to place bank toe material will take place below the water surface, measures will need to be implemented to control sediment release to the river. Coffer dams built of plywood and covered with plastic sheeting are one method for controlling sediment in water depths up to three feet. The plywood sheets can be arranged to enclose the work area and isolate water in the work area from the river. Jersey barriers with plastic sheeting can be used if water depths are less than two feet. In deeper locations sacks filled with gravel can be used and stacked if necessary to isolate construction areas.

Table 4-4. Proposed Design Critical Shear Stress Analysis for Bank Toe Material

Cross-section	Station	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Grain Shear(1) (lb/sq ft)	Shear Channel (lb/sq ft)	R/W	Corr.	Corrected Shear(2) (lb/sq ft)	Critical D50(3) (in)
xs 62	4+50	0.00364	5.46	0.47	0.74	1.60	2.1	0.98	3.84
XS 63	6+60	0.00259	3.94	0.26	0.49	1.60	2.1	0.55	2.16
xs73	20+52	0.00329	4.42	0.29	0.49	6.23	1.4	0.40	1.57
XS78	29+18	0.00109	3.67	0.19	0.30	1.56	2.1	0.40	1.57
xs80	33+06	0.00444	7.09	0.73	1.15	1.90	2.2	1.60	6.25
XS89	49+51	0.00169	3.85	0.23	0.36	2.40	1.9	0.44	1.70
XS91	53+11	0.00037	2.19	0.07	0.11	0.91	2.2	0.15	0.58
xs98	63+06	0.00245	5.33	0.41	0.65	2.18	1.96	0.80	3.13
XS 110	82+46	0.00222	4.82	0.34	0.54	1.60	2.07	0.71	2.77
XS 111	84+03	0.00153	4.03	0.24	0.38	1.11	2.15	0.82	3.19

Notes: (1) Grain shear is the shear on bed and bank particles separated from the total shear which includes effects of channel geometry.

(2) Corrected shear is the grain shear the grain shear multiplied by the R/W correction factor.

(3) The critical D_{50} is the size particle that is expected to move under the stress of the corrected shear.

4.3.3 Reconstructed Oxbow and Secondary Channel Bank Design

The largely inactive oxbow channel located between main channel stations 16+20 and 19+50 will be reconstructed after tailings removal is complete in this area. This channel is an important habitat feature for aquatic and terrestrial life. This channel is about 1,200 feet long and carries very little flow. At low water it does barely flow and even at the 10-year recurrence flow it only will carry 224 cfs, about 18 percent of the total 10-year flow. The alignment will be similar to the original alignment except that the apex of the new oxbow will be shifted westward to keep it entirely on State of Montana property. Pools and riffle area will be developed as shown on the plans to mimic existing conditions. The banks will be sloped no steeper than 2H:1V and planted with riparian vegetation. Shear stresses in this channel are expected to be 0.08 lb/ft^2 or less at the 10-year recurrence flow and velocities will be less than 2 ft/s. Under these velocity and shear conditions (see, for example, Fischenich, 2001, Table 2), no reinforcement of banks with bioengineered materials will be needed. All banks will be seeded and planted with woody vegetation which will increase their strength over time.

The secondary channel beginning at main channel station 75+70 and rejoining the main channel at 84+50 is about 1,160 feet long. This channel also will not flow during lowest main channel flows, but will carry 413 cfs (about 34 percent of the flow) during the 10-year recurrence event. The channel will not be reconstructed although banks will be lowered and riparian wetlands installed as shown on Drawing C12. There are two sections on this channel that produce relatively high shear stresses under the 10-year flow event. One is at cross-section 107A where the relatively steep and narrow channel produces shears of 1.11 lb/ft^2, and the other is at cross-section 113A, also a relatively narrow and steep section, where the shear is estimated at 0.72 lb/ft^2. Water velocity is also high at cross section 113 A at 5.3 ft/s, but this velocity is within the stable range for well vegetated banks. In the preliminary design the bank treatment for the secondary channel is Group 2, willows behind the bank. This assumes that the banks are currently vegetated to some degree and additional reinforcement behind the banks is desirable. During final design the sections with relatively high shear will be

inspected to see if additional reinforcement is required such as Group 3 treatment in these locations. The location for the culvert crossing on the secondary channel will also be confirmed and any bank treatment requirements at this location determined.

4.3.4 Bank Treatment Layout

Drawings C15 and C16 show the layout of the different bank treatments for Phase 2 as field determined on November 12, 2012, by the design team. Table 4-5 summarizes the lengths of each treatment group.

Table 4-5. Lengths of Bank Treatments, Phase 2 Design

Bank Treatment Type	Length (feet)
Group 1 (Brush trench)	2,839
Group 2 (Willow cuttings behind bank)	5,000
Group 3 (Double vegetated soil lift)	8,431
TOTAL TREATMENT LENGTH	**16,270**
Preserve Vegetation	5,277
No treatment	932
TOTAL BANK LENGTH	**22,479**
Estimated extent of Group 3 banks requiring toe construction(1)	6,323

Note: (1) Based on 75 percent of DVSL treatments needing bank toe.

About 2,839 feet of passive margins (insides of bends and other low shear stress banks) require construction of a brush trench (Group 1). Another 5,277 feet of bank will be lowered but not rebuilt because they are considered to require strengthening. All other banks will be treated with Group 2 or Group 3 treatments. In addition, there will be no treatment on 932 feet of banks. The bank toe construction length is an estimate based on the frequency of adequate native bank toe material observed during the test pit excavation in Phase 2 and includes estimated full depth bank toe requirements and partial depth toe requirements. Bank toes will only be installed as needed during construction of Group 3 bank treatments.

4.4 Channel Stability and Design

The designed channel was investigated using the HEC-RAS hydraulic model developed for the designed condition to allow verification of the stability of the channel bed and bank toe design. Certain areas identified as unstable in the existing conditions hydraulic model will be reconstructed or realigned to provide stability commensurate with desired channel stability. In addition, the Phase 2 channel design was vetted using the hydraulic model to determine if there were any remaining areas that might compromise the stability of the channel.

4.4.1 Channel Stability Analysis

A HEC-RAS hydraulic model was developed based on the designed condition to evaluate the behavior of the channel/floodplain system under different flow conditions. In particular, the 2-year recurrence flow was modeled to evaluate the design criterion that the channel should hold the approximate 2-year peak flow, and the 10-year recurrence flow was modeled to evaluate the design criterion that the

channel should become deformable at the approximate 10-year peak flow. The inundation modeling is described in Section 4.2.4 and this section describes the evaluation of the stability of the channel under the designed condition.

The designed condition differs from the existing condition of the channel in two primary ways. The banks have generally been lowered allowing out-of-bank flow at the approximate 2-year recurrence flow, and two sections of channel have been redesigned to reduce highly erosive conditions as described in Section 4.4.2. This discussion addresses the stability of the majority of the channel where reconstruction is not anticipated. The designed condition was modeled with full floodplain vegetation reestablishment. Pasture lands were assumed to have a Manning's n value of 0.035 and riparian areas planted with willows were assumed to have a Manning's n value of 0.15. Overbank conditions did not have much effect on the 2-year recurrence flow but had considerable effect on the 10-year recurrence flow because there was significant out-of-bank flow as discussed in section 4.2.4. In general, the 10-year recurrence flow generates higher channel shear stresses than the 2-year recurrence event and this discussion of channel stability centers on the 10-year flow.

The output of the 10-year HEC-RAS model was reviewed to identify areas of high channel shear stress at surveyed cross sections. For areas of relatively high channel shear stress (generally over 0.60 lb/sq ft), the shear stress on the grains (the bed material) was partitioned using Strickler's method as developed by Wilcock *et al.* (2006) and modified for English units. These values are presented as "Grain Shear" in Table 4-6 and fall within reasonable values when related to total shear. Then Shields' equation used the grain shear stress to estimate the median particle size that would become mobilized at that condition. A value of 0.030 for the dimensionless Shields' coefficient was selected based on current research by Mueller *et al.* (2005) that found that the Shields coefficient is typically 0.025 to 0.035 for gravel-bed rivers with slopes in the range 0.001 to 0.006. The slope of the Clark Fork River in Phase 2 varies from 0.002 to 0.003 so a midpoint of 0.030 appears appropriate for the Shields coefficient. Using the Shields equation, the values of "Critical d_{50}" were calculated. For unimodal gravel distributions, this is the characteristic size at which incipient motion on the bed would occur at the modeled flow.

Table 4-6 presents calculation of the critical particle sizes for incipient motion in the main channel bed in Phase 2. This table was obtained by calculating the critical D_{50} for all sections with channel shear stress greater than 0.60 lb/ft^2 and retaining those where the critical D_{50} exceeds the median D_{50} of 1.9 inches found from pebble counts in Phase 2. The averaged pebble count gradation values for Phase 2 may not reflect the site-specific bed sediment at the cross sections shown in Table 4-6; as such the cross-sections identified in Table 4-6 are identified only as potential locations of channel instability.

The areas of relatively high grain shear in Table 4-6 are often associated with areas of high velocity caused by steepening of the main channel. At cross section 66 shown in Appendix A, the channel steepens near the cutoff that occurred below cross section 67. This steepened channel may be an indication of grade adjustments associated with this steeper section of channel. Similarly, the high shear at Cross Section 80 could reflect channel steepening within the shortened reach that flows against the railroad embankment just downstream of this location. The high shear stresses at Cross Sections 104 and 105, which are just upstream of the split flow at the secondary channel, may be related to the relatively steep grade in this reach (about 0.6%) and the large energy losses at the split flow.

Table 4-6. 10-Year Event Critical Shear Stress Analysis for Main Channel Bed, Phase 2.

Cross-section	Station (ft)	E.G. Slope (ft/ft)	Velocity Channel (ft/s)	Grain Shear (lb/sq ft)	Shear Channel (lb/sq ft)	Critical D_{50} (in)
xs66	12+76	0.00415	6.16	0.58	0.93	2.26
xs80	33+06	0.00444	7.09	0.73	1.15	2.84
xs104	74+28	0.00609	6.59	0.71	1.11	2.76
xs105	75+55	0.00395	5.71	0.51	0.82	1.99
xs112	85+73	0.00399	5.65	0.50	0.80	1.97
xs113	88+45	0.00627	6.69	0.73	1.15	2.84
xs115	94+80	0.00502	5.47	0.51	0.81	1.99
xs119	2147	0.00371	5.83	0.52	0.91	2.03

Notes: D_{50} is 1.9 inches and D_{84} is 2.8 in for channel bed material.
Shield's Coefficient = 0.030

The high shear stresses at cross sections 112, 113, and 115 are associated with the very steep gradient (about 0.7%) downstream of the diversion dam for the Helen Johnson irrigation ditch. This steep reach is probably a result of historical relocation and steepening of the main channel in the vicinity of Perkins Lane Bridge. It is possible that this reach is still vertically adjusting in this area although it is likely (but unverified) that rock sizes are significantly larger in this reach and are preventing rapid erosion. The final potentially unstable cross section is cross section 119, which is in the steepened reach upstream of Perkins Lane where the river floodplain becomes narrower and channel velocities are high.

In summary, it appears that many of the potentially unstable locations on the main channel at the 10-year recurrence flow are associated with steepened and possibly actively adjusting areas which result from shortening of the channel whether through natural avulsion or human activities. It is possible that some of these areas will result in channel erosion at the 10-year flow, but the magnitude of this erosion is expected to be within the range of gradual river evolution and not of the magnitude that causes the channel erosion discussed in the next section.

4.4.2 Channel Reconstruction and Reshaping

As described in Section 2.1, an avulsion took place in Phase 2 at Station 16+00 sometime before the collection of the 1954 air photos (Figure 4-1). The avulsed channel appears relatively young in the 1954 image, as it is notably straight and deep. The avulsion may therefore reflect a flood event prior to 1954, or alternatively, it may have been intentionally excavated. There was a very large flood on the Clark Fork River in 1948 when spring rains on a heavy snowpack resulted in a 31,500 cfs discharge at the Clark Fork River above Missoula gage, which exceeded a 25-year event. Regardless of its cause of formation, the channel has been rapidly eroding and lengthening since, migrating westward approximately 80 feet between 1954 and 2006, and an additional 20 feet between 2006 and 2011. Figure 4-1 shows 1955 and 2006 air photos of the avulsion with the 2009 bank inventory results plotted on each image.

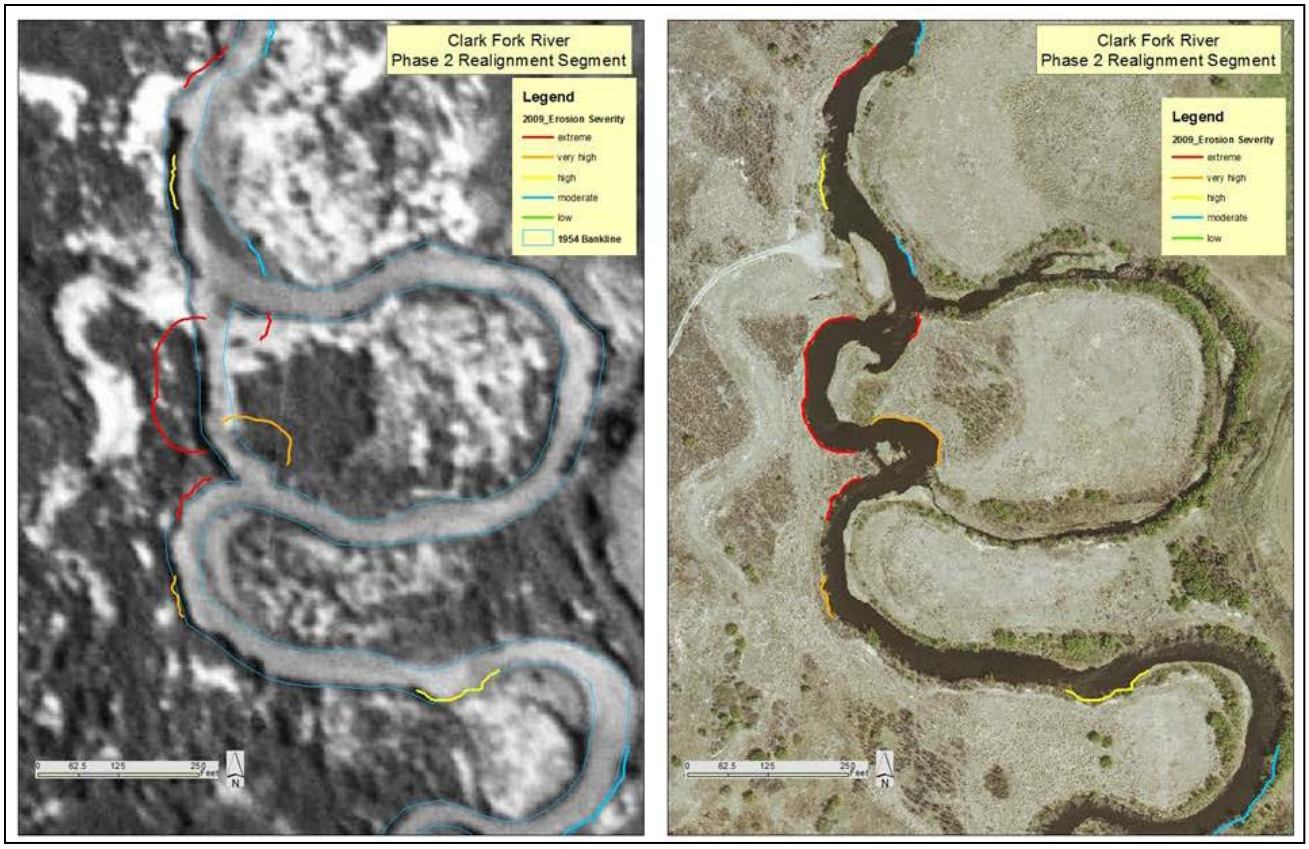


Figure 4-1. Oxbow cutoff in 1955 (left) and 2006 (right) showing mapped erosion severity.

The only way to stabilize this bank at its present location is with hard armoring systems such as riprap. Because the ROD recommends the use of bioengineered bank treatments except where necessary to protect infrastructure, the channel will be realigned at this location to permit construction of a stable stream at the 10-year recurrence interval flood. The reconstructed channel will provide a more stable planform and profile (Figure 4-2). Currently the slope of the avulsed channel is highly variable on a local scale, but averages approximately 0.27%. Radius of curvature to width ratios (R_C/W) through the cutoff are approximately 1.0. The proposed channel realignment will have a radius of curvature of 128 feet, a radius of curvature to width ratio of approximately 2.8, and a slope of 0.31%. This alignment was selected to optimize slope, planform, and connectivity with the existing oxbow features that will intersect the realignment.

To construct the new channel, it will be necessary to divert the river using a combination of coffer dams and inflatable water dams. The oxbow can be used to carry diverted water around a large portion of the new channel but not all of it. At the upper and lower ends of the oxbow, the stream will be constricted with coffer dams and inflatable water dams placed across the left side of the coffer dams at the upstream and downstream ends. The new channel will be constructed in its entirety where feasible, and the left bank and the left portion of the channel will be constructed at the upstream and downstream ends. Then the river will be diverted into the new portion of the channel by removing the downstream and upstream water inflatable dams, and the coffer dams and inflatable water dams will be rearranged to allow reconstruction of the remaining right bank and right channel areas.

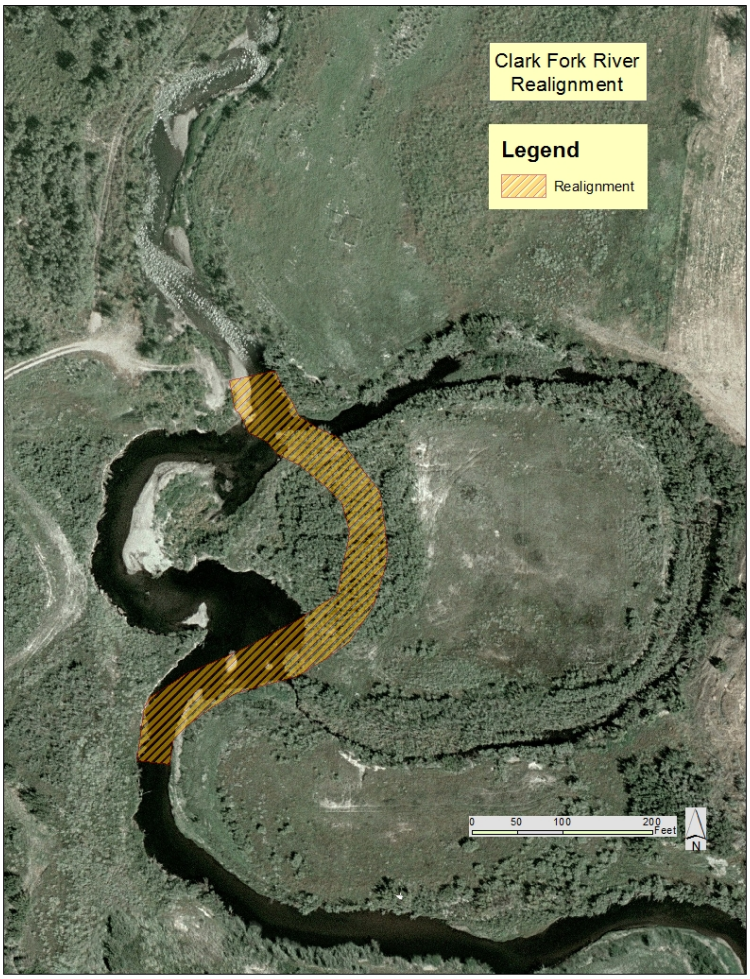


Figure 4-2. Realignment layout for cutoff area.

Another location in Phase 2 where banks are eroding rapidly and allowing rapid channel migration is the right bank at station 50+00. The bend has a severely small centerline radius of about 45 feet that has created shear stresses that have caused the right bank to move about four feet in the last five years. The solution here will also be to reduce the radius in this reach by reshaping the right bank of the stream between stations 50+00 and 51+00. This will relieve stress on the right bank and protect the pasture on the right bank that is currently diminishing. In the long-term, it is likely that the river will continue to migrate to the east at this location, but the migration rates should be much slower with reshaping and bank treatments. Figure 4-3 shows the proposed realignment of the stream to mitigate this problem. This channel has a minimum centerline radius of 120 feet and a radius of curvature to width ratio of approximately 2.4, just short of the design criterion of 2.5. The newly excavated portion of the channel will be lined with one-foot of channel bed material described in Section 4.5.4, and portions of the new channel that lie within the original channel will remain untouched to the extent possible. To construct the new channel at this location, it will be necessary to divert the river using coffer dams but inflatable dams should not be necessary.

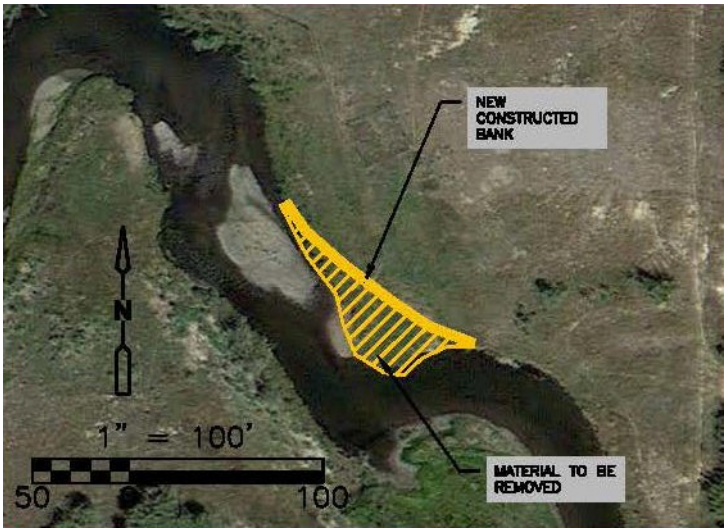


Figure 4-3. Reshaping of the right channel at Stations 50+00 to 51+00.

4.5 Borrow Sources and Backfill Design

Borrow materials will be needed to backfill the excavation to the designed floodplain elevation. They will also be needed for temporary infrastructure such as haul roads and to provide appropriately sized alluvial material for channel construction and for surfacing depositional areas. The primary borrow types needed are vegetative backfill and floodplain alluvium with approximately equal amounts of each type needed. At the preliminary design stage, it is estimated that about 89,600 cubic yards of vegetative backfill and 197,700 cubic yards of floodplain backfill are required.

4.5.1 Vegetative Backfill Requirements

Vegetative backfill is relatively fine-grained material that is suitable for plant growth including grasses, forbs, shrubs and trees. Vegetative backfill will be used throughout the floodplain to support vegetation establishment. Table 4-7 presents the soil suitability requirements for vegetative backfill in Phase 2.

4.5.2 Vegetative Borrow Material Availability and Quality

The quantity of vegetative backfill available at the State's borrow site (also referred to as the Beck Ranch borrow area) three miles south-southwest of Deer Lodge exceeds the vegetative backfill requirement for Phase 2. The borrow area location is shown on the Transportation Plan (Drawing C23). Floodplain backfill of a suitable gradation may also be located at this site, but investigations on its quantity and gradation are still being conducted. Additional vegetative borrow areas are being considered nearer the site and are currently being investigated for quantity and quality of material. One site is located on the Logan's property at the south end of their alfalfa field, and another is on the Lampert's property on the hill west of their house and shed.

Table 4-7. Chemical and Physical Criteria for Vegetative Backfill

Parameter	Value
pH	6.5 to 8.5
Arsenic (As)	<30 ppm
Cadmium (Cd)	<4 ppm
Copper (Cu)	<100 ppm
Lead (Pb)	<100 ppm
Zinc (Zn)	<250 ppm
Texture:	Sandy loam or finer; no clay
Coarse fragments (>2 mm diameter)	< 45% by volume
Maximum size	6 in.
Specific conductance	<4.0 dS/m
No weeds or weed seeds	

Notes: ppm – parts per million
dS/m – deciSiemens per meter
mm – millimeters

At the Beck borrow area, soils generally meet the criteria for vegetative backfill of Table 4-7. The results of soil analysis at the Beck borrow area are described in the *Beck Ranch Cover Soil Investigation* (PBS&J, 2008). During borrow area development the top one-half foot of material will be stripped and stockpiled at the borrow area for borrow area reclamation cover soil. This upper horizon may be contaminated with aerially deposited arsenic and will not generally meet vegetative backfill chemistry requirements. The borrow material will generally be taken from the lower A and B horizons. The higher salinity material found in the C horizon will be avoided if possible. Organic matter will need to be added to these soils for use as vegetative backfill. Vegetative Backfill will generally be used in the upper one-half foot of the floodplain to support vegetative growth and in the development of wetlands. It will also be used in the construction of vegetated soil lifts.

At neighboring sites such as the Streamside Tailings Operable Unit along Silver Bow Creek, salts in cover soils have been an occasional problem. Salts originate either from the cover soil material or from underlying in situ material. The primary concern is that salts can accumulate at and near the surface through a combination of capillary rise and evaporation. Water must be available for seed germination and for rooted plants to survive. In a saline soil, especially one with a very saline surface, the osmotic potential of soil water or even pooled water favors water not moving into the seed, preventing germination. Once germinated, the plant must overcome both the matrix and osmotic potentials of the soil to take up water.

For the Clark Fork River, the soil at the Beck borrow area is generally not particularly saline. Only three of 42 soil samples had electrical conductivity (EC) greater than the 4 dS/m criteria listed in Table 4-6, and none of these samples was from the B horizon. The B horizon, which has an average EC near 2 dS/m, is the primary source of vegetative backfill for this project. Placement of

the much coarser floodplain alluvium below the vegetative backfill will serve as a capillary break and reduce the potential for salts to wick to the surface.

Initial investigations of the potential Logan borrow area found that the upper four feet of soil meet chemical criteria (other than organic content) for vegetative backfill but the texture is loamy sand, which is coarser than required by criteria. However, this soil may be suitable for use as vegetative backfill in low lying, moister portions of the floodplain, and may be preferable to the finer, occasionally saline soils available from the Beck borrow area. Soils at greater depth become too sandy for use as vegetative backfill but could be used as general fill material on parts of the reconstructed site. Organic content is not a limiting factor because it can be adjusted using compost additions. Additional investigations are on-going to determine the extent of suitable material at this site.

Initial investigations at the potential Lampert borrow area found that soils to about four feet met the physical and chemical criteria (except for organic content) for use as vegetative backfill but only one test pit was opened. Additional investigations are on-going at the Lampert site to determine the extent of suitable material at this site.

4.5.3 Vegetative Backfill Borrow Area Development

The primary criteria for vegetative backfill borrow area development are:

- The top one foot of topsoil will be stripped and stockpiled for replacement on the site to allow reestablishment of vegetation;
- A maximum slope of 2H:1V slope will be maintained during construction;
- Side slopes will be recontoured to a maximum slope of 4H:1V at reclamation; and
- Existing drainage ways and positive drainage will be maintained.

Initial staking of the borrow limits and clearing and grubbing in the borrow areas will be limited to the area detailed on Drawing C19, Vegetative Backfill Borrow Area Plan - Beck. Field adjustments or changes to the borrow area limits may be needed during construction. Once the topsoil is stockpiled, the borrow material will be excavated to the elevations shown on Drawing C19. The construction contractor will implement an excavation approach that limits ponding of surface water and erosion. Excavation cut faces where equipment is not working should immediately be sloped back to a 2H:1V slope or less. Sideslopes will be monitored for stability and potential safety concerns.

There will probably be small portions of the borrow areas that don't meet all of the required vegetative borrow criteria. If these zones are sufficiently small such that their mixing during excavation produces material that meets the criteria, they will be incorporated as vegetative backfill. If these areas can't meet criteria with mixing, they won't be used. Field testing should be conducted to verify rock content, soil texture, conductivity, and pH.

The disturbed portions of the borrow areas will be reclaimed using the stockpiled A horizon and revegetated with an upland seed mixture or other seed mix meeting landowner approval.

4.5.4 Alluvial Material Design

Alluvial materials are planned to be used in floodplain reconstruction, bank toe construction, new point bar construction, and new channel beds. Alluvial materials are generally sand, gravels and cobbles that have been transported by water. Although channel reconstruction is not a large part of this remedial design, alluvial materials are needed for construction of certain channels features. Two short reaches of the main channel will be rebuilt to improve the channel alignment as discussed in Section 4.4.2. These new channels as well as smaller, constructed secondary side channels will require alluvial material for their beds.

Floodplain Alluvial Backfill

Besides being used for reconstruction of the floodplain, floodplain alluvium will also be used to construct soil lifts and secondary channel beds. Floodplain backfill materials are designed to be similar to existing floodplain alluvium. No incipient motion calculation has been performed for floodplain material because the hydraulic conditions on the floodplain will be highly variable. In general, however, shear stresses on the floodplain are much less than in the channel because the water depths are less, flows are dispersed, and surface roughness provided by vegetation and microtopography reduces velocities. The assumption made for design purposes is that the alluvial borrow material placed in the floodplain in the most critical locations should have a gradation similar to the gradation of existing floodplain alluvium. Critical locations are areas within the CMZ and potential avulsion paths. Existing floodplain alluvium has a relatively high soil fraction (30 to 40 percent) most of which is sand as is shown by gradations from test pits excavated by Tetra Tech (2011) (Figure 4-4). The floodplain material is designed to be similar to the coarser materials found in this test pit investigation (Table 4-8). The design gradation for this material has a D_{80} of about 3 inches.

Table 4-8. Alluvial Material Design Gradations

Size (inches) or Screen Size	Floodplain (%)	Point Bar (%)	Channel Bed (%)
6	100		100
3	70-100	100	75-95
2	55-80	60-90	40-75
1	35-55	40-70	10-30
0.25	15-35	30-60	0-10
No. 10	10-25	10-30	0-5
No. 200	0-10	0-10	0-2

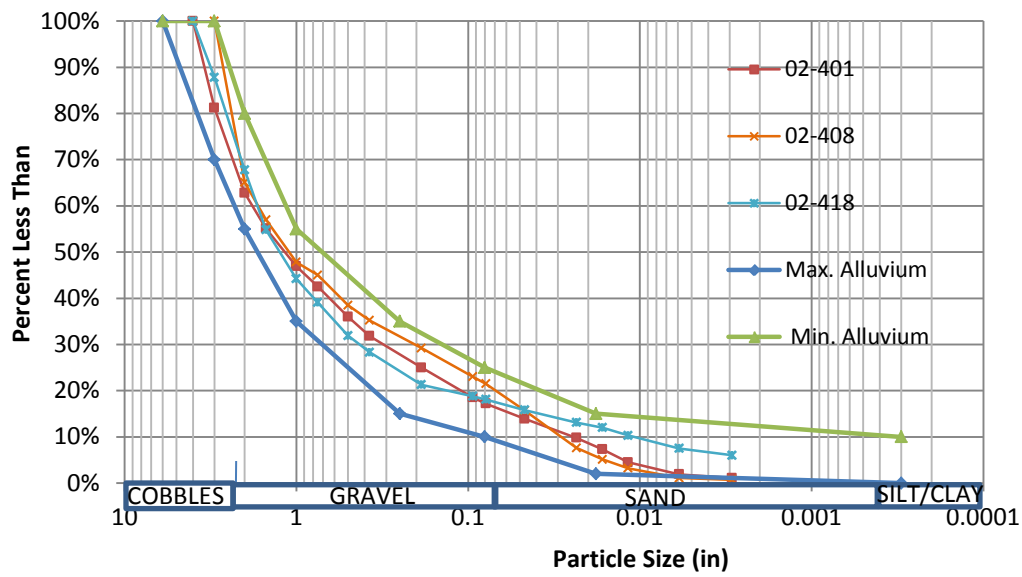


Figure 4-4. Proposed Floodplain Alluvium Gradation

Bank Toe Alluvial Material

Bank toe alluvium will be used to reconstruct the lower portion of banks where suitable materials are not present. As described in Section 2.3, approximately 75 percent of locations where banks will be rebuilt are anticipated not to have suitable toe material. In general, floodplain alluvium can be used as bank toe material as discussed in Section 4.3.2. However, four locations were identified in Phase 2 where the combination of high velocity, energy slope and small radius to width ratio causes high enough shear stresses that coarser gradations would be needed if suitable bank materials are not present. These determinations will be made in the field and suitable gradations developed to meet the specific requirements at these locations.

Point Bar Alluvium

The gradation for point bars is based on observed deposition of point bars in Phase 2. Typically, these depositional zones have smaller sizes of gravel than the channel riffles with a typical D_{50} of 1 inch and occasional cobble sizes (Table 4-8). Some soil (10-30 percent sand or smaller) is included in the point bar gradation to allow some degree of compaction. No incipient motion calculations were performed on this gradation because point bar locations are not subject to high shear stresses except under extreme floods and generally are depositional areas during smaller floods.

Channel Bed Alluvium

At two locations in Phase 2, the channel alignment will be changed to allow reconstruction of more stable channels as described in Section 4.4.2. The channel bed and banks will need to be reconstructed in the new alignment. The channel bed material gradation is based on pebble counts taken in Phase 2 (D_{50} = 1.9 in.) and is equivalent to the floodplain material without a major soil

fraction (Table 4-8). The purpose of the reduced soil fraction is to minimize initial transport of finer sediment in the stream when the constructed channels become active.

4.5.5 Alluvial Borrow Area Availability and Quality

An alluvial borrow area has been investigated on State Land just west of the borrow area for CFR Reach A, Phase 1 (Drawing C1). Investigations are on-going at this borrow source, but sampling of initial test pits indicates that suitable alluvial borrow materials should be available in large quantities at this site. Material samples were analyzed for gradations and one sample was analyzed for soil pH, electrical conductivity and metals to ensure it would be chemically suitable as borrow.

The gradational requirements for alluvial materials are given in Table 4-8. Unprocessed alluvium at the alluvial borrow area will generally meet the floodplain alluvium gradation. Bank toe alluvium can be produced by supplementing the available borrow with 6 inch plus cobbles. The available borrow contains a significant soil fraction, but alluvium with little soil is needed to produce channel bed material. This alluvium should be obtained from a washed pit run alluvium or purchased from a gravel operation. Channel bed alluvium is needed to reconstruct the bed of the main channel from Stations 14+25 to 20+75 and at 50+00 to 51+00 (right bank only). Point bar alluvium will also need to be manufactured from pit run or purchased.

4.5.6 General Backfill

General backfill is uncontaminated material that can be placed as subgrade material instead of alluvial material in areas outside the CMZ where erosion is not expected to occur in the near future. It should not be used in other potentially erosional areas such as subgrade for secondary channels. This material should meet the specifications shown in Table 4-9.

Although general backfill could be taken from a number of sources, in Phase 2 it may be excavated from landowners' properties. Both Phase 2 private landowners have indicated they would like certain portions of their property leveled if they can be developed as borrow sources. Vegetative backfill sources are under investigation on both properties. It is likely at these sources that some of the materials, particularly those at depth, will not meet vegetative backfill requirements but may meet general backfill requirements. If this is the case, general backfill may be obtained economically from these sources and used in floodplain reconstruction.

4.6 Vegetation Design

The design described in this document relies on close integration between floodplain grading, substrate placement, streambank construction, and vegetation treatments. Each of the structural design components integrated into the floodplain is intended to create conditions that will support natural development of riparian and wetland vegetation which will provide increasing floodplain and streambank stability over time. In addition, some structural design components are intended to support specific land uses, such as hay production. Achieving the desired future condition for vegetation relies on a combination of passive treatments, such as creating floodplain conditions that will support natural colonization, and more active revegetation treatments, such as planting and seeding. In the vicinity of the Project area, passive revegetation (relying on some portions of the floodplain to colonize naturally) is a feasible approach for the following reasons:

- Several willow (*Salix*) species present within and around the Project area are adapted to colonizing fluvially deposited surfaces near rivers where elevations are near the average 2-year flood return interval river stage;

Table 4-9. Chemical and Physical Criteria for General Backfill.

PARAMETER	SUITABILITY CRITERIA	Comments
Physical Characteristics		
Soil Texture	Well sorted or poorly sorted gravel, silty gravel, clayey gravel, well sorted or poorly sorted sands, or clayey sands with a fine fraction less than 12%. (USCS)	Material must be strong and compactable.
Coarse Fragment Content	Maximum rock size is 6 inches (15 cm)	To ensure good compaction.
Chemical Characteristics		
pH	> 6.0 and < 8.5 standard units	Neutral range
Specific Conductivity	6.0 dS/m in upland areas	6.0 dS/m considered suitable for many upland plant species (Scianna 2003)
Sodium Adsorption Ratio (SAR)	≤ 12	≥ 13 SAR suggests likelihood of reduced soil permeability and decreased plant survival and growth (MT NRCS 1996)
Exchangeable Sodium Percentage (ESP)	<15	ESP ≥ to 15 percent is considered sodic and therefore unsuitable as growth media (Tiedemann and Lopez 2004)
Element Analysis		
As	< 30 ppm	Taken from the ROD
Cd	< 4 ppm	Taken from the ROD
Cu	< 100 ppm	Taken from the ROD
Pb	< 100 ppm	Taken from the ROD
Zn	< 250 ppm	Taken from the ROD

Notes: ppm– parts per million
dS/m – deciSiemens per meter
mm – millimeters

- Eleven percent of the constructed floodplain surface will be at or below the average 2-year flood return interval river stage;
- Abundant native plant seed sources are available upstream of, and adjacent to, the Project area; and;
- Deep-rooted, mature willows are present within the tailings removal area, and some root stock will likely remain and sprout after tailings are removed.

This section describes the revegetation related treatments for each design cover type. Figure 4-5 shows the distribution of design floodplain cover types in Phase 2 based on the preliminary grading plan. Figure 4-6 shows an example floodplain cross-section comparing existing, design and future floodplain vegetation and substrate.

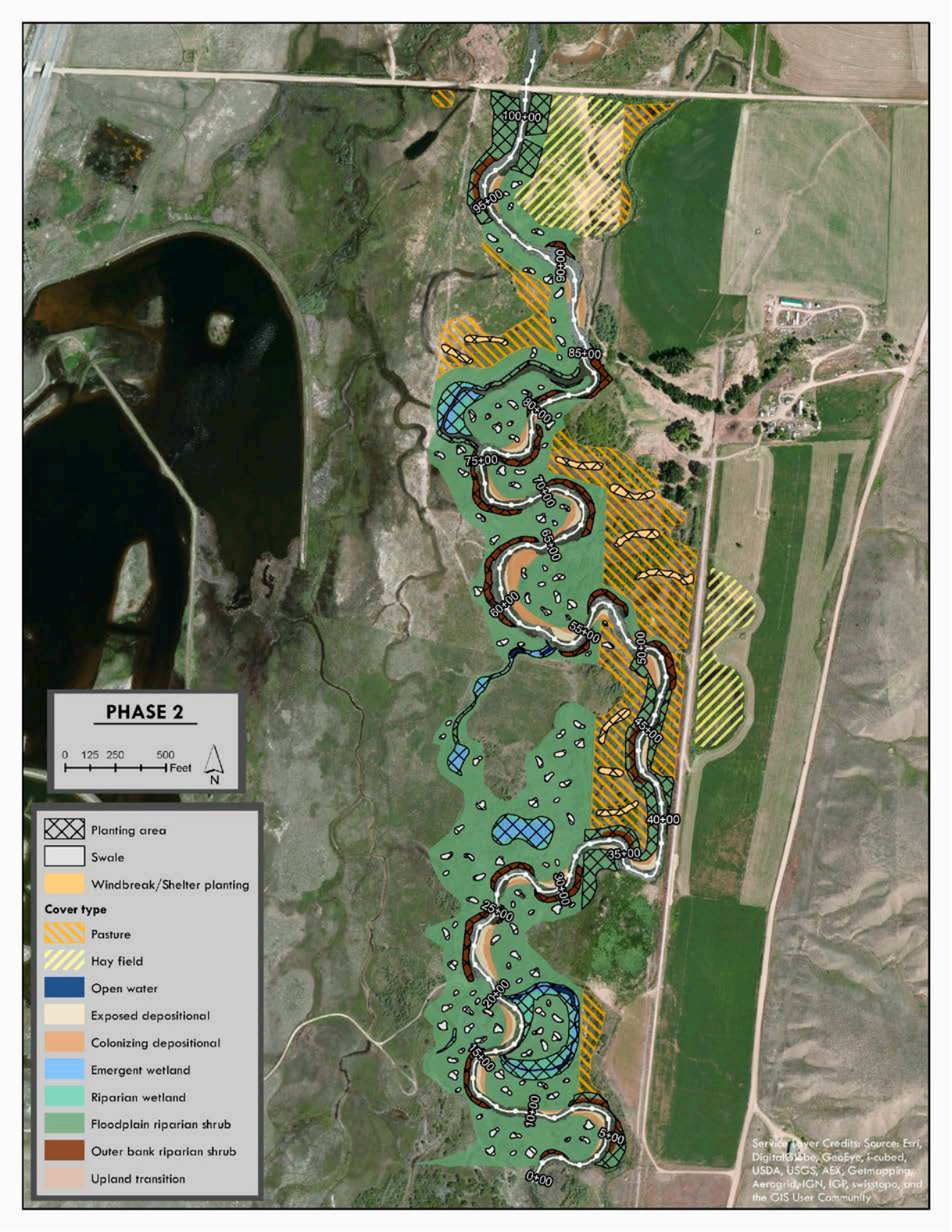


Figure 4-5. Phase 2 Design Cover Types, Planting Areas, Swale Features and Windbreak/Shelter planting areas.

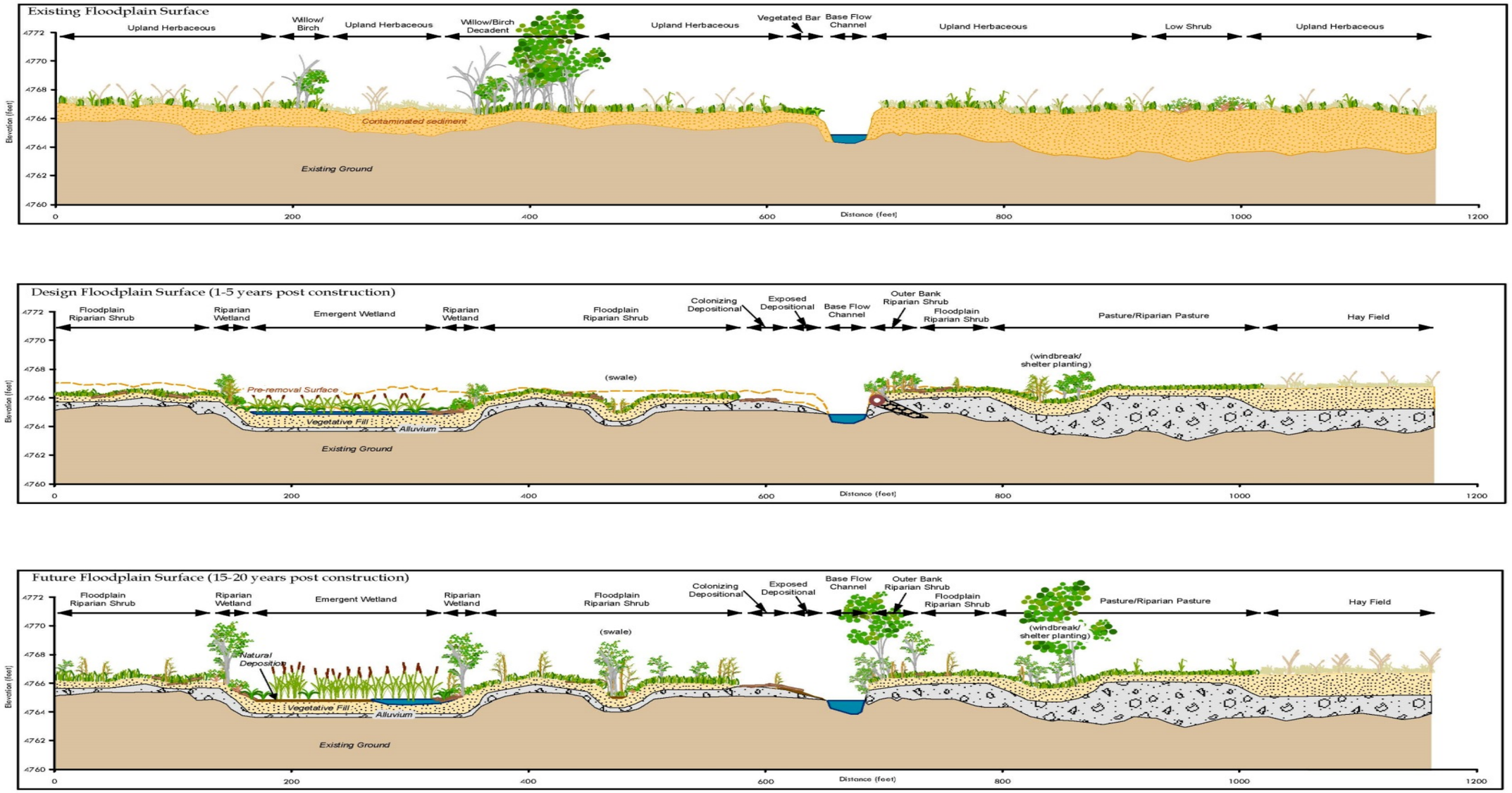


Figure 4-6. Example Cross-section of the Existing, Design and Future Floodplain Surface.

4.6.1 Exposed Depositional

Description

Within the Project area, the Exposed Depositional cover type is located at low elevations along the inside of meander bends between base flow and approximately 1.5 feet above base flow. These areas are subject to frequent scour and often do not support vegetation, but they have the potential to recruit sediment and eventually become vegetated as they aggrade. This type of feature forms naturally from the sediment transport and deposition process, is composed entirely of exposed alluvial substrate such as cobble and gravel, and supports mostly scattered annual vegetation. Because these surfaces are subject to frequent disturbance, over the long term they tend to change shape and may be eliminated altogether. In some locations, once these features have matured they may be colonized with willows (*Salix* species) or herbaceous vegetation that will trap fine sediments, thus creating more niches for other plant species to colonize. These areas may become higher over time as they continue to trap sediment and aggrade, causing them to encroach on the channel forming defined banks. Because these areas are so dynamic and unpredictable, no active revegetation treatments are proposed.

Strategy

The revegetation strategy for the Exposed Depositional cover type includes the following:

- Grading associated with floodplain construction to create surfaces with gradual slopes extending from base flow to below the 2-year WSE.
- Construction using floodplain alluvium consisting of fine to coarse gravel or cobble.

Table 4-10 summarizes the revegetation criteria and treatments for the Exposed Depositional cover type.

4.6.2 Colonizing Depositional

Description

The Colonizing Depositional cover type occupies areas on point bars between the Exposed Depositional cover type and the 2-year WSE. These surfaces are partially vegetated, so they trap finer material than the Exposed Depositional cover type. Typical substrate in these areas consists of recently deposited sediments - patches of sand and silt over gravel and cobble. Successful natural recruitment of willows requires bare, moist, mineral-rich surfaces that are protected from scour so seedlings can survive beyond the first growing season. In addition to willows and other riparian trees and shrubs, annual and perennial herbaceous vegetation will develop on these surfaces. The bare patches created by scour and re-shaping also provide places for additional recruitment, resulting in a variety of age classes and diverse plant community structure. The Colonizing Depositional cover type is a transition between the Exposed Depositional surfaces that experience frequent re-sorting and the more stable Floodplain Riparian Shrub or Riparian Wetland cover type surfaces that experience lower magnitude and lower frequency floods. Over time, some areas within this cover type will continue to be re-shaped by the river. Other areas will become more stable and may transition to one of the other cover types such as Floodplain Riparian Shrub or Riparian Wetland.

Strategy

The revegetation strategy for the Colonizing Depositional cover type includes the following:

- Grading associated with floodplain construction to create surfaces at a higher elevation and, often, further away from the channel than the Exposed Depositional cover type.
- Construction using floodplain alluvium consisting of fine to coarse gravel or cobble.
- Placement of coarse woody debris and logs on the surface (microtopography) to provide protected sites where existing cottonwood and willow seedlings can survive frequent flooding, and to trap sediment and debris floating downstream, creating additional microsites where seeds can germinate and survive.
- Planting of herbaceous wetland plugs to encourage development of desired plant communities along the channel margins.
- Seeding with a two-stage seed mix. The seed mix will include a quick germinating cover crop to prohibit weed infestations and a mix of native grasses and forbs that are generally slower to germinate but longer-lived.
- Table 4-10 summarizes the revegetation criteria and techniques for the Colonizing Depositional cover type.

Table 4-10. Colonizing Depositional Cover Type Criteria and Revegetation Treatments.

Colonizing Depositional Cover Type	**Total Area = 2.3 acres** **Percent of Total Area = 2.6%**	
Treatments	**Criterion/Description**	**Treatment Area**
Grading	-1 to 0 feet relative to 2-year water surface elevation	2.3 acres
Soil Texture	Sand, fine to coarse gravel or cobble (alluvium)	2.3 acres
Vegetative Backfill Depth	No vegetative backfill	N/A
Microtopography	Partially buried woody debris	2.3 acres
Containerized Planting: Shrubs and Trees	Shrubs and trees will be installed in approximately half of this cover type area	1.2 acres
Containerized Planting: Herbaceous Plugs	Herbaceous wetland plugs will be installed in approximately half of this cover type area to promote establishment of desired plant communities	1.2 acres
Seeding	Seed with native mix of grasses and forbs	2.3 acres

4.6.3 Emergent Wetland

Description

The Emergent Wetland cover type will occur primarily within off-channel wetland features and connected wetland complexes throughout the floodplain. It will occupy a zone adjacent to the Riparian Wetland cover type (Section 4.5.4). This cover type will consist of herbaceous wetland plants such as sedges (*Carex* species), bulrushes (*Scirpus* species), rushes (*Juncus* species), and some wetland grasses. These areas have deeper soils than adjacent cover types and more stable hydroperiods (less groundwater fluctuation within the rooting zone than would be present in the Riparian Wetland cover type), and they would likely be submerged during flows above the 2-year return flow. The Emergent Wetland cover type will support several floodplain functions including flood water retention and energy dissipation, sediment storage, primary production, aquatic and terrestrial habitat, aquifer recharge, and nutrient cycling.

Strategy

The revegetation strategy for Emergent Wetland cover type includes the following:

- Grading and substrate placement in association with floodplain shaping to create suitable growing conditions for native wetland vegetation.
- Placing large and coarse woody debris (microtopography) within connected wetland complexes to mimic floodplain and wetland features that are created and maintained by beaver.
- Planting herbaceous plugs within wetlands according to hydrologic zones preferred by various wetland species.
- Seeding with a two-stage seed mix to provide short- and long-term vegetative cover, and to promote a diverse native seed bank.

Table 4-11 summarizes revegetation criteria and treatments for the Emergent Wetland cover type.

Table 4-11. Emergent Wetland Cover Type Criteria and Revegetation Treatments.

Emergent Wetland Cover Type	**Total Area = 1.7 acres** **Percent of Total Area = 2.0%**	
Treatment	**Criterion/Description**	**Treatment Area**
Grading	-2.5 to -1.0 feet relative to 2-year water surface elevation	1.7 acres
Soil Texture	Silt to sandy loam (vegetative backfill)	1.7 acres
Vegetative Backfill Depth	12 inches (over alluvium)	1.7 acres
Microtopography	Placement of coarse woody debris up to the edge of open water.	1.7 acres
Containerized Planting: Herbaceous Plugs	Herbaceous plugs installed according to appropriate hydrologic zones	1.7 acres
Seeding	Seed with diverse native mix of grasses and forbs	1.7 acres

4.6.4 Riparian Wetland

Description

The Riparian Wetland cover type aims to mimic the floodplain landscape features that would have been created and maintained by beaver or natural abandoned channel meanders (oxbows) over time in this type of floodplain system. Plant communities in this cover type include a shrubby overstory of willows (*Salix* species), birch (*Betula* species), and dogwood (*Cornus* species) with a diverse understory comprised of various bulrushes (*Scirpus* species), sedges (*Carex* species), rushes (*Juncus* species), wetland grasses, and forbs. Understory species composition will develop at a local-scale in response to elevation, depth to groundwater, and other hydrologic factors that influence vegetation development into distinct "zones". The Riparian Wetland cover type will contribute to primary production, nutrient cycling, and aquatic and terrestrial habitat among other desired functions. This cover type will occupy floodplain areas that are 0 to 1.0 feet below the 2-year WSE. Soils within this cover type are expected to remain saturated or inundated throughout much of the growing season, and therefore support various riparian and wetland plant communities. Over time, this community could shift to the Floodplain Riparian Shrub cover type depending on floodplain processes and plant community succession.

Strategy

The revegetation strategy for the Riparian Wetland cover type includes the following:

- Grading associated with floodplain construction to create connected off-channel wetlands, connected wetland complexes and along secondary channels where floodplain elevations and depth to groundwater will support a wide range of riparian and wetland plant species.
- Substrate variation and microtopographic enhancements to provide suitable growth media and microsites for better germination and plant survival.
- Installation of large and coarse woody debris (microtopography) to create niches and microsites for vegetation development and add organic matter to the soil.
- Installation of containerized plant material to promote establishment of the vegetation community and provide a long-term seed source.
- Installation of browse protection to protect containerized plants from livestock and wildlife browse and damage.
- Seeding with a two-stage seed mix to provide immediate cover for erosion protection, establish perennial vegetation, and establish a native seed bank in the soil.

Table 4-12 summarizes the revegetation criteria and treatments for the Riparian Wetland cover type.

Table 4-12. Riparian Wetland Cover Type Criteria and Revegetation Treatments.

Riparian Wetland Cover Type	**Total Area = 2.0 acres** **Percent of Total Area = 2.3%**	
Treatment	**Criterion/Description**	**Treatment Area**
Grading	-1.0 to 0 feet relative to 2-year water surface elevation	2.0 acres
Soil Texture	Silt to sandy loam (vegetative backfill) overlying gravel or cobble (alluvium)	2.0 acres
Vegetative Backfill Depth	6 inches	2.0 acres
Microtopography	Large and coarse woody debris will be partially buried and scattered throughout floodplain and within connected wetland complexes as grade control features	2.0 acres
Containerized Planting: Shrubs and Trees	Shrubs and trees will be installed in all areas of this cover type; features include off-channel wetlands, connected wetland complexes and along secondary channels	2.0 acres
Browse Protection	Exclosure fence where possible; individual protectors where not	TBD
Seeding	Seed with diverse native mix of grasses and forbs	2.0 acres

4.6.5 Floodplain Riparian Shrub

Description

The Floodplain Riparian Shrub cover type will occupy the largest percentage of floodplain area within the Phase 2 Project area. It will occur mostly at the 2-year WSE, but will include areas slightly below and slightly higher than this elevation. Soils are expected to be saturated for long enough during the growing season to support riparian plant communities with some wetland characteristics. Plant

communities will consist of a variety of shrubs including those species that are components of the Riparian Wetland cover type described above. The Floodplain Riparian Shrub cover type will also have an overstory component consisting of patches of quaking aspen (*Populus tremuloides*) and black cottonwood (*Populus balsamifera ssp. trichocarpa*). Understory species will include some wetland graminoids, but drier species such as silver buffaloberry (*Shepherdia argentea*) will also be present, particularly where the design requires higher floodplain elevations to limit risk of a channel avulsion. This cover type will provide structural diversity in the floodplain, diverse terrestrial habitat, and long-term floodplain stability.

Strategy

The revegetation strategy for the Floodplain Riparian Shrub cover type includes the following:

- Grading and substrate placement associated with streambank treatments and floodplain construction. This cover type will occupy the floodplain that is connected at the 2-year WSE with lower elevation swales incorporated into this surface.
- Substrate variation and microtopographic enhancements to provide suitable growth media and microsites for better germination and plant survival.
- Installation of large and coarse woody debris (microtopography) to create niches and microsites for vegetation development and add organic matter to the soil.
- Installation of containerized plant material within swale features and potential meander cut-offs to promote the establishment of the vegetation community and provide a long-term seed source.
- Installation of browse protection to protect containerized plants from livestock and wildlife browse and damage.
- Installation of fencing to protect establishing vegetation from wildlife.
- Seeding with a two-stage seed mix to provide immediate cover for erosion protection, establish perennial vegetation, and establish a native seed bank in the soil.

Table 4-13 summarizes revegetation criteria and treatments for the Floodplain Riparian Shrub cover type.

4.6.6 Outer Bank Riparian Shrub

Description

The Outer Bank Riparian Shrub cover type includes areas where the desired long-term vegetation community is dense, deeply rooted riparian trees and shrubs on outer meander bends where the objective is streambank stability. This cover type will be concentrated along outer meander bends to enhance streambank stability, provide overhanging bank vegetation, and create roughness along the channel margins. Native woody shrub and tree species will dominate the overstory and mid-canopy layers while a mix of native forbs and grasses will occupy the understory. Plant communities developing in this cover type will contribute organic material to the stream through leaf litter and vegetation falling into the channel as banks erode over time; larger vegetation pieces will support aquatic habitat by creating roughness along the channel margins. This cover type differs from the Floodplain Riparian Shrub cover type because it has a denser distribution of native woody shrubs.

Table 4-13. Floodplain Riparian Shrub Cover Type Criteria and Revegetation Treatments.

Floodplain Riparian Shrub Cover Type	**Total Area = 47.1 acres** **Percent of Total Area = 54.3%**	
Treatment	**Criterion/Description**	**Treatment Area**
Grading	-0.5 to 2.5 feet relative to 2-year WSE	47.1 acres
Soil Texture	Silt loam to sandy loam	47.1 acres
Vegetative Backfill Depth	6 inches	47.1 acres
Microtopography	Partially buried large and coarse woody debris scattered throughout floodplain	47.1 acres
Containerized Planting	Shrubs and trees installed in swales, potential meander cut-off areas and along the Clark Fork River	7.7 acres
Browse Protection	Exclosure fence where possible; individual protectors where not	TBD
Seeding	Seed with diverse native mix of grasses and forbs	47.1 acres

Strategy

The revegetation strategy for the Outer Bank Riparian Shrub cover type includes the following:

- Grading and substrate placement in association with streambank treatments and floodplain shaping to create suitable growing conditions for native vegetation.
- Installation of large and coarse woody debris (microtopography) to create niches and microsites for vegetation development and promote soil development.
- Installation of containerized plant material in conjunction with streambank treatments.
- Installation of browse protection to protect containerized plants from livestock and wildlife browse and damage.
- Seeding with a two-stage seed mix to provide immediate cover for erosion protection, establish perennial vegetation, and establish a native seed bank in the soil.

Table 4-14 summarizes revegetation criteria and treatments for the Outer Bank Riparian Shrub cover type.

4.6.7 Upland Transition

Description

The Upland Transition cover type occurs at the outside edges of the newly constructed floodplain where the floodplain transitions to significantly higher ground. This cover type serves as a transition between the riparian and floodplain vegetation communities to surrounding drier, upland vegetation communities. This Upland Transition cover type will consist primarily of herbaceous grasses and forb species that are typically adapted for drier growing conditions. However, some species adapted to a wider range of hydrologic tolerance will be included to occupy slightly wetter microsites and prohibit weed invasion. The depth to groundwater is deeper than other cover types and soils will likely be relatively dry through most of the growing season. The Upland Transition cover type will primarily

Table 4-14. Outer Bank Riparian Shrub Cover Type Criteria and Revegetation Treatments.

Outer Bank Riparian Shrub Cover Type	**Total Area = 3.8 acres** **Percent of Total Area = 4.4%**	
Treatment	**Criteria/Description**	**Treatment Area**
Grading	0 to 2.0 feet relative to 2-year water surface elevation	3.8 acres
Soil Texture	Silt loam to sandy loam (vegetative backfill)	3.8 acres
Vegetative Backfill Depth	6 inches	3.8 acres
Microtopography	Partially buried large and coarse woody debris scattered throughout floodplain	3.8 acres
Containerized Planting: Trees and Shrubs	Planted in all areas throughout the cover type	3.8 acres
Browse Protection	Exclosures or individual protectors depending on proximity to channel and size of planting area	TBD
Seeding	Seed with diverse native mix of grasses and forbs	3.8 acres

serve as an intermediate zone between the floodplain and adjacent uplands, but also supports some floodplain functions such as providing terrestrial habitat, filtering sediment and nutrients associated with agricultural runoff, flood storage during large flood events, and food web support.

Strategy

The revegetation strategy for the Upland Transition cover type includes the following:

- Grading and substrate placement in association with floodplain shaping to create suitable growing conditions for native upland vegetation.
- Seeding with a two-stage seed mix to promote a diverse, native seed bank.

Table 4-15 summarizes revegetation criteria and treatments for the Upland Transition cover type.

Table 4-15. Upland Transition Cover Type Criteria and Revegetation Treatments.

Upland Transition Cover Type	**Total Area = 0.1 acres** **Percent of Total Area = 0.1%**	
Treatment	**Criterion/Description**	**Treatment**
Grading	2.0+ feet relative to 2-year water surface elevation	0.1 acres
Soil Texture	Silt to sandy loam (vegetative backfill)	0.1 acres
Vegetative Backfill Depth	6 inches	0.1 acres
Seeding	Drill seed with two-stage seed mix for early germination cover crop and long-term diverse native mix of grasses and forbs	0.1 acres

4.6.8 Hay Field

Description

The Hay Field cover type occurs at various locations within the removal boundary. Hay fields occur in locations where the current land use practice is hay production. This Hay Field cover type will consist of grass, legumes or other herbaceous species. This cover type will be constructed to mimic approximate pre-removal elevations and conditions.

Strategy

The revegetation strategy for the Hay Field cover type includes the following:

- Grading and substrate placement in association with floodplain shaping to create suitable growing conditions for hay crop species.
- Seeding with hay crop species.

Table 4-16 summarizes revegetation criteria and treatments for the Hay Field cover type.

Table 4-16. Hay Field Cover Type Criteria and Revegetation Treatments.

Upland Transition Cover Type	**Total Area = 10.0 acres** **Percent of Total Area = 11.5%**	
Treatment	**Criterion/Description**	**Treatment**
Grading	Similar to pre-removal elevations	10.0 acres
Soil Texture	Silt to sandy loam (vegetative backfill)	10.0 acres
Vegetative Backfill Depth	18 inches	10.0 acres
Seeding	Seed with hay crop species as determined by land owner	10.0 acres

4.6.9 Pasture

Description

The Pasture cover type occurs at various locations within the removal boundary. Pastures occur in locations where the current and desired land use practice is grazing. These areas will be rebuilt either to the approximate existing elevation or lower and left relatively flat with no surface roughness features. This Pasture cover type will consist of native grass and forb species. Planting of trees and shrubs will occur within narrow depressions within the pasture to create windbreaks and shelter areas for livestock.

Strategy

The revegetation strategy for the Pasture cover type includes the following:

- Grading and substrate placement in association with floodplain shaping to create suitable growing conditions for native upland vegetation.
- Installation of containerized plant material in windbreaks/shelter planting areas.
- Installation of browse protection to protect containerized plants from livestock and wildlife browse and damage.
- Seeding with native grasses suitable for grazing.

Table 4-17 summarizes revegetation criteria and treatments for the Pasture cover type.

4.7 Weed Management

Weed management will occur prior to, in conjunction with, or after the revegetation activities described above. During construction the following practices should be followed to avoid the introduction and spread of noxious weeds:

- All vehicles and equipment should arrive free of weeds and weed seeds.

Table 4-17. Pasture Cover Type Criteria and Revegetation Treatments.

Pasture Cover Type	**Total Area = 18.3 acres** **Percent of Total Area = 21.0%**	
Treatment	**Criterion/Description**	**Treatment**
Grading	2.0+ feet relative to 2-year water surface elevation	18.3 acres
Soil Texture	Silt to sandy loam (vegetative backfill)	18.3 acres
Vegetative Backfill Depth	6 inches	18.3 acres
Containerized Planting: Trees and Shrubs	Shrubs and trees installed in windbreaks/shelter planting areas	1.4 acres
Browse Protection	Exclosure fence around windbreaks/shelter planting areas	TBD
Seeding	Drill seed with pasture grasses	18.3 acres

- Vehicle and equipment traffic should remain within designated construction limits and on designated access routes.
- Driving through existing weed infestations should be avoided to the greatest extent possible.
- Noxious weed infestations adjacent to construction limits should be treated according to the weed management plan in order to prohibit the spread of infestations within construction limits.
- All vegetative backfill used during revegetation should be noxious weed and noxious weed seed free.

Preliminary vegetation mapping conducted during summer 2010 identified the state-listed noxious weed species listed in Table 4-18 within the Project area. All the noxious weeds identified at the site are listed as Priority 2b by the State of Montana (2010). Priority 2b weeds are abundant in Montana and widespread in many counties. Management criteria require eradication or containment where less abundant (State of Montana, 2010).

A long term weed management plan will be necessary to control weed infestations at the site post-construction and to ensure project goals and objectives are met. Weed management will be most successful if it is coordinated with local weed management experts and authorities. Development of a long-term vegetation management plan for the site and post-construction weed mapping should be coordinated with the Anaconda/Deer Lodge Weed Coordinator, adjacent private landowners and watershed groups such as the Upper Clark Fork River Vegetation Working Group.

Table 4-18. Phase I Noxious Weed Species found within the Project area and their listing category

Scientific Name	**Common Name**	**Priority**
Cardaria draba	whitetop	2b
Centaurea maculosa	spotted knapweed	2b
Cirsium arvense	Canada thistle	2b
Euphorbia esula	leafy spurge	2b
Linaria dalmatica	Dalmatian toadflax	2b
Linaria vulgaris	yellow toadflax	2b

4.8 Supporting Design Elements

This section describes supporting design elements that enable the construction of the project but don't directly affect the goals of tailings / impacted soil removal, floodplain and bank reconstruction, and revegetation. These supporting design elements are groundwater dewatering, and transportation routes.

4.8.1 Groundwater Dewatering

A significant portion of tailings in Phase 2 are saturated by groundwater. To mitigate the problems associated with excavation, transport, and disposal of saturated materials, the groundwater level in the floodplain will be lowered through groundwater dewatering. The system consists of a series of collector trenches and sumps from which water will be pumped into sediment detention ponds before being discharged to the Clark Fork River.

Objectives

The objective of groundwater dewatering is to permit handling of relatively dry tailings during removal activities. It is difficult to keep uncontaminated and contaminated in-situ materials from mixing when they are saturated. In addition, wet tailings would otherwise have to be stockpiled and allowed to drain prior to hauling, which would require additional handling by the construction contractor. Dewatered tailings will be more easily handled and will be lower in moisture content for direct placement in the B2.12 cell at the Opportunity Ponds.

Design Criteria

Based on construction experience gained from past floodplain dewatering projects, the following design criteria will serve as guidelines for locating the groundwater dewatering sumps and trenches:

1. Use trenches to dewater large, linear areas and sumps alone to dewater contained areas such as peninsulas.
2. Locate the centerline of perimeter trenches within 40 feet of the outer extent of the impacted soils saturated by groundwater.
3. Groundwater must be detained for a sufficient amount of time to reduce turbidity prior to release to the Clark Fork River. Sediment detention ponds will be sized based on the projected flow in the trenches and guidelines outlined in *Montana Sediment and Erosion Control Manual* (DEQ, 1996).

Design Components

The groundwater dewatering system consists of three design components: (1) dewatering trenches designed to lower the groundwater in the floodplain, (2) sediment detention ponds designed to capture sediment from the dewatering trenches; and (3) collection sumps and pumps and piping to transmit the water to and from the sediment detention basins. Collection sumps can be installed without connected trenches where the intent is to dewater a relatively small area.

Construction of the dewatering trenches will begin with excavation of the sumps at the downgradient end of the trenches. A typical detail of a sump is shown on Drawing D1,

Dewatering Details. The base of the sumps will be at least two feet below the grade of the dewatering trench. The sumps will be packed with gravel to filter sediment. The pump system must operate continuously with a backup pumping system available onsite consisting of a spare pump and generator or compressor.

The approximate locations of the groundwater dewatering trenches were determined using the design criteria mentioned above. A typical groundwater dewatering cross-section is shown on Drawing D1, Dewatering Details. After the construction of each trench is complete and the pumped discharge is clear, the discharge from that trench can be routed directly to the river. Construction of the dewatering trenches should be completed at least two weeks prior to the initiation of the tailings removal.

The tailings excavated from the trenches will be disposed in the B2.12 cell at Opportunity Ponds. Saturated tailings must be stockpiled to drain water prior to hauling.

Drawing D1, Dewatering Details, shows a cross section and plan of typical sediment detention ponds. Ponds can either be constructed using clean material to build berms, or they can be recessed into areas of the floodplain where tailings have been removed. Approximate pond locations are shown on drawings C5 and C6, Dewatering Plan. Most ponds will require excavation of tailings in the pond footprint before pond construction. Pond embankments will be constructed from clean local material or imported borrow material. The depth of the ponds will be 3.5 feet from the top of the embankment to the bottom of the basin.

The raised sediment detention pond embankments will be constructed in 12-inch maximum lifts and compacted as directed by the engineer. To minimize the size of the sediment ponds, the trenches should be constructed sequentially and connected one trench at a time. After the construction of each trench is completed and the discharge is visibly free from sediment, the dewatering discharge may be routed directly from the trench to the Clark Fork River. The inlet area of the sediment detention ponds will be protected from erosion with filter fabric covered by stone. The discharge areas from the ponds into the stream channel will be similarly protected. Ponds will be removed after they are no longer needed.

After ponds, trenches and sumps are decommissioned, they will be backfilled with uncontaminated material in accordance with the applicable backfill specifications.

4.8.2 Transportation Routes

Haul routes will be necessary to transport waste materials from and borrow materials to the Phase 2 Project area. The two main haul routes that involve public roads are the haul of wastes to the B2.12 cell at Opportunity Ponds, and the haul of vegetative backfill from the Beck Borrow Area to the site.

Waste materials excavated from Phase 2 will be transported to Opportunity Ponds. Approximately 389,000 cubic yards of waste material will be transported a distance of 7 to 8.2 miles to this facility with most of that distance on public roads. Drawing C23 shows the haul route to the B2.12 cell.

For floodplain reconstruction, approximately 200,000 cubic yards of alluvial borrow are needed to reconstruct the floodplain. A borrow source is available on State Land just west of the borrow source opened in Phase 1. This source is about 0.5 mile from the southern end of the Phase 2 construction site.

Vegetative borrow is obtainable from several sources, some of which are currently being evaluated for quality and quantity of soil. One source being evaluated is on the Logans' property and State Land just east of the construction site. Internal haul roads to be built by the contractor will be used to transport this material. Another site being evaluated is near the Lamping residence just off Eastside Road. Haul from this site could involve up to half a mile of public road on Eastside Road and Perkins Lane. The location of these potential borrow sources are shown on Drawing C1.

A confirmed source for vegetative backfill is the Beck Ranch Borrow Source located on Greenhouse Road about 2 miles north of Sager Lane (Drawings C23 and C19). The one-way travel distance from the Beck borrow area to the nearest (north) portion of the site is 11.25 miles. Over the Road (OTR) type vehicles will be utilized to transfer materials from this borrow source area. This haul route will require crossing the Burlington Northern Santa Fe (BNSF) Railway existing crossing, public road intersections, and utilities.

The remedial construction contractor will be required to construct a primary haul road along the west boundary of Phase 2 that will connect the southern and northern accesses to the site. Drawings C24 and C25 show the proposed location of this haul road. The southern access point is the existing, partially improved road beginning on Morrel road just east of the Warm Springs Interchange and terminating at the Clark Fork River near the Phase 2 southern boundary. The northern access point is from Perkins Lane on the west side of the Clark Fork River. The remedial contractor will be responsible for layout and construction of secondary haul roads within the site boundary and design and construction of the haul roads, approaches and crossings for the anticipated loads, and sizes of the trucks utilized for hauling waste materials and borrow material. Adequate drainage measures will be required, including culverts at drainage crossings and road ditches. During construction activities related to CFR Reach A, Phase 2 Remedial Action, haul routes and crossings (public roads, railways, and utilities) will be maintained and appropriate traffic control will be instituted to sustain safe traffic flows.

4.8.3 Traffic Control

Traffic control will be required and will be appropriate for the size and type of haul equipment used. It is anticipated that the primary haul vehicle for waste materials and borrow material will be OTR haul trucks; however, excavation equipment may be hauled on public roads during construction activities as well.

The contractor will be required to submit a Traffic Control Plan outlining controls, signing, barricades and access control stations in accordance with Part VI of the Manual on Uniform Traffic Control Devices (MUTCD) and Montana Department of Transportation Detailed Drawings.

Traffic control will include control of the two crossings of the BNSF Railway. The remedial construction contractor will coordinate the required crossing system with BNSF Railway. It is

anticipated that both the Sager Lane and the MT 48 crossings of the BNSF Railway will require flaggers during operational hours of the railway. Drawing C23 shows areas expected to require traffic control.

4.8.4 Stream and Utility Crossings

The construction of the Phase 2 internal haul roads system will require several stream and utility crossings during the transport of both waste and borrow materials. Water crossings in Phase 2 will be designed and constructed by the contractor and will be placed prior to streambank remediation efforts. Structures will be set high enough to pass the 2-year recurrence flow. Crossings will include erosion protection for the flow structures and fill embankments. Road approaches to the crossings will be constructed at or below the floodplain surface grades to allow passage of flood flows with minimal backwater accumulation.

Utility crossings will be constructed in accordance with the appropriate utility requirements and will be inspected by individual utility representatives prior to use by construction equipment. The only underground utilities on site are the optical fiber in the abandoned railroad grade and the buried electric and water lines associated with Logans' irrigation pump. Utility crossings for the haul roads will be required to contain measures to prevent damage to existing structures including both underground and overhead utilities. All known utilities have been identified on Drawings C3 and C4, Existing Conditions. Other utilities may exist that are not shown on the drawings. The remedial construction contractor will be responsible for coordination with the appropriate utility representatives to determine locations and crossing requirements. The remedial construction contractor will be required to have all utilities located at the exact crossing locations prior to excavation or heavy equipment mobilization, determine their depths below ground surface, obtain soil engineering properties of the overburden material, and conduct an engineering analysis to design an appropriate crossing structure. The design and installation procedures will be submitted to the appropriate utility and the State prior to implementation and installation. Public road crossings will be constructed to maximize vehicle visibility and stopping distances.

4.8.5 Waste Repository

This section describes the design for placement of tailings / impacted soils in the B2.12 cell at Opportunity Ponds during CFR Reach A, Phase 2 construction. Place tailings / impacted soils in the eastern portion of the B2.12 cell, as displayed on Drawing C26, Repository Plan.

Site Characteristics

The B2.12 cell lies in the northwest portion of Opportunity Ponds. The cell is approximately 200 acres in area and is surrounded by earthen berms. A railroad spur and load out structure that are currently used for delivery of mine waste materials from the Streamside Tailings Operable Unit projects are located near the cell's southwest corner. The site is located in a semiarid region and average annual precipitation is expected to be within the range of 10 to 14 inches per year based on rainfall data for Butte, Montana.

Tailings / impacted soils were placed in the cell during past operations of the nearby Anaconda Company Smelter. Initial depth of tailings material was estimated at 10 to 20 feet, based on

comparison of elevation contours for the cell to adjacent areas which were undisturbed. Characteristics of the smelter tailings were not determined but are expected to consist of mostly silt and sand size material. The cell's foundation material likely consists of sand and gravel similar to that exposed along the margins. Depth to groundwater is estimated at 10 to 20 feet below the contact between smelter tailings and foundation soil.

Waste Placement

Tailings / impacted soils will be in the eastern portion of B2.12 cell as displayed on Drawing C26, Repository Plan. This location was selected based on access into Opportunity Ponds from MT 48 and the need to separate Phase 2 placement activity from other construction activities ongoing within the cell.

The layout for the repository provides for placement of up to 400,000 cubic yards of waste. The final configuration of the waste will have side slopes at 4H:1V slopes. Tailings / impacted soils will be placed in maximum two-foot lifts and compacted by running haul traffic uniformly over the waste surface. If the Anaconda Smelter tailings are too soft to allow equipment operation and proper compaction, an alternate method of placing of an initial lift will be implemented. This lift will be 4 to 5 feet thick and graded and compacted to provide a surface on which equipment can then work and place two-foot lifts.

4.9 Construction Sequencing

Construction is expected to be completed within a one year time frame. A winter shutdown period may be needed depending on the start date and the severity of the winter. Certain activities should be performed at certain times of year because of seasonal high water, weather conditions, ranching operations, and vegetation requirements. The timing and extent of spring high water is variable but generally begins around mid-May through late June and tapers off in July. Winter weather conditions are also variable and long periods of cold temperatures and snow are possible from mid-November until March. There should be no more than 10 acres of floodplain under construction at one time including dewatering, excavation, and backfill to final grade.

Planting and constructing banks with willow cuttings entail seasonal restrictions. Dormant plant cuttings should be harvested during the fall, or between late winter and early spring. Cuttings harvested in the spring may be stored in a cooler, but if they are stored this way they must be installed before July 15. Wetland herbaceous plugs (graminoids) should be planted between May 1 and July 1. Trees and shrubs must be planted near dormancy, either during spring after the soil thaws and before leaf-out; or in the fall after October 15. Because willow cuttings are incorporated into some streambank reconstruction treatments, those treatments should be implemented either after willows become dormant in the fall (approximately mid-October) or between late winter and July 15 using dormant cuttings either collected at the time of installation or stored in a cooler. Seeding should occur at the first opportune time after completion of final grading including microtopography and incorporation of coarse wood. This will likely be in the fall if the above schedule is maintained. Seeding and planting can also occur in the spring if portions of the floodplain are finished in fall of the first year.

Other than contractual requirements to accommodate landowner operations or plant availability and timing, construction sequencing will be determined by the contractor. Given the constraints discussed above, construction activity may be conducted throughout the year.

4.10 Construction BMPs

Construction BMPs for the Clark Fork River Operable Unit are described in Appendix H of the *Combined Remedial/Restoration Design Work Plan* (DEQ, 2008c). The *Construction Storm Water Best Management Practices Plan* (DEQ, 2009) provides the information necessary to ensure that the substantive requirements of the *Montana General Permit for Storm Water Discharges Associated with Construction Activity* are met. This plan identifies typical areas where construction activities will require the use of erosion control BMPs and the BMPs suitable for each location. Erosion control BMPs are expected to be implemented at locations where tailings / impacted soils will be removed, at constructed roads, at borrow areas, at construction staging areas, along streambanks, and in areas where soils will be lime amended. In addition, the plan outlines the requirements for monitoring and documenting erosion control inspections. This plan is written for the entire Operable Unit and is distinct from the BMP plans to be written for long-term maintenance of individual sites after Remedial Action is completed.

Phase 2 has construction activities that may be unique to this area and were not contemplated in the *Construction Erosion Control* . Activities will be conducted instream and include placement of bank toe material and construction of stream diversions. The occasional need for construction of stable bank toes is mentioned in Section 4.3.2. The only banks that might require bank toe construction are those that have no suitable existing woody vegetation on them and no existing bank toe material beneath them. For these locations, estimated at 6,000 feet of bank, excavation below low water level will be required. It is not anticipated that these areas can be dewatered to a dry condition and toe material placement will need to occur in the water. However, to minimize siltation of the stream, coffer dams are planned to be constructed around the work area that will separate the flowing water from the work area. Coffer dams could consist of super sacs filled with alluvial rock placed next to each other. During excavation and material placement, sediment will remain in the still water inside the coffer dam and settle. After the construction is complete in this area and the water is clear, portions of the coffer dam can be opened at both ends to allow small amounts of flow through the construction area. The rate of flow will be monitored to minimize any sediment release. Gradually the remaining portions of the coffer dam can be removed until the natural flow pattern reestablishes.

Section 5

Supporting Plans

This section describes supporting plans for the Phase 2 remedial action. These plans are prepared by the agencies or the construction contractor to guide aspects of construction such as quality assurance and environmental protection that are outside the primary design objectives. Five plans are described here:

1. Construction Quality Assurance/Quality Control Plan,
2. Construction Erosion Control Plan,
3. Surface Water Management Plan
4. Dust Control Plan, and
5. Weed Control Plan.

In some cases DEQ has prepared a generic plan to address an activity for the entire Clark Fork Site; in other cases, a specific plan needs to be prepared by the construction contractor to address the activity. This section provides a summary of what is required by each plan and how responsibilities for items in the plan are apportioned.

5.1 Construction Quality Assurance/Quality Control Plan

Construction quality control (QC) will be the responsibility of the remedial action construction contractor. QC responsibilities are identified in the Special Provisions and Technical Specifications of the RA construction documents. DEQ and EPA (collectively, the "Agencies"), have the responsibility to implement and maintain a Quality Assurance (QA) program that ensures the overall quality of the project. DEQ has prepared a draft Construction Quality Assurance Plan (CQAP) for the Clark Fork Site for this purpose (DEQ, 2008a).

The main purpose of the CQAP is to outline the Agencies' QA procedures for confirming that the remedial Action for the Clark Fork Site meets all performance standards presented in the property specific remedial action work plans and bid packages, plans, specifications, and other remedial design/remedial action documents. The specific objectives of the CQAP are:

- Define the QA team organization and responsibilities;
- Define the interaction between the QA program and the contractor's QC plan;
- Describe project communication, documentation, and record keeping protocols, on-site communications, progress meetings, and preparation of progress reports and construction files; and
- Detail the role of the QA team in reviewing and approving certification and calibration submittals; surveying and verifying construction grade and alignment; conducting verification testing, sampling, and analysis; and monitoring during RA construction activities.

These QA efforts are in addition to the contractor QC program testing and analysis. The draft CQAP will be updated during final design to account for activities to be implemented in Phase 2 construction.

5.2 Construction Erosion Control Plan

The Special Provisions of the draft and final Remedial Action Work Plan (RAWP) for CFR Reach A, Phase 2 will require the remedial action construction contractor to prepare and submit a site-specific Erosion Control Plan to DEQ's Engineer for review. The RAWP will require the remedial action construction contractor to implement the Erosion Control Plan. The Erosion Control Plan will describe the Best Management Practices (BMPs) needed to implement the Remedial Action Work Plan for CFR Reach A, Phase 2 construction. The Erosion Control Plan identifies types of actions where construction activities will require the use of erosion control BMPs and the best type of BMP suitable for each location. Erosion control BMPs are expected to be implemented at locations where mine wastes and contaminated soils will be removed, construction roads, borrow areas, construction staging areas, streambanks, and areas where soils will be lime amended. In addition, the plan will outline the necessary requirements for monitoring and documenting erosion control activities.

5.3 Surface Water Management Plan

The Special Provisions of the draft and final Remedial Action Work Plan for CFR Reach A, Phase 2 will require the remedial action construction contractor to prepare and submit a site-specific Surface Water Management Plan to DEQ's Engineer for review. The RAWP will require the remedial action construction contractor to implement the Surface Water Management Plan. The Surface Water Management Plan shall describe the sequence of Construction, BMPs, coffer dam system for streambank toe construction, and other techniques to be used by the Contractor to prevent or eliminate, to the maximum extent practicable, sediments from entering the Clark Fork River due to construction activities. The Surface Water Management Plan shall also discuss planned mitigation measures during annual spring runoff to prevent or eliminate, to the maximum extent practicable, sediments from entering the Clark Fork River.

5.4 Dust Control Plan

The Special Provisions of the draft and final Remedial Action Work Plan for CFR Reach A, Phase 2 will require the remedial action construction contractor to prepare and submit a site-specific Dust Control Plan to DEQ's Engineer for review. The RAWP will require the remedial action construction contractor to implement the Dust Control Plan. The plan will include a description of the processes that will be implemented to address fugitive dust during construction activities. The plan will identify potential fugitive dust sources and activities at the construction site and applicable procedures to monitor and minimize dust generation.

5.5 Weed Control Plan

The Special Provisions of the draft and final Remedial Action Work Plan for CFR Reach A, Phase 2 will require the remedial action construction contractor to prepare and submit a site-specific Weed Control Plan to DEQ's Engineer for review. The RAWP will require the remedial action construction contractor to implement the Weed Control Plan. The draft *Weed Control Plan for the Clark Fork River Operable Unit* (DEQ, 2008b) describes the general approach to weed control f to ensure that remedial actions are achieving performance standards and remedial goals. The goal is to achieve healthy,

diverse, self-sustaining native vegetation with minimal noxious weeds. This plan will describe specific methods and procedures to be used by the contractor to prevent and/or minimize spread of noxious weeds. It will include designation of washing and decontamination areas. The Weed Control Plan describes measures that can be implemented to minimize spreading of noxious weeds by controlling weeds before they arrive on site, controlling weeds prior and during remedial activities, and ensuring that landowners control noxious weeds on their properties in compliance with state weed laws and county weed plans after remedial construction is complete.

Section 6
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Appendix A

Hydraulic Model Documentation

Table B1-HecRAS Output for 2-year Flow Event

Cross Section	Q Total	W.S. Elev	E.G. Slope	Vel Chnl	Vel Left	Vel Right	Shear Chan	Shear LOB	Shear ROB
	(cfs)	(ft)	(ft/ft)	(ft/s)	(ft/s)	(ft/s)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)
UP OXBOW XS 1	83.95	4775.39	0.002695	2.5		0.05	0.21		0.01
UP OXBOW XS 2	83.95	4775.13	0.000669	1.54			0.07		
UP OXBOW XS 3	83.95	4775.01	0.000539	1.42			0.06		
UP OXBOW XS 4	83.95	4774.98	0.000083	0.68			0.01		
UP OXBOW XS 5	83.95	4774.97	0.000084	0.69			0.01		
xs 106A	165.75	4764.03	0.001435	2.36			0.17		
xs 107A	165.75	4763.48	0.044613	2.34			2.18		
xs 108A	165.75	4763.32	0.000873	1.08	0.09	0.04	0.06	0	0
xs 109A	165.75	4763.26	0.001704	1.13	0.03	0.05	0.11		0
xs 110A	165.75	4763.14	0.001059	0.9	0.05	0.05	0.08	0	0
xs 111A	165.75	4763.07	0.000541	0.78	0.04	0.04	0.05	0	0
xs 112A	165.75	4763.03	0.000599	1.12	0.04	0.03	0.06	0	
xs 113A	165.75	4762.53	0.00425	3.75	0.05	0.05	0.44	0.01	0.01
xs 114A	165.75	4762.45	0.001093	2.25			0.14		
xs 115A	165.75	4762.33	0.000558	1.77			0.09		
xs 116A	165.75	4762.27	0.0006	1.81			0.09		
xs 58	584	4779.58	0.000765	2.52	0.02	0.02	0.16	0	0
xs 59	584	4779.41	0.002116	2.8	0.02		0.53	0	
xs 60	584	4779.26	0.000884	2.8		0.66	0.19		0.02
xs 61	584	4779.1	0.000865	3.15		0.06	0.23		0
xs 62	584	4778.68	0.002513	3.76			0.38		
xs 63	584	4778	0.004428	3.93	0.23		0.55	0.04	
xs 64	584	4777.52	0.002409	3.7			0.36		
xs 65	584	4777.01	0.004353	3.64	0.05	0.06	0.79	0	
xs 66	584	4776.41	0.003202	4.57		0.06	0.55		
xs 67	584	4775.96	0.004954	4.12		0.17	0.52		0.04
xs 68	584	4775.77	0.003438	3.65		0.04	0.4		0
xs 69	584	4775.37	0.002309	4.03			0.4		
xs 70	500.55	4775.31	0.001467	2.61	0.33		0.19	0.01	
xs 71	500.55	4775.1	0.002019	2.87			0.24		
xs 72	500.55	4774.86	0.002264	3.21		0.03	0.3		
xs 72a	500.55	4774.72	0.001681	3.34			0.29		
xs73	584	4774.43	0.003117	4.34			0.5		
xs74	584	4774.2	0.001349	2.57			0.19		
xs75	584	4773.91	0.001639	2.87		0.02	0.23		0
xs76	584	4773.54	0.001649	3.4	0.06	0.08	0.3	0.01	0.01
xs77	584	4773.35	0.001672	3.04		0.06	0.25		0.01
xs78	584	4773.21	0.000991	2.71	0.05		0.19	0	
xs79	584	4772.81	0.00167	3.83	0.09	0.11	0.36	0.01	0.01
xs80	584	4772.48	0.002061	4.24	0.04	0.04	0.44	0	0
xs81	584	4772.48	0.000503	2.06		0.04	0.1		0
xs82	584	4772.21	0.002203	3.27	0.07		0.3	0.01	
xs83	584	4771.63	0.00269	4.18			0.46		
xs84	584	4771.17	0.002504	4.1			0.44		
xs85	584	4770.73	0.001938	3.74			0.36		
xs86	584	4770.52	0.001322	2.93			0.23		
xs87	584	4770.28	0.001415	3.32		0.52	0.28		0.02
xs88	584	4769.97	0.002155	3.38	0.06	0.43	0.32	0.01	0.02
xs89	584	4769.66	0.001781	3.14	0.18		0.27	0.03	
xs90	584	4768.83	0.00622	4.79			0.69		
xs91	584	4768.7	0.000349	1.72	0.03	0.15	0.07	0	0
xs92	584	4768.35	0.00189	3.54		0.44	0.33		0.01

Cross Section	Q Total	W.S. Elev	E.G. Slope	Vel Chnl	Vel Left	Vel Right	Shear Chan	Shear LOB	Shear ROB
	(cfs)	(ft)	(ft/ft)	(ft/s)	(ft/s)	(ft/s)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)
xs93	584	4768.36	0.000721	2.05			0.11		
xs94	584	4768.19	0.002325	2.69	2.12		0.23	0.16	
xs95	584	4767.66	0.002161	3.8			0.38		
xs96	584	4767.24	0.003082	3.82		0.18	0.41		0.04
xs97	584	4767	0.001716	3.38		0.15	0.3		0.02
xs98	584	4766.69	0.002139	4.04		0.25	0.41		0.05
xs99	584	4766.03	0.001656	3.47			0.31		
xs100	584	4765.64	0.001256	2.76	0.13		0.2	0.02	
xs101	584	4765.26	0.001303	3.51	0.03		0.29	0	
xs102	584	4765.03	0.001317	3.13			0.25		
xs103	584	4764.94	0.000944	2.65		0.11	0.18		0.01
xs104	584	4764.42	0.00599	5.12			0.76		
xs105	584	4763.9	0.003369	4.23			0.49		
xs106	418.27	4763.94	0.000713	2.59		0.04	0.16		0
xs107	418.27	4763.68	0.003897	4.12	0.11	0.03	0.49		
xs108	418.27	4763.47	0.001478	2.69	0.04	0.04	0.18	0	0
xs109	418.27	4762.87	0.002706	3.88			0.41		
xs110	418.27	4762.42	0.002045	3.67			0.35		
xs111	418.27	4762.2	0.001409	3.05			0.24		
xs112	584	4761.81	0.004343	4.39			0.56		
xs113	584	4760.76	0.005813	5.02			0.73		
xs114	584	4760.72	0.001921	3.41			0.31		
xs115	584	4759.96	0.008637	5.47			0.92		
xs116	584	4759.99	0.000778	2.13			0.12		
xs117	584	4759.77	0.002152	2.94			0.26		
xs118	584	4759.44	0.001673	3.53			0.32		
xs119	584	4758.58	0.004383	4.72		0.15	0.62		0.03
xs120	584	4758.04	0.00343	3.68		0.26	0.4		0.06
xs121	584	4757.84	0.000822	2.67			0.17		
xs122	584	4757.36	0.003431	4.46	0.05		0.54	0.01	
xs122A	584	4756.95	0.00086	2.78			0.19		
	584	4756.9	0.001596	2.93			0.33		
	Bridge								
	584	4756.67	0.002808	3.72			0.54		
xs123	584	4756.42	0.003196	3.62			0.38		
xs124	584	4755.44	0.005653	5.18			0.76		
xs125	584	4754.34	0.003062	4			0.44		

Table B2-HecRAS Output for 10-year Flow Event

Cross Section	Q Total	W.S. Elev	E.G. Slope	Vel Chnl	Vel Left	Vel Right	Shear Chan	Shear LOB	Shear ROB
	(cfs)	(ft)	(ft/ft)	(ft/s)	(ft/s)	(ft/s)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)
UP OXBOW XS 1	224	4776.66	0.000504	1.69	0.23	0.23	0.08	0.03	0.03
UP OXBOW XS 2	224	4776.57	0.000331	1.59	0.17	0.21	0.06	0.02	0.02
UP OXBOW XS 3	224	4776.48	0.000411	1.8	0.18	0.14	0.08	0.02	0.02
UP OXBOW XS 4	224	4776.46	0.000104	1.04	0.1	0.13	0.03	0.01	0.01
UP OXBOW XS 5	224	4776.45	0.000105	1.04	0.1	0.13	0.03	0.01	0.01
xs 106A	413	4765.11	0.001965	3.57	0.29	0.24	0.33	0.06	0.05
xs 107A	413	4764.74	0.00876	1.96	0.57	0.59	1.11	0.26	0.28
xs 108A	413	4764.64	0.000725	1.14	0.54	0.25	0.11	0.04	0.04
xs 109A	413	4764.6	0.000891	1.2	0.22	0.2	0.13	0.03	0.03
xs 110A	413	4764.53	0.000744	1	0.23	0.19	0.12	0.03	0.03
xs 111A	413	4764.47	0.000504	0.95	0.18	0.14	0.09	0.02	0.02
xs 112A	413	4764.43	0.000565	1.37	0.32	0.14	0.11	0.01	0.02
xs 113A	413	4763.75	0.004123	5.26	0.46	0.54	0.72	0.13	0.08
xs 114A	413	4763.73	0.001346	3.37	0.22	0.22	0.28	0.03	0.04
xs 115A	413	4763.64	0.000637	2.49	0.32	0.25	0.15	0.02	0.04
xs 116A	413	4763.6	0.000556	2.31	0.57	0.1	0.13	0.01	0.01
xs 58	1216	4781.08	0.000825	3.32	0.37	0.37	0.24	0.08	0.08
xs 59	1216	4780.84	0.002808	3.89	0.66	0.65	0.94	0.23	0.24
xs 60	1216	4780.6	0.001158	3.91	0.35	0.62	0.34	0.08	0.08
xs 61	1216	4780.18	0.00186	5.21	0.09	0.33	0.58	0.01	0.08
xs 62	1216	4779.56	0.003625	5.45	0.41	0.23	0.73	0.06	0.05
xs 63	1216	4779.11	0.002539	3.92	0.5	0.32	0.49	0.16	0.08
xs 64	1216	4778.6	0.002927	4.71	0.42	0.29	0.62	0.12	0.07
xs 65	1216	4778.14	0.003796	4.18	0.58	0.55	0.94	0.22	0.18
xs 66	1216	4777.25	0.004149	6.16	0.44	0.51	0.91	0.15	0.19
xs 67	1216	4777.02	0.002821	4.19	0.39	0.49	0.47	0.07	0.16
xs 68	1216	4776.95	0.001819	3.66	0.22	0.45	0.34	0.04	0.12
xs 69	1216	4776.58	0.002172	4.86	0.25	0.42	0.52	0.05	0.12
xs 70	992	4776.57	0.00101	2.94	0.56	0.3	0.21	0.03	0.06
xs 71	992	4776.42	0.001341	3.29	0.25	0.3	0.27	0.03	0.06
xs 72	992	4776.28	0.001362	3.47	0.31	0.44	0.29	0.04	0.11
xs 72a	992	4776.18	0.001199	3.69	0.22	0.36	0.31	0.04	0.08
xs73	1216	4775.73	0.003292	5.6	0.32	0.36	0.75	0.09	0.11
xs74	1216	4775.62	0.001071	3.11	0.25	0.21	0.23	0.04	0.04
xs75	1216	4775.37	0.001285	3.47	0.29	0.28	0.29	0.06	0.06
xs76	1216	4774.97	0.001771	4.51	0.27	0.37	0.46	0.06	0.09
xs77	1216	4774.84	0.001322	3.68	0.17	0.31	0.32	0.03	0.06
xs78	1216	4774.67	0.001094	3.67	0.15	0.24	0.3	0.02	0.04
xs79	1216	4774.25	0.001752	4.87	0.36	0.43	0.52	0.06	0.08
xs80	1216	4773.3	0.00444	7.09	0.24	0.31	1.15	0.05	0.09
xs81	1216	4773.43	0.000849	3.11	0.3	0.19	0.22	0.02	0.03
xs82	1216	4773.39	0.000225	1.38	0.74		0.05	0.01	
xs83	1216	4773.31	0.00057	2.59	0.61	0.67	0.15	0.03	0.02
xs84	1216	4772.48	0.003077	5.69	0.75		0.75	0.12	
xs85	1216	4771.95	0.002436	5.18	0.91	1.25	0.62	0.09	0.09
xs86	1216	4771.72	0.001591	4.05	0.65	0.27	0.38	0.05	0.06
xs87	1216	4771.34	0.001983	4.74	0.52	1.15	0.51	0.05	0.08
xs88	1216	4771.09	0.00155	3.69	1.05	1.07	0.33	0.09	0.07
xs89	1216	4770.74	0.001689	3.85	0.76	0.77	0.36	0.11	0.05
xs90	1216	4770.1	0.003215	4.9	1.14	0.69	0.61	0.13	0.07
xs91	1216	4770.05	0.000367	2.19	0.17	0.54	0.11	0.02	0.01
xs92	1216	4769.59	0.002063	4.68	0.28	0.62	0.51	0.06	0.07
xs93	1216	4769.64	0.000787	2.65	0.2	0.3	0.17	0.03	0.02
xs94	1216	4769.56	0.001082	2.5	2	0.29	0.17	0.09	0.02
xs95	1216	4769.03	0.002132	4.82	0.39	0.5	0.54	0.1	0.08
xs96	1216	4768.73	0.002014	4.27	0.37	0.43	0.44	0.08	0.1

Cross Section	Q Total	W.S. Elev	E.G. Slope	Vel Chnl	Vel Left	Vel Right	Shear Chan	Shear LOB	Shear ROB
	(cfs)	(ft)	(ft/ft)	(ft/s)	(ft/s)	(ft/s)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)
xs97	1216	4768.53	0.001528	4.17	0.31	0.38	0.4	0.06	0.08
xs98	1216	4768.14	0.002447	5.33	0.16	0.55	0.65	0.02	0.12
xs99	1216	4767.45	0.001948	4.79	0.31	0.35	0.52	0.07	0.09
xs100	1216	4767.17	0.001067	3.42	0.32	0.23	0.27	0.07	0.04
xs101	1216	4766.62	0.001862	5.1	0.37	0.29	0.56	0.09	0.07
xs102	1216	4766.33	0.001634	4.38	0.32	0.27	0.43	0.07	0.06
xs103	1216	4766.25	0.001143	3.69	0.25	0.23	0.31	0.05	0.04
xs104	1216	4765.55	0.006093	6.59	0.34	0.44	1.11	0.11	0.17
xs105	1216	4765.01	0.003948	5.71	0.34	0.36	0.81	0.1	0.11
xs106	803	4765.09	0.001066	3.7	0.17	0.22	0.3	0.03	0.04
xs107	803	4764.81	0.003209	4.97	0.4	0.32	0.62	0.1	0.08
xs108	803	4764.73	0.001142	3.02	0.29	0.24	0.23	0.06	0.04
xs109	803	4764.17	0.002218	4.6	0.4	0.45	0.5	0.11	0.12
xs110	803	4763.67	0.00222	4.82	0.48	0.74	0.54	0.15	0.13
xs111	803	4763.47	0.00153	4.03	0.38	0.4	0.38	0.09	0.08
xs112	1216	4762.99	0.003989	5.65	0.38	1.07	0.79	0.12	0.07
xs113	1216	4761.84	0.006272	6.69	0.37	1.48	1.15	0.13	0.12
xs114	1216	4761.85	0.002666	4.85	0.24	0.33	0.57	0.05	0.05
xs115	1216	4761.3	0.00502	5.47	0.45	2.72	0.8	0.16	0.27
xs116	1216	4761.36	0.00076	2.79	0.21	0.9	0.18	0.03	0.03
xs117	1216	4761.19	0.001413	3.39	0.44	0.28	0.29	0.05	0.06
xs118	1216	4760.73	0.002168	4.92	0.51	0.35	0.55	0.1	0.08
xs119	1216	4759.86	0.003714	5.83	0.56	0.64	0.82	0.2	0.2
xs120	1216	4759.65	0.001612	3.75	0.34	0.64	0.34	0.08	0.12
xs121	1216	4759.46	0.000889	3.56	0.33	0.54	0.27	0.06	0.05
xs122	1216	4758.97	0.00259	5.33	0.52	0.41	0.65	0.16	0.12
xs122A	1216	4758.66	0.000892	3.63	0.32	0.95	0.28	0.04	0.04
	1216	4758.55	0.001912	4.05			0.56		
	Bridge								
	1216	4758.17	0.003364	5.25			0.95		
xs 123	1216	4758.02	0.002719	4.07			0.44		
xs 124	1216	4756.99	0.005452	5.86			0.91		
xs 125	1216	4755.86	0.003064	4.59			0.54		

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Figure No. B1
HEC-RAS CROSS SECTIONS
MARCH 2014

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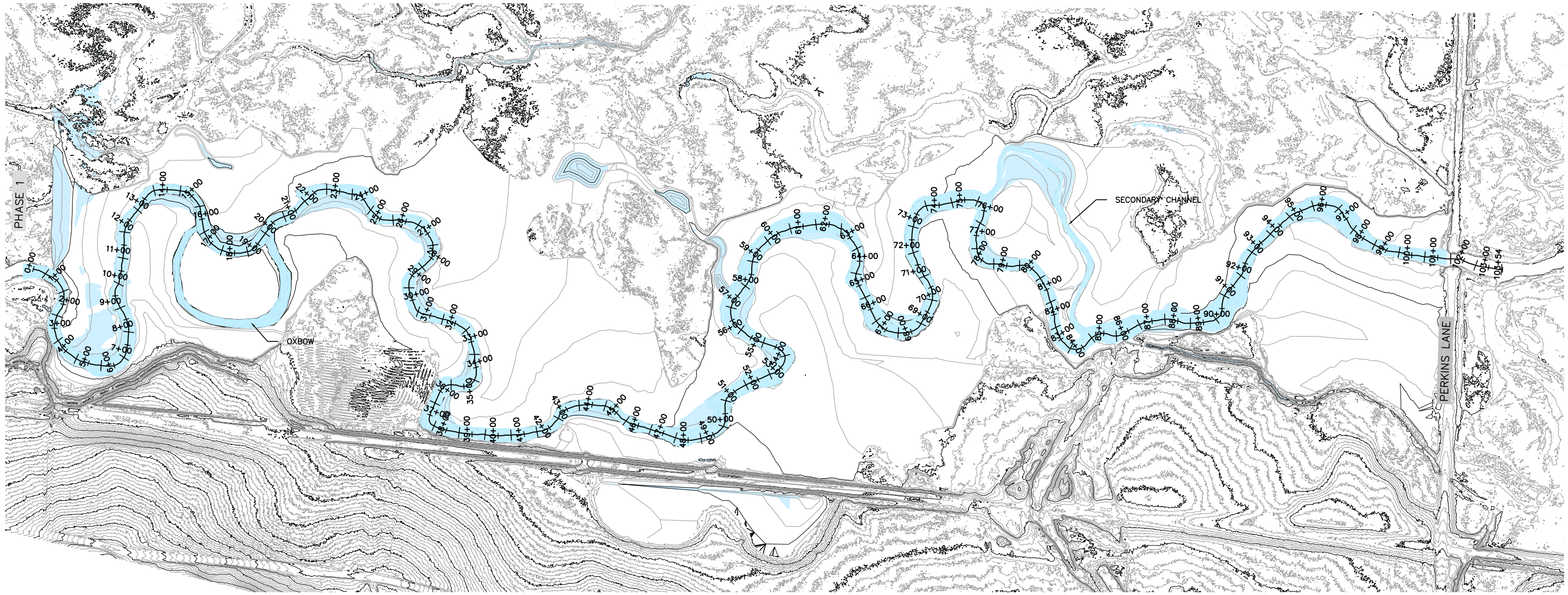
Figure No. B2
HEC-RAS CROSS SECTIONS
MARCH 2014



NOTE:
A PORTION NEXT TO PHASE 1 WILL BE INUNDATED DURING THE 2-YEAR REOCCURRENCE INTERVAL BECAUSE THE FLOWS ESTIMATED DURING THE PHASE 1 DESIGN WERE LOWER (522 CFS) THAN THE FLOWS CALCULATED DURING PHASE 2 DESIGN (584 CFS). THE DIFFERENCE IN FLOWS WAS DUE TO LARGE FLOW EVENTS DURING 2011 AND 2012 ADDED TO THE STATISTICAL ANALYSIS.

N

1" = 400'

200 0 400

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Figure No. B3
CLARK FORK RIVER - PHASE 2 - 2 YEAR FLOOD INUNDATION MAP
MARCH 2014

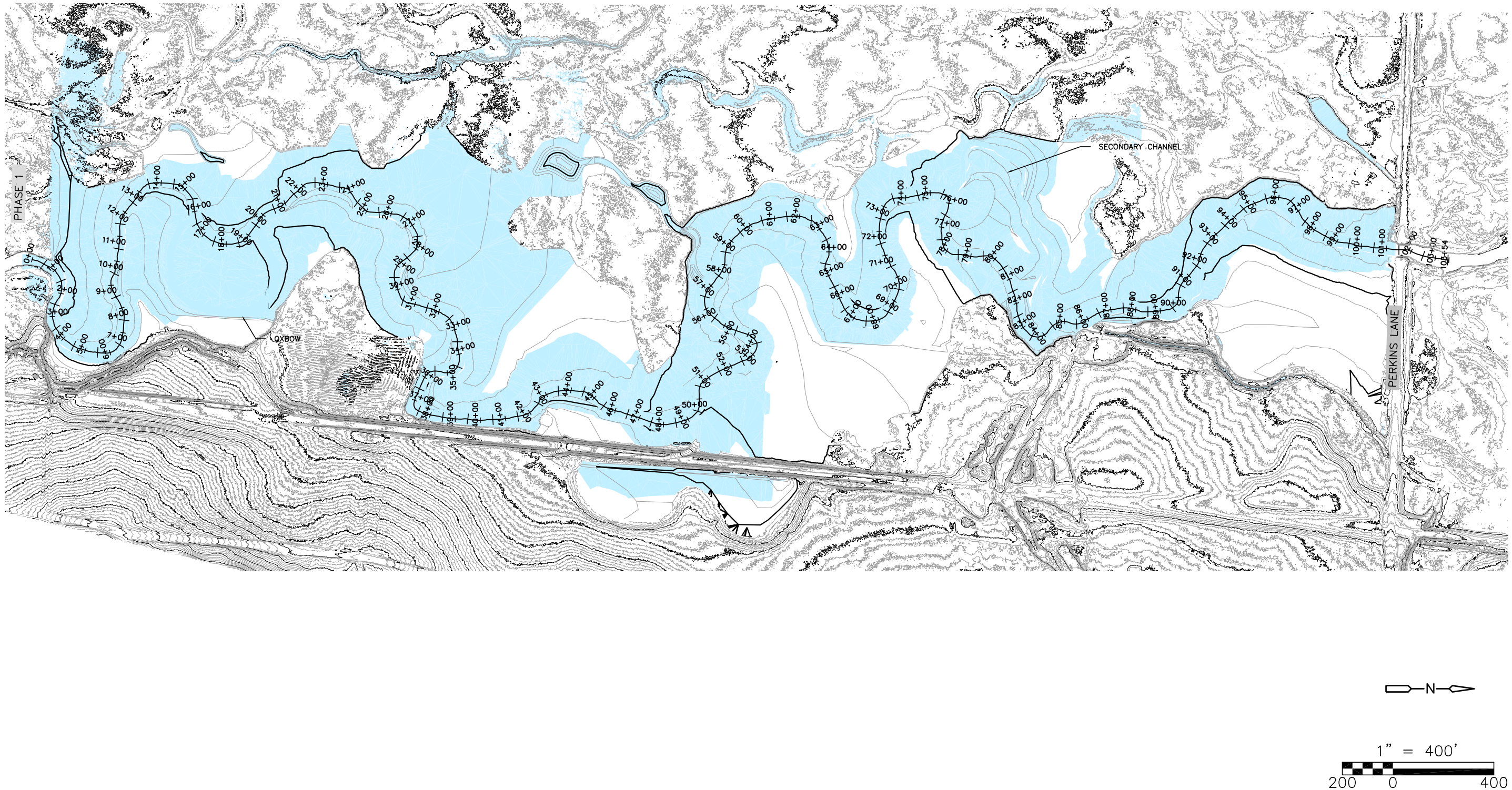

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Figure No. B4
CLARK FORK RIVER - PHASE 2 - 10 YEAR FLOOD INUNDATION MAP
MARCH 2014