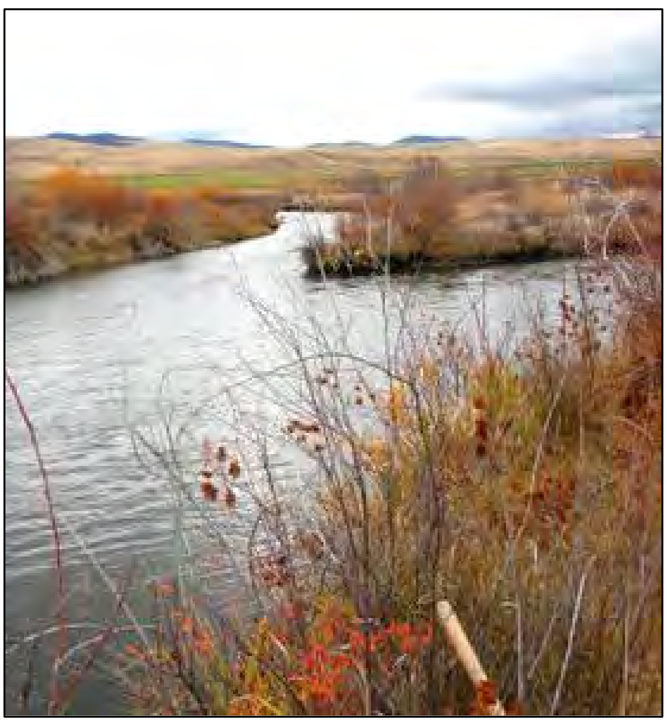
Clark Fork River Reach A Phases 3 and 4
Draft Preliminary Design Plan

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

April 8, 2016

Geum Environmental Consulting, Inc.

Applied Geomorphology, Inc.

CDM Smith

Clark Fork River Reach A Phases 3 and 4 Draft 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
Remediation Division
PO Box 200901
Helena, MT 59620-0901

Montana Department of Justice
Natural Resource Damage Program
P.O. Box 201425
Helena, MT 59620-1425

Prepared By:

CDM Smith
50 West 14th Street, Suite 200
Helena, Montana 59601

Applied Geomorphology, Inc.
211 North Grand, Suite C
Bozeman, MT 59715

Geum Environmental Consulting, Inc.
307 State Street
PO Box 1956
Hamilton, MT 59840

April 8, 2016

Table of Contents

List of Figures

List of Tables

Appendices

LIST OF ACRONYMS

ARCO	Atlantic Richfield Company
ASTM	American Society for Testing Materials
BM	Brush Matrix
BMP	Best Management Practice
BNSF	Burlington Northern Santa Fe (railroad)
BP	British Petroleum
BT	Brush Trench
CFR	Clark Fork River
cfs	Cubic feet per second
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
D_{50}	The particle diameter which exceeds 50 percent of the sample sizes
D_{84}	The particle diameter which exceeds 84 percent of the sample sizes
DEM	Digital Elevation Model
DEQ	Department of Environmental Quality
DVSL	Double Vegetated Soil Lift
EC	Electroconductivity
EPA	Environmental Protection Agency
ESD	Explanation of Significant Differences
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
SSTOU	Streamside Tailings Operable Unit
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). Depending on land ownership, DEQ coordinates with the State of Montana Natural Resource Damage Program (NRDP) and/or 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, Phases 3 and 4 Remedial Action Project (Project), which consists of 4.5 river miles starting at Perkins Lane and ending at Galen Road. The Phases 3 and 4 Project Area, shown on Figure 1-2, consists of the river and its floodplain within these boundaries. Phases 3 and 4 include properties that are owned by the Lampert Ranch LP, Kelley Ranch (Formerly Rosemarie Silzly), and the Deer Lodge River Ranch, LLC (Hadley).

This PDP applies design-level factors to site-specific conditions, which, through remedial design/remedial action (RD/RA), allow implementation of the Clark Fork River Record of Decision (ROD) requirements (USEPA and DEQ, 2004), as clarified by the Explanation of Significant Differences (ESD) (DEQ and EPA, 2015), including Performance Standards and Remedial Goals. Remedial Design 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 set of Drawings showing, among other things, the proposed floodplain grading and streambank treatments.

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

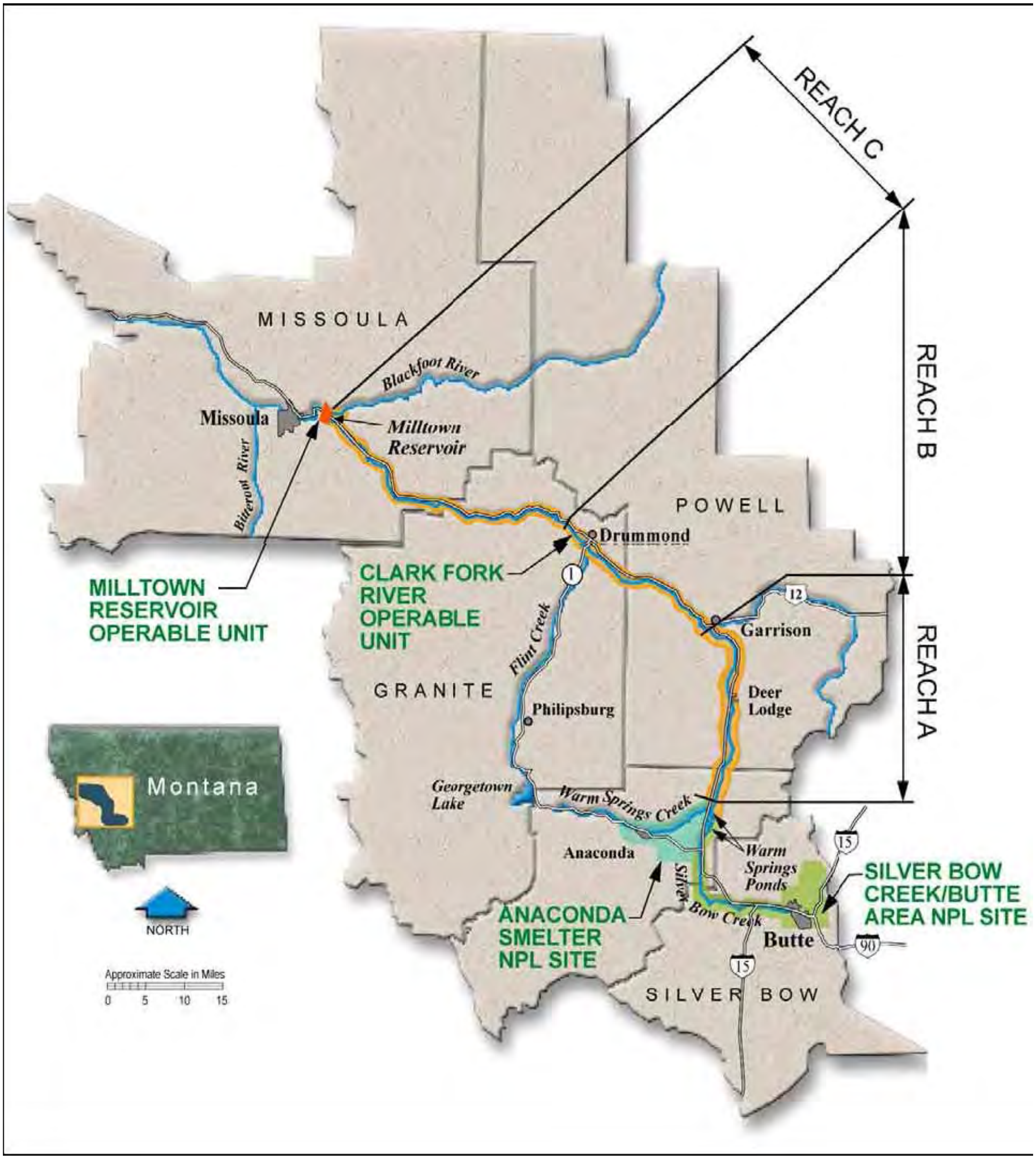


Figure 1-1 Clark Fork River Operable Unit Reaches.

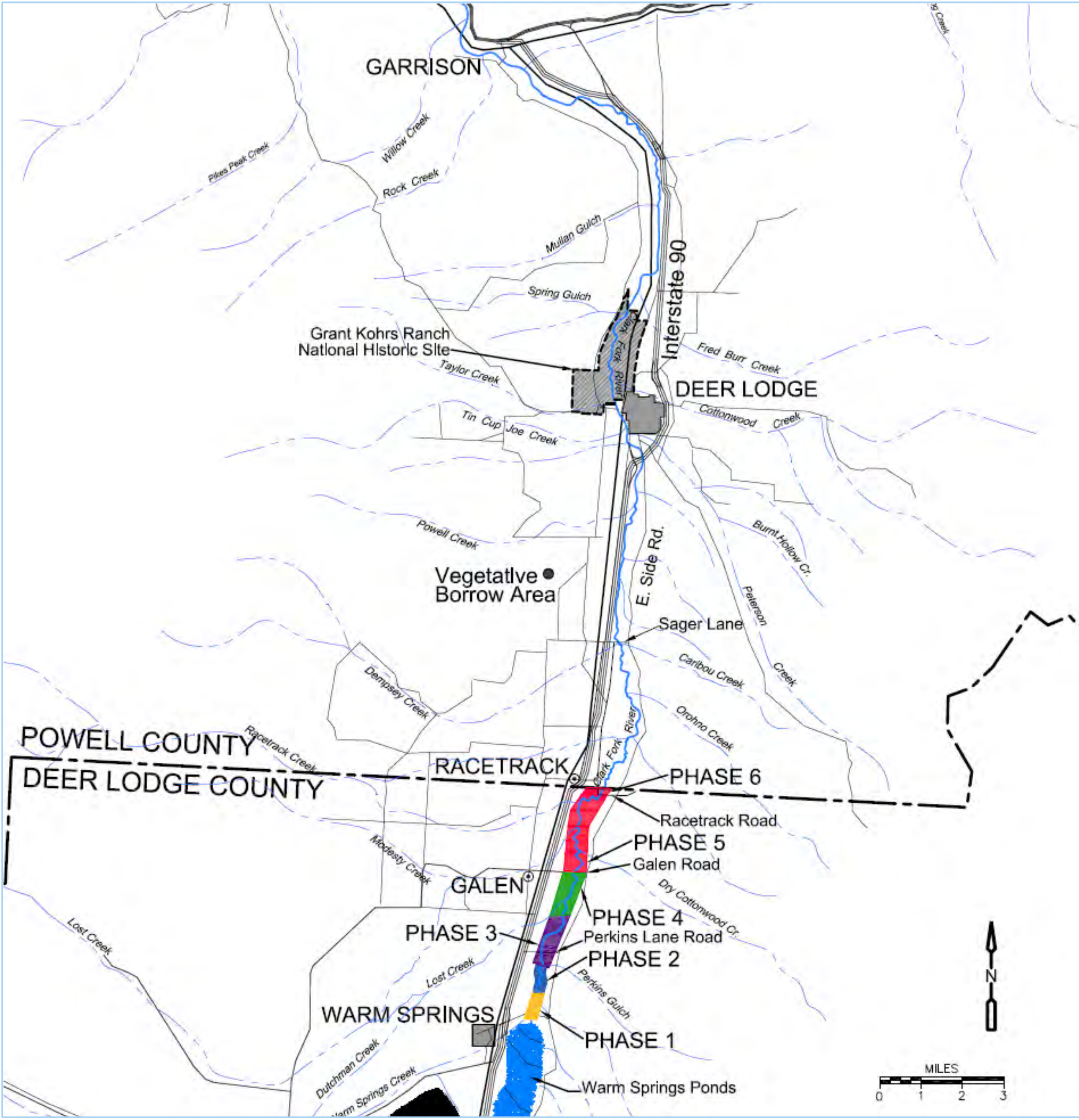


Figure 1-2 Reach A of the Clark Fork River Operable Unit.

1.1 Site Description

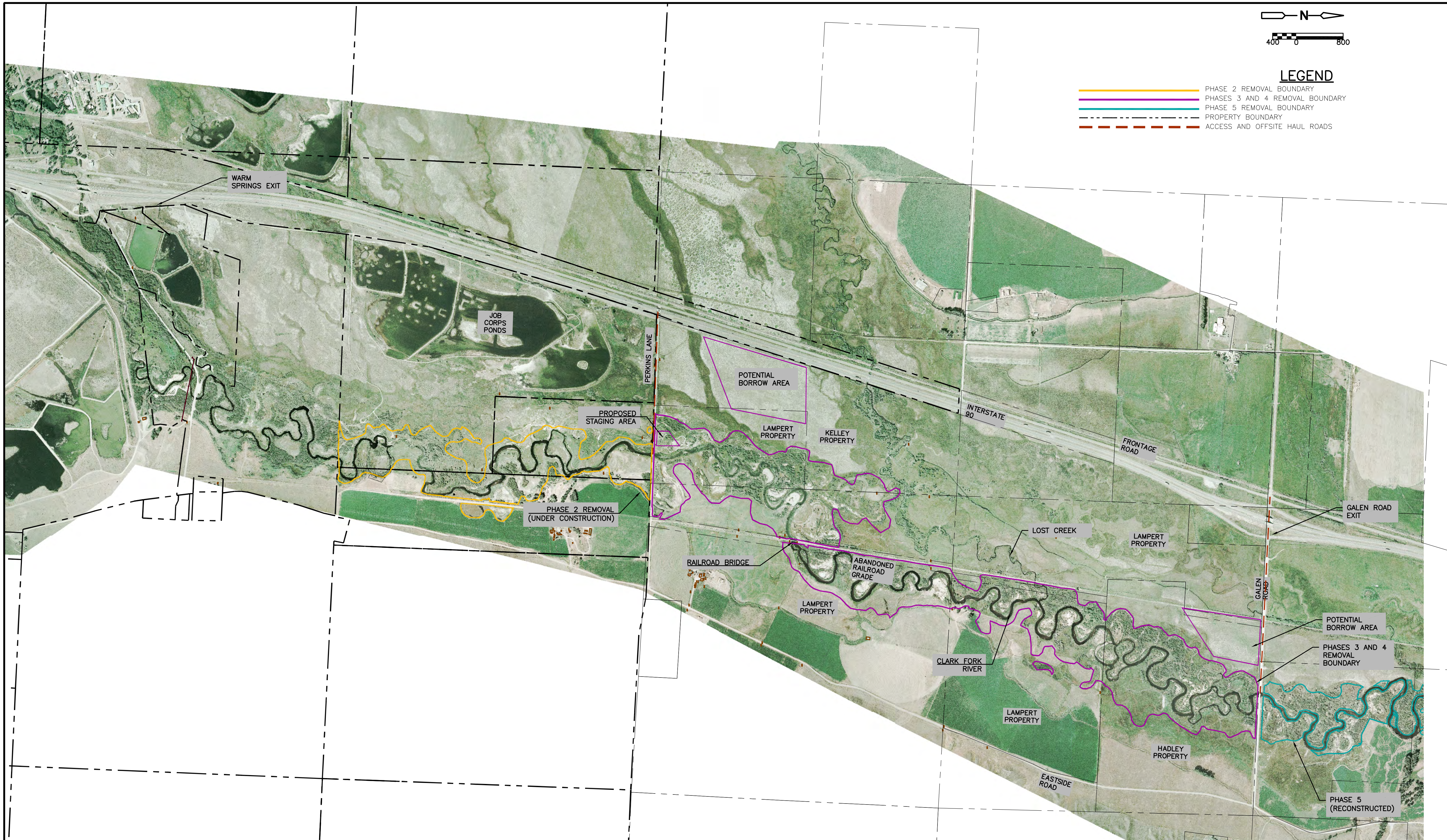
Heavy metals originating from historic mining activities, milling and smelting processes associated with the Anaconda Company operations in Butte and Anaconda have accumulated on the Clark Fork River streambanks and floodplain over the last century. The primary sources of contamination are tailings and contaminated sediments mixed with soils in the stream banks and floodplains (tailings/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 and DEQ, 2004). The 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.

Figure 1-3 is a site map of Phases 3 and 4 referred to here as the Project Area. This map shows the extents of removal of contaminated floodplain tailings/impacted soils in the Project Area. The abandoned Chicago, Milwaukee Railroad grade bisects the project and crosses the river in one location on the Lampert property. Lost Creek enters the project from the west. There are no irrigation diversion dams in the Project Area although there are two pump withdrawals for sprinkler irrigation on the Lampert Ranch. An irrigation ditch enters the project west of the river, traverses the removal area in Phase 3, and irrigates hayfields north of the removal area and west of the railroad grade. The Helen Johnson Ditch lies east of the project area outside the removal area. On the Deer Lodge River Ranch (also referred to as the Hadley property), there are two secondary channels that split from the main flow.

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). Construction of the Warm Springs Ponds in 1911 reduced the transport of contaminated sediment delivered to the Clark Fork River, but higher banks have restricted the access of floodwaters to the floodplain for over 100 years and resulted in significant changes in floodplain vegetation and river morphology in addition to the effects 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 Phases 3 and 4 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/impacted soils into groundwater and surface water. The lack of typical floodplain vegetation in portions of Phases 3 and 4 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.



CDM Smith

Figure 1-3
PROJECT VICINITY MAP
APRIL 2016

1.3 Contaminant Processes

Section 2.0 provides information on groundwater, riparian vegetation, geomorphic stability, contaminant sampling, ownership, infrastructure, land use, and site-specific remedy requirements. Phases 3 and 4 exhibit extensive contamination within the floodplain system. The term floodplain as used in this report is the low lying area adjacent to the river generally contaminated with metals. It is not necessarily the 100-year floodplain. Within the floodplain, the design team has outlined a Channel Migration Zone (CMZ) where the river is most likely to migrate within a 100-year period. The intent of the CMZ is to create a streambank and riparian area buffer zone that empirically addresses direct tailings entrainment hazards. A detailed description of the development of the CMZ for the Project Area is found in Section 3.1.2. Areas of Phases 3 and 4 within the CMZ meet the Clark Fork River Riparian Evaluation System (RipES) classification of slickens/impacted areas as developed by EPA (Reclamation Research Unit and BRI, 2004). 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/impacted soils extending deeper than 2 feet) and below the 2-year water surface elevation (tailings/impacted soils too wet to effectively treat). These areas outside the CMZ are also classified as impacted areas. Lastly, certain discrete areas in addition to these two areas demonstrate arsenic levels above 620 mg/kg, the rancher/farmer cleanup level, and therefore also are classified as impacted.

The Contaminants of Concern (COCs) at the Site are arsenic, cadmium, copper, lead and zinc. The primary sources of contamination in Reach A are concentrated tailings deposits and tailings mixed with soil along the river banks and within 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 Phases 3 and 4 will: 1) remove severely impacted areas, 2) provide geomorphic stability during reestablishment of riparian vegetation after construction, and, ultimately, 3) establish plant communities capable of stabilizing soils against wind and water erosion, reducing transport of COCs to groundwater and surface water, and comply with ARARs or replacement standards, in perpetuity.

1.4 Design Concept

This section outlines the general concept for remediation of Phases 3 and 4 that is planned to fulfill project objectives. Components of the design are described in detail in later sections of this document.

The design for the Project relies on machine excavation to remove tailings/impacted soil from streambanks and the floodplain. 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 CMZ, 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 with several identified in the Project Area including grassland pasture, riparian floodplain, and hayfields. In places the reconstructed floodplain will be lower than the existing floodplain to allow for hydraulic reconnection with the river. Some river bends will be recontoured as point bars and existing depositional features will be preserved to the extent possible. Native vegetation will be established within the Project Area except in hayfields which will be managed long-term by landowners for hay production. Microtopography will be developed and coarse woody debris will be imbedded in the floodplain in many areas to provide additional roughness, erosion resistance, sediment and seed trapping, micro-sites for plant establishment and a source of organic material. Microtopography is defined as small scale variation in topography of 3 to 10 feet horizontally and about one-foot vertically. For pasture or hayfield end uses, 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. Pasture vegetation will consist of primarily native grass species suitable for grazing.

Eroding, contaminated stream banks will be rebuilt after removal of tailings/impacted soil. 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, alluvial gravels, and live plant material such as willow cuttings, transplanted shrubs, and containerized nursery stock. Native species will be used in revegetation of the stream banks.

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. All areas of the floodplain except depositional features 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, along constructed streambanks, within high risk and moderate risk avulsion paths, 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 the Project Area 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 Phases 3 and 4 remedial design is found in the following chapters. Chapter 2, Design Investigation, briefly summarizes investigations which were conducted in 2012 through 2015 to support the design of Phases 3 and 4. Chapter 3, Design Criteria, presents the technical criteria that will guide the design of the remedial components in Phases 3 and 4. 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.

This page intentionally left blank.

Section 2

Design Investigations

Several investigations have been undertaken by DEQ on Phases 3 and 4 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 Phases 3 and 4. 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). Additional geomorphic investigations were conducted in 2015 specific to Phases 3 and 4 and are described in this section. A 2014-2015 investigation gathered data concerning the nature and extent of soil contamination within the floodplain and banks of the Clark Fork River (CDM Smith, 2015a). This investigation also collected groundwater level measurements.

In 2014 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 (hereafter referred to as the 2-year flow), tailings thickness, and hydrologic connectivity to help develop a vegetation remediation scenario for Phases 3 and 4. A detailed topographic map for Phases 3 and 4 was developed using Light Detection and Ranging (LiDAR) in August 2011 (Fugro EarthData, 2011). In October 2014 Geum, CDM Smith and AGI performed a field inventory of the streambanks in Phases 3 and 4 intended as a basis for preliminary streambank design.

The sections below summarize the results of the investigations. If material has previously been documented, it is summarized in this section; new material is presented in its entirety (Section 2.1, Geomorphic Investigation and Section 2.7, Vegetation Investigations).

2.1 Geomorphic Investigation

The geomorphic investigation for Phases 3 and 4 includes an initial field inventory and data workup in fall 2012 (CDM Smith and AGI, 2013), a streambank evaluation in fall 2014, and a field inventory of pools and bed sediment sampling in summer 2015. In general, results indicate that, within Phases 3 and 4, the Clark Fork River flows through a geologically unconfined valley bottom with a broad stream corridor and floodplain that abuts the eastern margin of coarse outwash deposits of the Upper Deer Lodge Valley (CDM Smith and AGI, 2013). The river is highly meandering and largely entrenched below the 2-year WSE. This entrenchment is due to the deposition of tailings-rich material on the floodplain that has increased floodplain elevations and bank heights.

Phase 3 is about 2.0 river miles long whereas Phase 4 is slightly longer at 2.5 miles. The channel is low gradient, with a slope of 0.17% and a sinuosity ranging from 1.8 (Phase 3) to 2.2 (Phase 4). Numerous meanders have a low radius of curvature and are prone to cutoff, and two cutoffs have occurred in Phase 4 since 1950. Phase 4 has two split flow sections that create large islands and secondary channels.

Tailings exposures are common in the aggraded streambanks of Phases 3 and 4, and the tailings are typically underlain by fine grained historic floodplain deposits or coarse gravels and cobbles.

Some bank stability is provided by old willows that are rooted in the historic floodplain surface and exposed in the mid-bank area. Bed material consists of gravel and cobble, and Lost Creek contributes some gravel to the CFR. The historic railroad grade was constructed in the floodplain parallel to the stream valley axis such that it bisects the floodplain in Phase 3. Overflows in the upper portion of Phase 3 have the potential to become isolated from the CFR behind the west side of the abandoned railroad grade, re-entering the main river channel via Lost Creek. Figures 2-1 and 2-2 show overview maps for Phases 3 and 4 and major geomorphic parameters are tabulated in Table 2-1. The parameters for the two phases are quite similar although Phase 3 has notably higher bank migration rates and pool densities than Phase 4.

Table 2-1 Major Geomorphic Parameters for Clark Fork River Phases 3 and 4.

Parameter	Phase 3	Phase 4
Length (miles)	2.0	2.5
Slope (percent)	0.17	0.17
Sinuosity	1.81	2.23
Mean Modeled Q2 Channel Width (feet)	59	57
Mean Modeled Q2 Channel Depth (feet)	3.2	3.0
Mean Modeled Q2 Width to Depth Ratio	21.3	23.1
Mean1955-2011 Migration Distance (feet)	42	39
Mean 1955-2015 Migration Rate (feet per year)	0.7	0.7
Maximum 1955-2011 Migration Distance (feet)	98	84
Maximum 1955-2015 Migration Rate (feet per year)	1.7	1.5
Pools per Mile	13	7.6
Mean Number of Bankfull Widths Between Pools	7	12
Max Residual Pool Depth (feet)	5.9	4
Median Residual Pool Depth (feet)	2.7	3.3

2.1.1 Channel Profile and Planform

Plotted profiles for the channel bed and HEC-RAS modeled 2-year WSE for Phases 3 and 4 are shown in Figure 2-3. In general, the slopes are quite consistent through both phases, averaging 0.17%. This slope is fairly typical of all of the Phases in Reach A, where slopes range from 0.15% to 0.21% (CDM Smith and AGI, 2013). Figure 2-4 shows that, on the two major secondary channels in Phase 4, channel gradients are flatter than both the main channel and all of Reach A, indicating that these channels will be susceptible to abandonment with time due to their low gradient and associated propensity for sediment infilling.

Although the main channel gradient in Phases 3 and 4 is fairly typical of those throughout Reach A, the sinuosity of Phase 4 is the highest measured in any of the 22 Phases. Phase 4 has a sinuosity of 2.23, meaning that the channel length is 2.23 times longer than the straight valley distance. The high sinuosity coupled with a typical slope for the entire reach indicates that in Phase 4 the CFR has lengthened to accommodate a relatively steep valley slope, which was also measured as the steepest in all of Reach A at 0.4% (CDM Smith and AGI, 2013). A consequence of this lengthening and high sinuosity development is the formation of meander features that migrated laterally and down valley, and can be prone to cutoff. One bendway in Phase 4 at Station 175+00 cut off in the past several years. This meander began to develop a chute channel

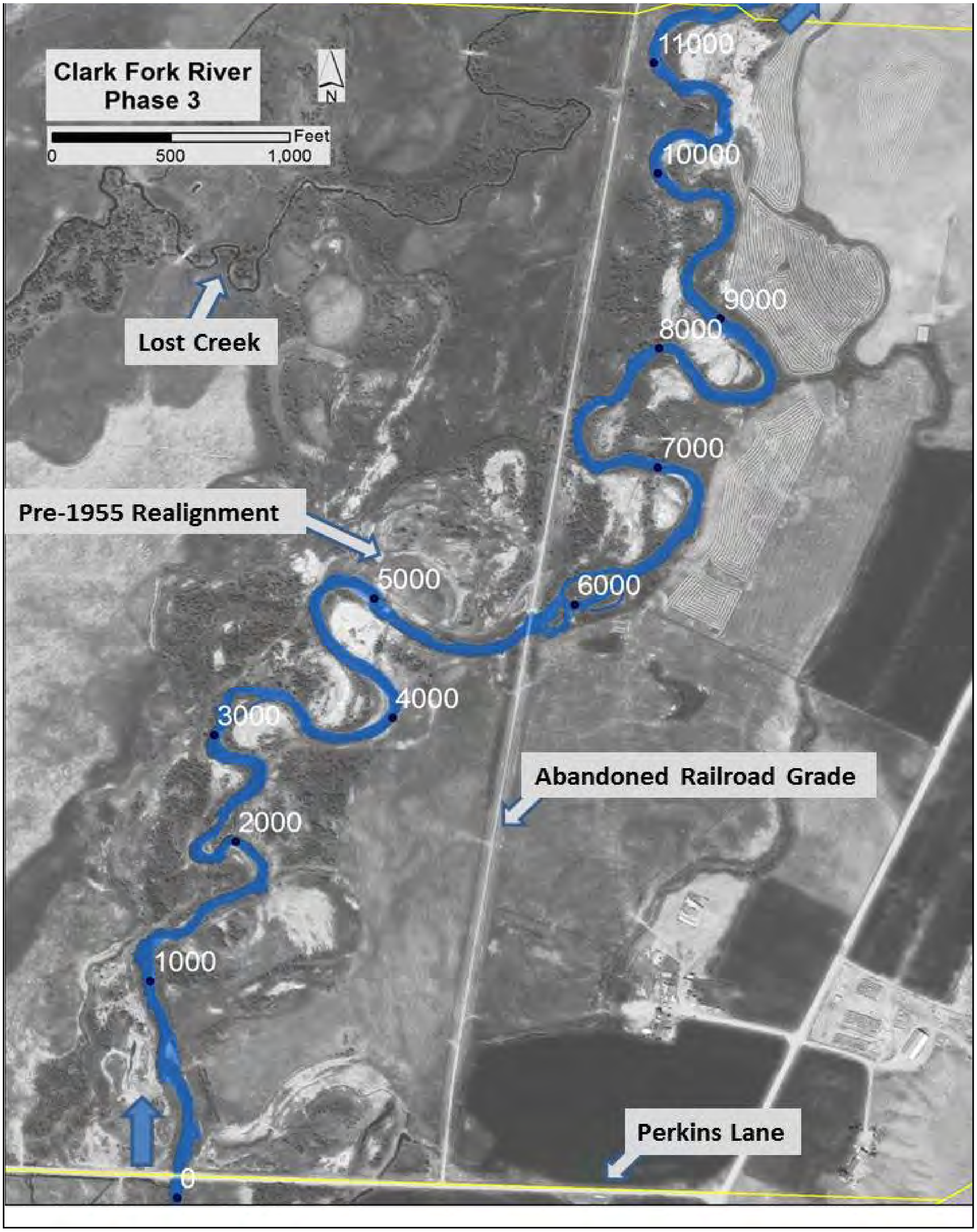


Figure 2-1 Geomorphic overview map showing stations and major features, Phase 3.

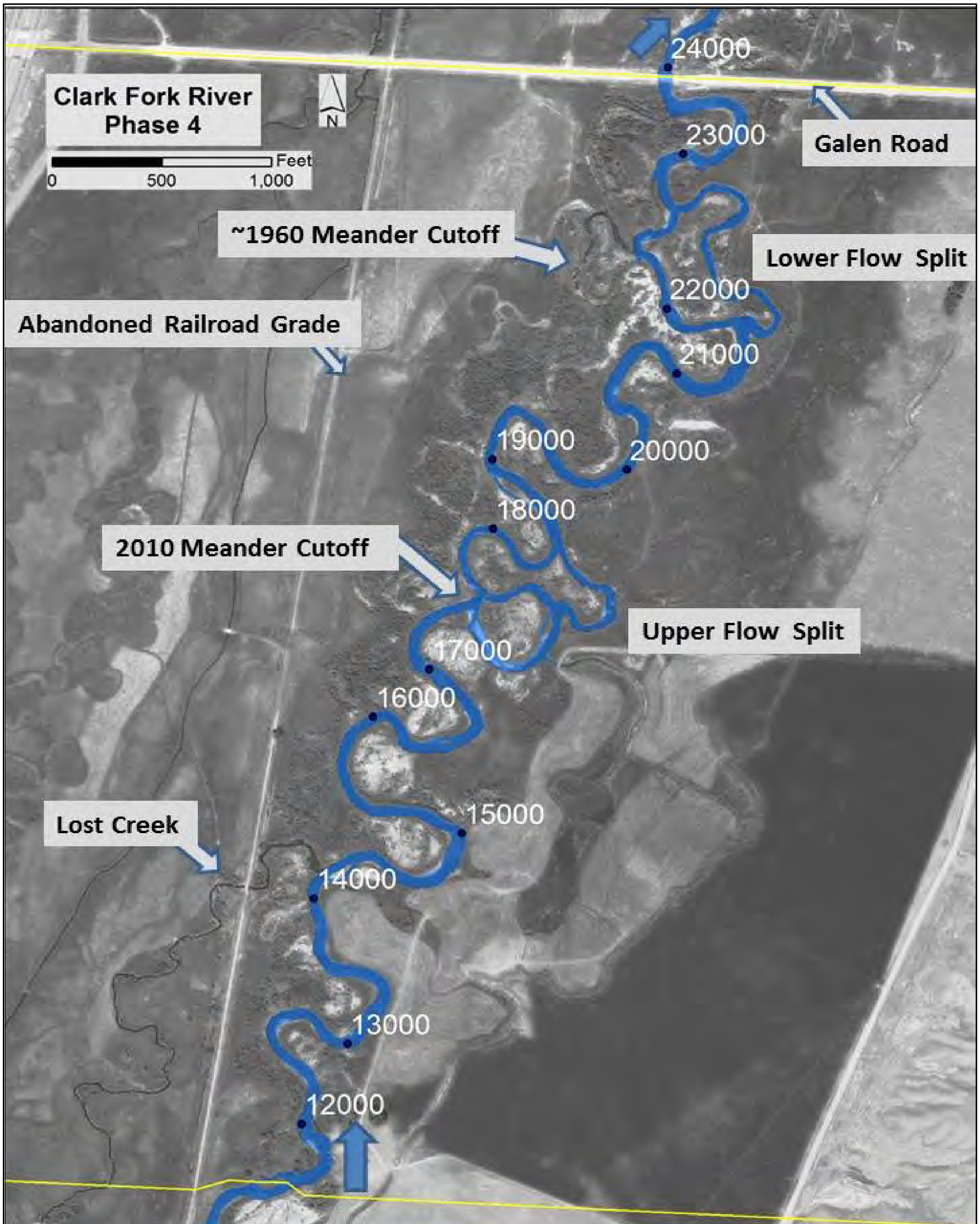


Figure 2-2 Geomorphic overview map showing stations and major features, Phase 4.

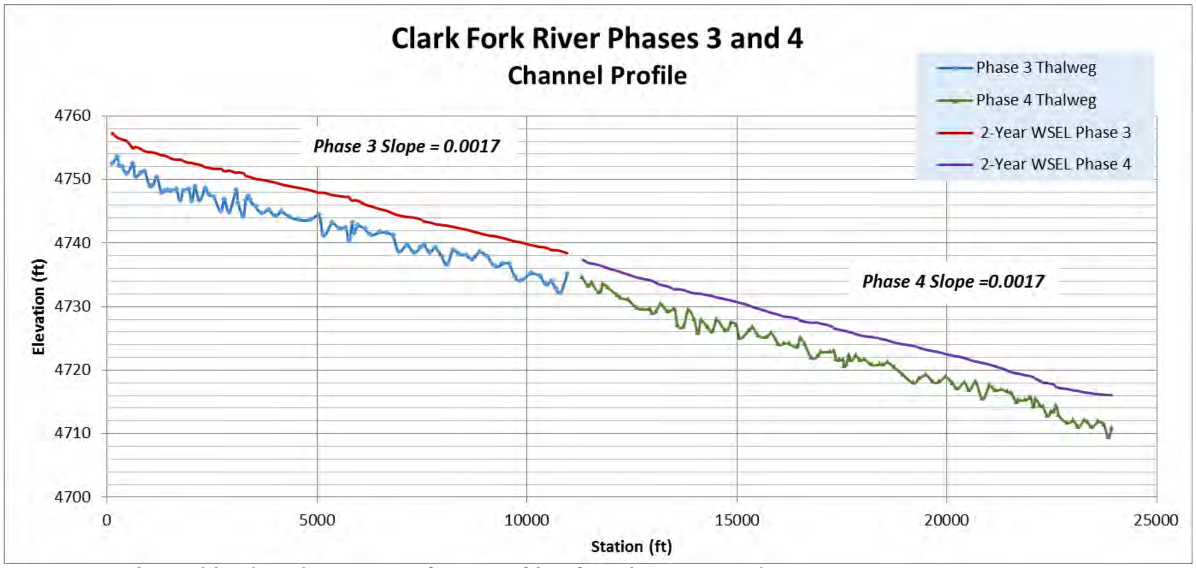


Figure 2-3 Plotted bed and water surface profiles for Phases 3 and 4.

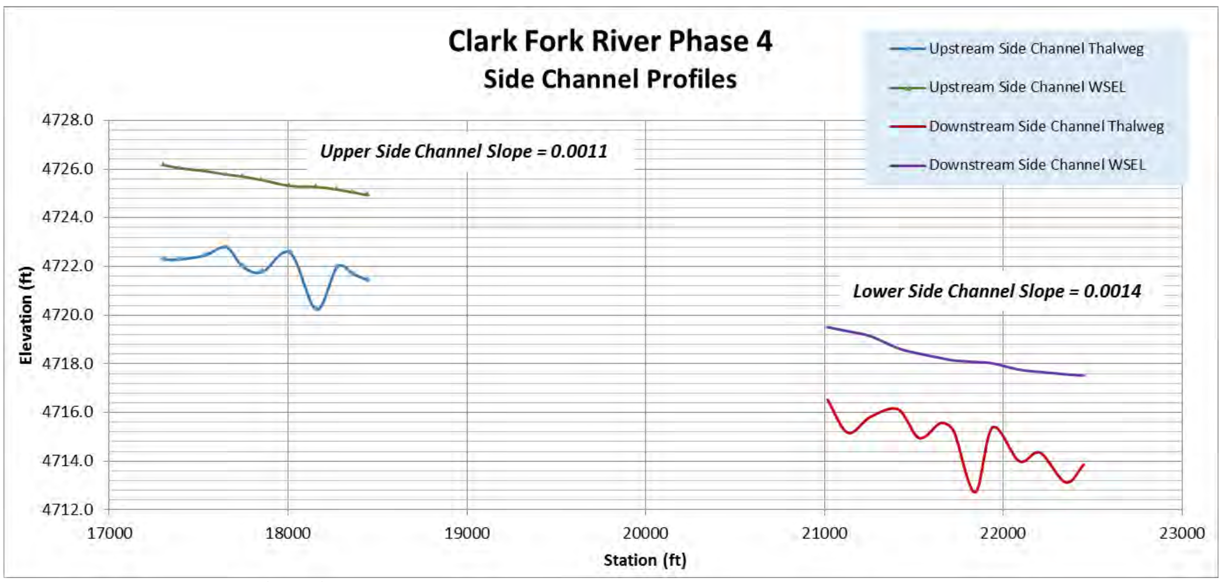


Figure 2-4 Plotted profiles for Phases 3 and 4 Side Channels.

across its core when the “neck” of the meander bend was approximately 50 feet wide. The chute channel deepened and expanded between 2009 and 2014, progressively carrying more flow, and eventually shortening the river by about 1,150 feet (Figure 2-5 through Figure 2-7). The abandoned meander currently flows seasonally and is progressively aggrading on its upstream end (Figure 2-8). A similar cutoff occurred at Station 222+00 sometime around 1960 (Figure 2-2).

Figure 2-5 View downstream (2008) of chute channel formed in meander core at Station 175+00.

Figure 2-6 View downstream (2010) of chute channel forming in meander core at Station 175+00.

Figure 2-7 View downstream (2014) of enlarged chute channel at Station 175+00; the chute has captured the entire river.

Since the cutoff occurred prior to 2014, the upstream end of the abandoned channel segment has aggraded and converted the cutoff channel, which now forms an oxbow, into a seasonal channel that will progressively lose connectivity with the river as sediment infilling into the oxbow continues (Figure 2-8).

Figure 2-8 View across river at Station 175+00 showing aggradation in upstream end of new meander cutoff.

Another major cutoff occurred in Phase 3 just above the abandoned railroad grade at Station 50+00 sometime prior to 1955. This meander cutoff appears to be an intentional relignment to improve the approach of the CFR to the railroad bridge (Figure 2-9). Portions of the new channel have been riprapped to maintain stability.

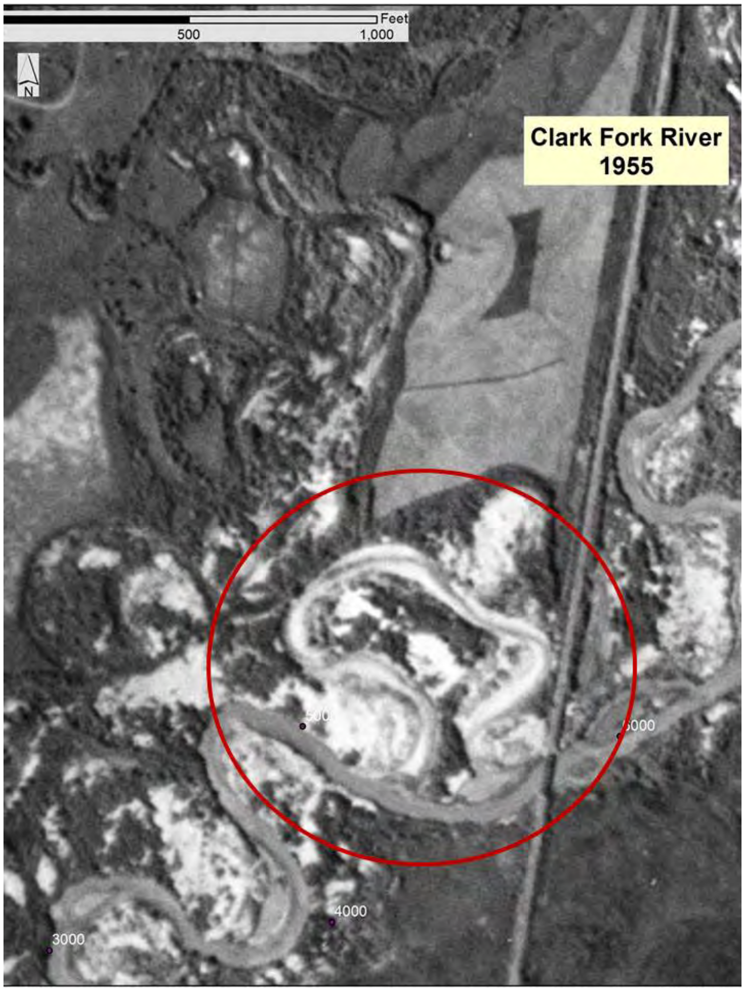


Figure 2-9 CFR in Phase 3 showing meander cutoff just upstream of railroad line, 1955.

2.1.2 Channel Morphology and Floodplain Access

As described previously, the CFR within Phases 3 and 4 has become disconnected from its floodplain due to the deposition of up to several feet of tailings-laden sediment on the floodplain (Figure 2-10). This is most clearly evidenced in the field by notably high banks as well as bank exposures of tailings deposits overlying historic floodplain and channel deposits (Figure 2-11). The aggradation of the CFR floodplain above the stream channel and resulting entrenched cross section is also evidenced by field indicators of bankfull flow that are typically 1-2 feet below the top of the stream bank (Figure 2-10), vegetation patterns that are indicative of hydrologic disconnection, and hydraulic modeling results.


Figure 2-10 View downstream showing entrenched channel segment in Phase 3.


Figure 2-11 View of right streambank showing dark historic floodplain deposits and rooting zone overlain by light orange tailings-laden sediment.

Hydraulic modeling of the existing 2-year flow condition shows that very little cross section width is inundated beyond the channel margins at this flow (Figure 2-12) as determined through HEC-RAS modeling. The HEC-RAS modeling for the Project Area is described in Section 2.2.3. There is one small area near Station 25+00 where a low bar surface is inundated, however this total inundated cross section width of about 40 feet is fairly minimal when considering overall floodplain connectivity. This is consistent with other phases in that the entrenched condition seen throughout Reach A is largely due to floodplain aggradation, and that the current bed elevation is similar to that of the pre-mining impacted channel (Smith *et al.*, 1998). In contrast, the 10-year recurrence flood does access the floodplain up to several hundred feet in width at numerous cross sections (Figure 2-12).

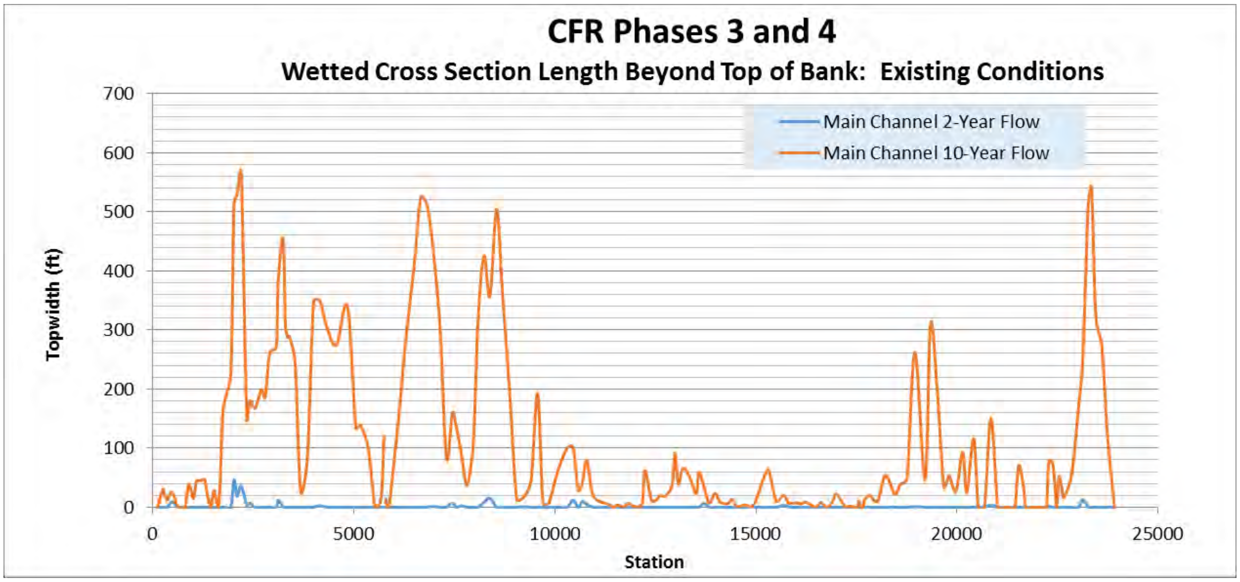


Figure 2-12 Cross section width beyond channel topbank wetted at 2-year and 10-year recurrence flows, CFR existing condition.

Floodplain connectivity in Phases 3 and 4 is discussed in detail throughout this document. From a geomorphic perspective, a lack of floodplain inundation at the 2-year flow indicates some level of hydrologic "disconnection" between the river and its floodplain. Throughout Reach A floodplain connectivity has been variably compromised by floodplain aggradation (CDM Smith and AGI, 2013), and restoring this connectivity has become a key component of the remedy to stabilize streambanks and floodplain and meet vegetation performance standards. This goal is driven by the understanding that floodplain connectivity is a critical aspect of riparian recovery and associated long-term geomorphic stability of the CFR.

Typical channel dimensions defined by the 2-year flow condition are shown in Figures 2-13 through 2-15. These plots show the range of values represented by the 189 modeled cross sections developed for the two phases. The individual box and whisker plots show the main channel in Phases 3 and 4 as well as the individual split flow segments in Phase 4. Although the plots show a fairly wide range of parameter values for the main stem segments, most of the variability is beyond the 90th percentile value for each dataset. The majority of modeled cross sections cluster around a 2-year WSE channel width of 60 feet, mean depth of 3 feet, and width:depth ratio of 22. The river would be classified in the Rosgen Classification (Rosgen, 2001) as a slightly to moderately entrenched C channel.

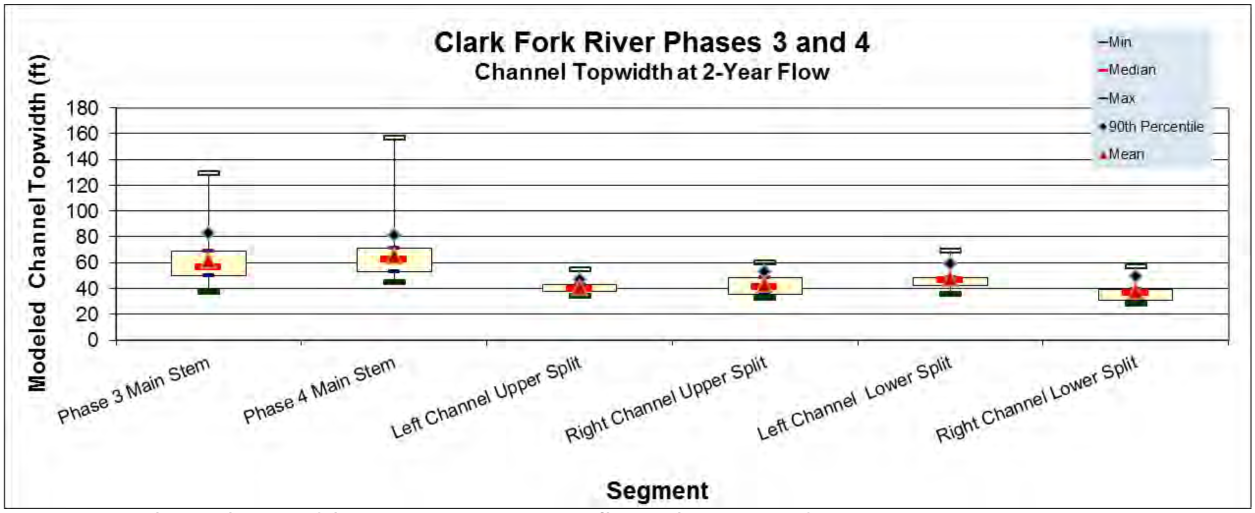


Figure 2-13 Channel topwidth at 2-year recurrence flow, Phases 3 and 4.

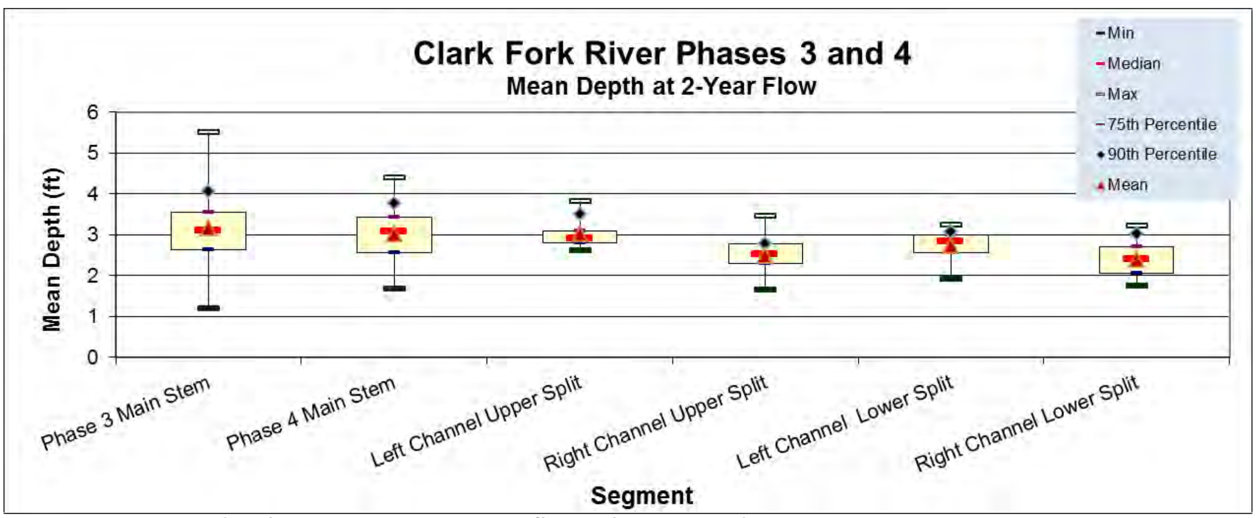


Figure 2-14 Mean depth at 2-year recurrence flow, Phases 3 and 4.

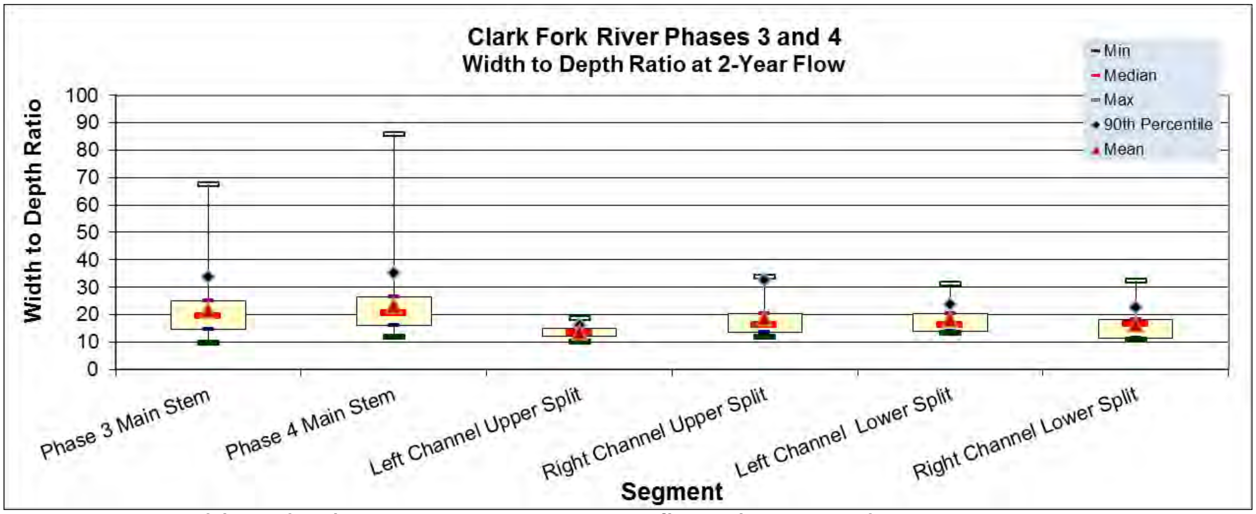


Figure 2-15 Width-to-depth ratio at 2-year recurrence flow, Phases 3 and 4.

2.1.3 Bed Material

Four pebble counts were collected in the project reach at riffles. Riffle features in both phases are moderately-well formed, forming discrete breaks in the channel profile (Figure 2-16). In the Reach A Geomorphic and Hydrology report (CDM Smith and AGI, 2013), Phases 3 and 4 were shown to have the highest riffle density of all phases, with about 12.6 riffles per mile in Phase 3 and 10.5 riffles per mile in Phase 4. This is a reflection of low frequencies in downstream phases; however, riffle frequencies in these phases are on the order of 5 to 7 channel widths which is typical for gravel bed meandering streams.

Pebble count gradations are shown in Figure 2-17 and summarized in Table 2-2. The median (D_{50}) grain size of the riffles averages 1.7 inches or 42mm, which is classified as coarse gravel. The mean D_{84} particle size is 2.7 inches or 69mm, which is classified as very coarse gravel/small cobble.

Figure 2-16 View downstream of typical riffle crest, Phase 3.

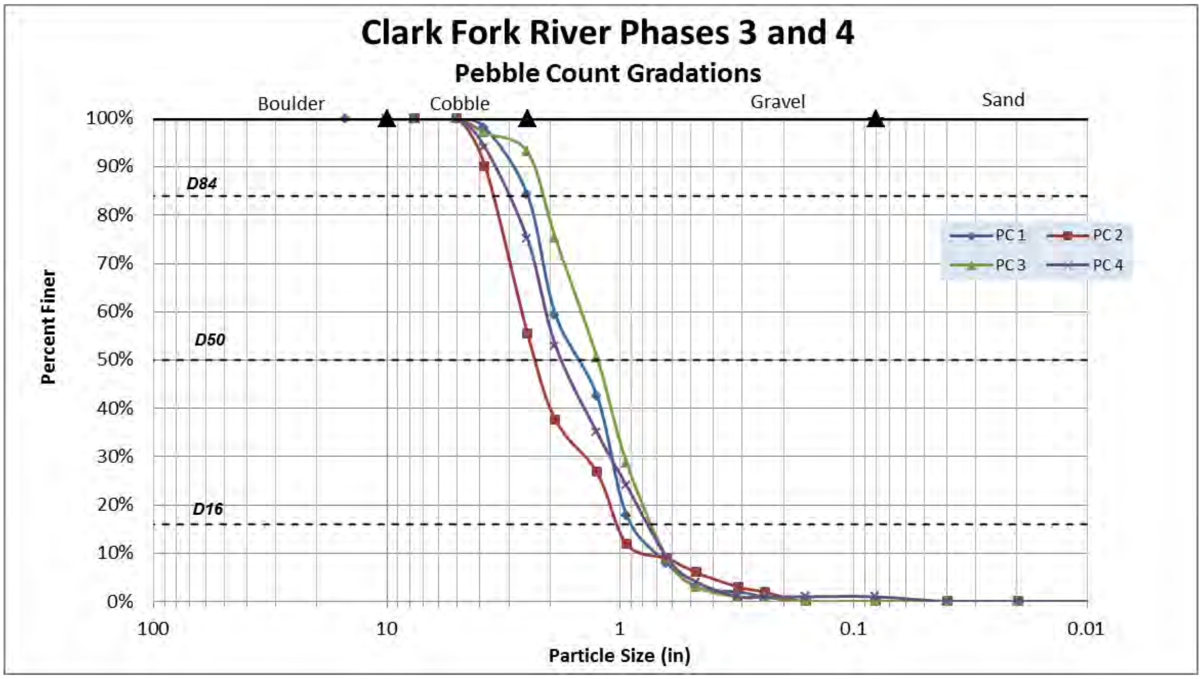


Figure 2-17 Sediment gradation curves for pebble counts, Phases 3 and 4.

Table 2-2 Pebble Count Gradation Summary, Phases 3 and 4.

Sample	Phase	Station (feet)	Gradation (inches)			Gradation (mm)		
			D16	D50	D84	D16	D50	D84
Site 1	3	5+20	0.83	1.46	2.52	21	37	64
Site 2	3	109+90	0.94	2.28	3.27	24	58	83
Site 3	4	213+20	0.75	1.26	2.13	19	32	54
Site 4	4	228+20	0.71	1.65	2.95	18	42	75
Average			0.80	1.7	2.7	20.5	42.3	69.0

In addition to riffle features, there are numerous gravel bar deposits in Phases 3 and 4 that are notably coarse, reaching cobble size material (Figure 2-18). These features were sampled at each pebble count to generally assess whether the Project Area has received "excessive sediment" from upstream source by calculating the "Riffle Stability Index" (RSI). This method compares riffle gradations to coarse fragment measurements on an adjacent bar surface (Kappesser, 2002). Riffle particles in the channel that are smaller than the large size fraction on the adjacent bar surface are interpreted to be mobile. The RSI value is calculated as the mobile percentile of particles in the riffle. Results from Phases 3 and 4 indicate that, downstream of the Station 5+20 sample, over 80% of riffle material is mobile (Figure 2-19). This indicates a condition of "excess sediment" in the system (Kappesser, 2002). The only sample that does not exhibit excess sediment is Station 5+20 in the upstream end of Phase 3. All other samples are located below the mouth of Lost Creek suggesting that this tributary may be contributing a substantial mobile sediment load to the CFR. Alternatively, the difference may reflect the very high sinuosity in Phase 4 which can result in excessive backwater and reduced sediment transport at high flows. This notion is supported by the low pool frequency in Phase 4 (7.6 pools/mile compared to 13 pools/mile in Phase 3). A combined condition of low pool frequency and sediment loading in riffles may also be a short-term response to the high water events of 2011 and 2014.

Figure 2-18 View downstream of coarse bar deposit, Phase 3.

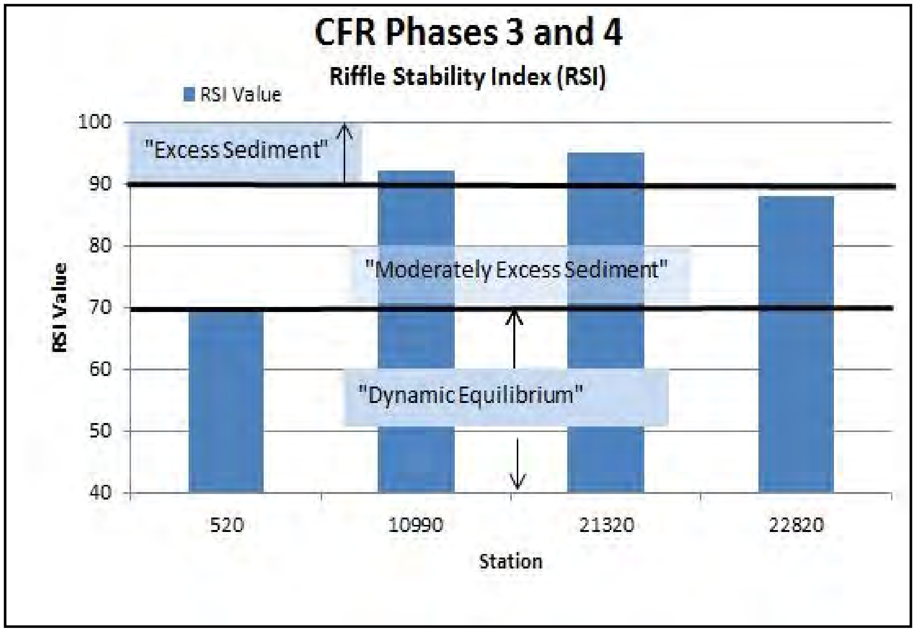


Figure 2-19 Riffle stability index (RSI) values for pebble counts, Phases 3 and 4.

2.1.4 Pool Frequency and Depth

During the field investigation of summer 2015, pool features were inventoried for location, depth, residual pool depth, and pool type. A total of 26 pools were measured in Phase 3, and 16 in Phase 4. Pools were not measured in split flow segments in Phase 4 so that statistics could be generated only for the main channel hydraulics. With the adjusted channel length taken into account (split flow length removed), pool frequencies are still higher in Phase 3 (13 pools per mile) relative to Phase 4 (7.6 pools per mile). Residual pool depths show a median value of 2.7 feet in Phase 3 and 3.3 feet in Phase 4 (Figure 2-20) A comparison of bendway radius of curvature (Rc) and residual pool depth shows an increasing pool depth on lower radius of curvature bends (Figure 2-21).

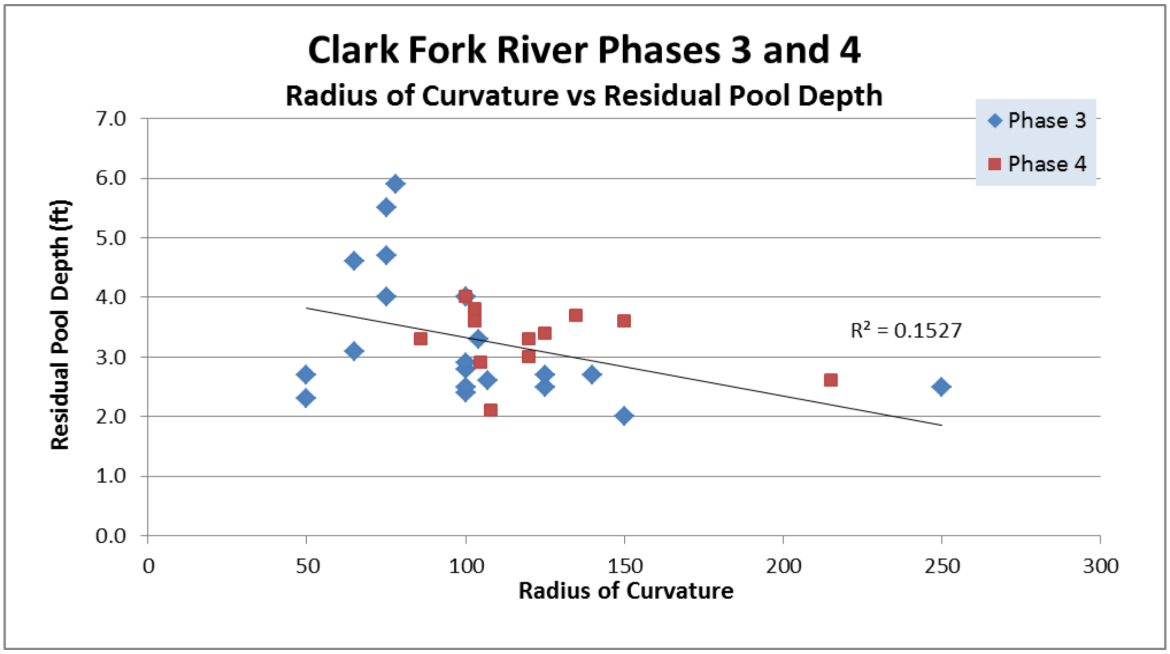


Figure 2-20 Box and Whisker plot for residual pool depth data, Phase 3 and Phase 4.

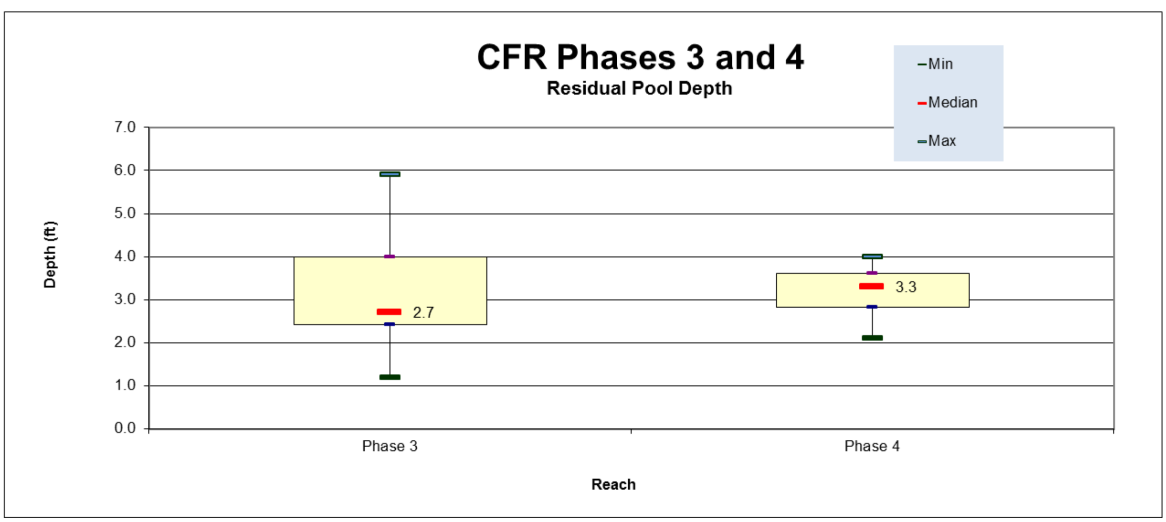


Figure 2-21 Bendway radius of curvature and associated residual pool depth.

2.1.5 Channel Migration Rates

Channel migration rates were evaluated for Phases 3 and 4 in the Reach A overview assessment (CDM Smith and AGI, 2013). The measurements were collected to determine the potential for tailings entrainment through bank erosion. Migration vectors were developed in GIS that record migration distances between the 1950s air photos and 2011 imagery including photography between these dates. These vectors were collected where active bank movement exceeding 20 feet had occurred over the period, and the vectors were collected at approximately 20 foot intervals along any given eroding bankline. A total of 59 migration measurements were made in Phase 3, and 100 measurements were made in Phase 4. The maximum migration distances measured for the 61-year timeframe are 98 feet in Phase 3 and 84 feet in Phase 4, with mean migration rates of 0.7 and 0.5 feet per year, respectively.

Between 2006 and 2011, about 1.5 acres of mapped impacted soils were recruited into the river in Phases 3 and 4, much of which likely occurred during the 2011 flood (CDM Smith and AGI, 2013). During the same time frame, over 2,000 square feet of floodplain area comprised of slickens were eroded into the river.

2.1.6 Streambank Tailings Exposures

Tailings are exposed on the floodplain in Phases 3 and 4 (Figure 2-22), and channel migration into floodplain areas has resulted in extensive exposures of tailings deposits in streambanks (Figure 2-23). These upper bank deposits range in thickness from a few inches to several feet. The historic floodplain surface is commonly visible below the tailings layers, and this unit commonly supports mid-bank woody vegetation, or lower bank root remnants. Mid-bank woody vegetation tends to be of moderate density but clearly contributes to bank stability and roughness. Bank trampling by cattle is common. In the bank toe, materials consisting of gravel and cobble are relatively common, and their upwardly convex shape indicates they are old gravel bars.

Figure 2-22 Slickens exposure on floodplain, Phase 3.

Figure 2-23 Tailings exposure in right bank, Phase 3.

2.1.7 Geomorphic Evolution of Phases 3 and 4

The geomorphic evolution of Phases 3 and 4 includes the post-glacial conversion of the ancestral Clark Fork River from a wide braided glacially-fed stream system in Pleistocene time to a single-thread meandering river (CDM Smith and AGI, 2013). As the alpine glaciers retreated, the river incised through valley bottom glacial outwash deposits. Currently, coarse bed and lower bank material that is prevalent throughout the system likely in part represents a lag deposit from that early process of glacial outwash reworking.

Early descriptions of the Deer Lodge Valley describe dense woody vegetation including birch, willows, and alder on the stream banks and floodplain. In the early 1800's, beaver were present and aggressively trapped from tributary streams in the valley. Although extensive historic beaver damming has been suggested on the main stem Clark Fork River (Smith *et al*., 1998), their historic presence in Reach A is poorly documented (Swanson, 2002). To date, no mention of beaver on the main stem Clark Fork River through the Deer Lodge Valley has been identified in the General Land Office Survey notes of the late 1800's, although beaver may have been fully trapped out by then. The common exposure of small channel fill deposits in the modern streambanks of the river support the concept of historic beaver activity, and there have been accounts of buried dams being encountered in floodplain sediment (Swanson, 2002). Currently, beaver dams are very common on smaller side channels and tributaries, and there is currently a large beaver dam upstream of the mouth of Lost Creek. Bank burrowing beaver are very common on the mainstem although the river appears to be too wide to allow dam-building. Some dam building activity has been observed on the mainstem river but very few persist beyond one year.

Large-scale cattle operations were introduced into the Deer Lodge Valley in the 1850s, which would have impacted the previously dense woody riparian vegetation along the channel and within the floodplain. This land use change, along with potential eradication of beaver, would have degraded the riparian corridor, and potentially caused some down-cutting, widening, and consolidation of channels.

Sediment loading from upstream mining operations apparently affected this area starting in the late 1860s due to hydraulic mining for gold in Silver Bow Creek (Swanson, 2002). This sediment loading continued through the late 1800s as smelters and concentrators in Anaconda and Butte produced a combined total of 1,400 tons of tailings per day. Tailings were deposited in Ramsay Flats as early as the late 1880s, and landowners in the Deer Lodge Valley were building dikes to keep tailings within the channel in the 1890s (Quivik, 1998). Even before the great flood of 1908, agriculturalists were seeing the accumulation of tailings in their fields from flooding and/or irrigation practices. Charles Williams, who owned a farm six miles north of Deer Lodge, believed by 1898 that irrigation water was damaging his crops, and by the early 20th Century had many spots in his fields “where nothing grew”. Hugh Magone ranched in the Racetrack area and noticed that by the early 1900s tailings had settled over all of the low-lying areas of his bottom land; some areas were white, some green, some “slate gray”, and many of these areas no longer supported vegetation (Quivik, 1998). The 1908 flood then caused massive additional deposition of tailings on the Clark Fork River floodplain.

Warm Springs Ponds were built in 1911 to trap mine tailings before they entered the Clark Fork River, cutting off the supply of these materials shortly after the 1908 flood. The modern geomorphology of the system currently reflects that rapid reduction in sediment loading. In Phases 3 and 4, tailings that had accumulated in the channel appear to have been rapidly flushed out, leaving dense woody vegetation on the banks and a high, perched floodplain with up to several feet of tailings contamination.

Phases 3 and 4, like most Phases of Reach A, currently have poor floodplain access during frequent flood flows due to floodplain aggradation. High contaminated banks are very common, overlaying a historic fine-grained floodplain unit which in turn overlays a complex mosaic of coarse gravels (bar deposits) and fine-grained abandoned channel fills.

2.2 Hydrologic and Hydraulic Investigation

Site peak flow hydrology for the Clark Fork River was developed in the report *Geomorphology and Hydrology of Reach A* (CDM Smith and AGI, 2013). This information was updated based on more recent stream gauging records in a memorandum to Katie Garcin at DEQ dated May 20, 2015 (CDM Smith, 2015b). Although Lost Creek has a drainage area of about 60 square miles, it contributes relatively little flow during peak flows on the Clark Fork River, which occur in May and June, because Lost Creek flows are diverted for irrigation in this period. Therefore, the 2-year flow downstream of Lost Creek was estimated to be only 23 cfs greater than the flow upstream of Lost Creek.

Hydraulic modeling was conducted to determine the river peak flow behavior under existing and design conditions in terms of flood elevations, velocities and shear stresses. This information is summarized in memoranda to Katie Garcin at DEQ dated February 2016 (CDM Smith, 2016a and 2016b).

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. However, in Phases 3 and 4, Lost Creek enters from the west.

2.2.2 Flood Hydrology Analysis

Peak flow estimates for Phases 3 and 4 of the Clark Fork River were determined using regression equation methods and gage records analysis. A flood insurance study of the Clark Fork River in Reach A 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 peak flow calculations 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 upstream boundary of Phase 3. Table 2-3 summarizes the estimated peak annual flows for Phases 3 and 4 at this gage and the estimated peak annual flows below the confluence with Lost Creek. The methods used to determine these flows are described in CDM Smith, 2015b.

Table 2-3 Peak Annual Flow Summary.

Recurrence Interval Interval	▪ Galen Gage 26 year record (Applied Upstream of Lost Creek) (cfs)	Galen Gage + Lost Creek 26 year record (Applied Downstream of Lost Creek) (cfs)
2-year	569	592
5-year	926	966
10-year	1169	1221
25 year	1377	1445

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 based on existing conditions provides a baseline for comparison with the design conditions. Different model runs were developed to evaluate the different peak flow events because assumptions on overbank flooding differed with different peak flows. Because there are many areas in the floodplain that are lower than bank height, determinations were made as to whether these areas were connected to the river at each modeled flow. If they were not connected, levees or ineffective flow areas were placed in these low areas to prevent flow from occurring in these areas. The assumption for connection to the river depend on the modeled flow and therefore different levee and ineffective flow arrangements were made for the 2-year and 10-year flows. Reach averaged velocities and shear stresses were calculated for Phases 3 and 4 for the 2-year and 10-year flow events.

Hydraulic modeling of existing conditions shows that the 10-year flow event overflows the existing banks in portions of the mainstem upstream and downstream of the abandoned railroad grade bridge. Below Lost Creek there is very little out-of-bank flow on the mainstem during the 10-year event, and neither of the two secondary channels in Phase 4 produces significant out-of-bank flow during this event. During the 10-year return event, only 4.2% of the floodplain is inundated under existing conditions. During the 2-year return event, less than 1% of the floodplain is inundated. See Appendix A for the model output for existing conditions, location of cross-sections, and inundation maps for the 2-year and 10-year return events. The results of the models for proposed conditions relate to the proposed design and are described in Section 4.

2.3 Streambank Investigation

Streambanks in Phases 3 and 4 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 October 21 to 23, 2014, 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 passive margins, in particular on the inside of meander bends, where shear stress is low. In Phases 3 and 4, the inside of meander 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 2-24 shows photographs of two existing Group 1 streambanks. The following are typical characteristics of Group 1 streambanks in the Project Area:

- Located in passive geomorphic positions such as the inside of meander 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.

Figure 2-24 Examples of Group 1 Streambanks.

2.3.2 Group 2 Streambanks

Group 2 streambanks are located on straight or the outside of meander bends 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 but can also have herbaceous vegetation if sufficiently stable. Figure 2-25 shows photographs of two existing Group 2 streambanks.

Figure 2-25 Examples of Group 2 Streambanks.

The following are typical characteristics of Group 2 streambanks in the Project Area:

- Geomorphic position varies between straight reaches and the outside of 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 or stable herbaceous vegetation.
- 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.

2.3.3 Group 3 Streambanks

Group 3 streambanks are typically located on the outside of 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 2-26 shows photographs of existing Group 3 streambanks. The following are typical characteristics of Group 3 streambanks in the Project Area:

Figure 2-26 Examples of a Group 3 Streambanks.

- Geomorphic position varies between straight reaches and the outside of 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.

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.

2.4 Bank Toe Material Investigation

Test pits excavated near streambanks during the tailings investigation and described in Section 2.5 are used to estimate the presence or absence of suitable toe material in the vicinity of banks to be reconstructed. 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. These unsuitable materials tend to lack sufficient coarse fractions (gravel and cobbles) to provide the needed stability. In some cases that stability can also be provided by thick (greater than 2 feet) layers of dense clay.

Test pits were excavated in the Phases 3 and 4 floodplain to determine the extent and depth of tailings. These test pits also provide information on other materials present including alluvial gravels. Seventy of these test pits were located close enough to the streambanks (about 30 feet or less) that they potentially provide information on existing materials near the streambanks. In particular, they provide the following information:

- The vertical position of any suitable bank toe materials in relation to the bank toe elevations,
- An estimate of the frequency of occurrence and approximate locations of unsuitable bank toe materials to determine where constructed bank toes may be needed during bank reconstruction, and
- An estimate of the quantity of alluvium that may be required to build bank toes where existing alluvium is below the elevation of the base of the upper bank.

For this analysis suitable in-place materials for bank toes are materials logged as gravels in the test pit logs. In general, the alluvial materials that are available as an in-situ bank toe reflect native Clark Fork River alluvium and will mobilize under certain events, permitting long-term deformability of the banks. However, these materials are coarse enough to preclude significant deformation at flows less than a 10-year flood event at most locations.

For design purposes, imported toe material will be needed where there is no competent toe above the scour depth or any existing, competent native toe is greater than 0.5 feet below the base elevation of the constructed upper bank. Test pit data suggest that 60% of the Group 3 banks will require some added toe material. Using the elevation of the top surface of existing gravel compared to the elevation of the base of the constructed bank, estimates of each bank's requirements for toe material were calculated. These volumes averaged 0.22 cubic yards per foot of Group 3 streambank requiring bank toe construction.

To support these conclusions with additional field evidence, bank toes located at planned Group 3 bank locations were probed during the October 21-23, 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 Group 3 bank that might require bank toe construction. The percentages for all Group 3 streambanks in the Project Area were averaged and an estimate that 82% of the Group 3 bank length would require bank toe construction was determined using this method. This is more than the 60% estimate from the test pit investigation, but confirms that a large portion of the Group 3 banks in the Project Area will require bank toe construction.

2.5 Contaminant Characterization

The purpose of the Phases 3 and 4 contaminant characterization investigation was to collect and identify design level data concerning the nature and extent of soil contamination. The Phases 3 and 4 contaminant characterization was completed between October 26, 2014 and February 11, 2015. 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 in accordance with the Reach A, Phases 3 and 4 Sampling and Analysis Plan Addendum (CDMSmith, 2014). Select samples expected to bracket the depth of contamination were sent to Energy Laboratories in Helena, MT, for analysis of concentrations of Contaminants of Concern (COCs).

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. Samples were collected at 6-inch intervals to provide a profile of contamination. 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. If contamination extended below the level first excavated, the test pit was opened wider and sampling extended to the depth of contamination. Deep samples were normally obtained by bucket sampling to avoid entry into the pit. Dewatering was required on all but the shallowest pits.

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 Drawings, Sheets C7 to C11, Existing Conditions and Test Pit Locations, display the test pit locations and depth of contamination for Phases 3 and 4. Samples were sent to the laboratory for determination of the lowest contaminated interval. Contamination was defined as the sum of the COCs (As, Cd, Cu, Pb and Zn) exceeding 1,400 mg/kg. A memorandum prepared by DEQ and sent to EPA on March 19, 2014 provides the basis for the contaminant removal design criterion (DEQ, 2014). The *Basis for Remedial Design Assumption: Contamination Benchmark* (DEQ, 2014) was added to the Clark Fork Site Administrative Record in support of the ESD (June 2015). A Data Summary Report (CDM Smith, 2015a) was prepared describing the test pit excavation and sampling program and presenting the sampling results. The analysis included identification of the predicted base of tailings at each location. Sampling data were also provided to DEQ in an EQuIS compatible database.

2.6 Groundwater Investigations

The soil test pit investigation completed by CDM Smith between October 2014 and February 2015 (CDM Smith, 2015a) provides information on groundwater conditions throughout Phases 3 and 4. Depth to water in test pits ranged from 1 foot below ground surface to 7.5 feet. The average depth to ground water was 3.8 feet indicating that ground water levels are near the base of tailings on the average in winter. This elevation is also approximately the elevation of the water surface in the river in winter. However, based on the upper Reach A 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. Additional groundwater studies in Phase 3 and 4 have been initiated by the Natural Resource Damage Program (NRDP). Piezometers with data loggers are collecting continuous data across Phases 3 and 4 with the objective of determining more accurate ground water levels for design of wetlands.

2.7 Vegetation Investigations

This section describes vegetation within the Project 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 Reach A, including Phases 3 and 4, have been completed by various agencies and researchers to assist with remediation and restoration efforts. Smith *et al*. (1998) evaluated vegetation establishment after the 1908 flood of record. This study showed that vegetation along the CFR 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 of record in areas where tailings were 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% of the floodplain tabs (floodplain area between meander bends) have less than 40% of their surface covered by shrub canopy, with an average shrub canopy cover of

29% 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 Reach A 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 Phases 3 and 4 to better guide vegetation community mapping.

To support development of the ROD, USEPA also assessed vegetation and wetlands in Reach A. 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 RipES with the thought that plant community composition and structure might correlate with degree of contamination (USEPA, 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 USEPA and its contractors as part of developing the ROD.

Consultation between State and Federal agencies will continue for the 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 CFROU 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 that will be developed for Phases 3 and 4 will include tracking of wetlands. Wetland monitoring will continue (consistent with the Phase 1 plan) in CFR Reach A, Phases 3 and 4 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 agreed upon timeframe for this process under the Streamside Tailings Operable Unit (SSTOU) Consent Decree.

2.7.2 Historical Vegetation

Historical reports of the vegetation and CFR 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 CFR.

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 CFR 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, as described in Section 2,1, Geomorphic Investigation.

2.7.3 Existing Vegetation

To support preliminary design and refine Remedial Actions, site-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 elevation data.

Existing vegetation communities were evaluated using two methods. Field mapping first identified the composition and location of existing vegetation communities within Phases 3 and 4. 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 2014 growing season. Vegetation communities were mapped in the field using the following spatial data for reference:

- 2013 National Agriculture Imagery Program (NAIP) imagery (USDA FSA, 2013)
- 2013 National Agriculture Imagery Program (NAIP) imagery Color Infrared (CIR) (USDA FSA, 2013)
- 2011 aerial photography (ESRI, 2011)
- National Wetlands Inventory mapping including wetlands and riparian areas (USFWS, 2005)
- Deer Lodge County Area Soil Survey (USDA NRCS, 2012)
- Water surface elevations derived from the LiDAR
- Elevations relative to the LiDAR WSE using processed LiDAR data collected between August 6, 2011, and August 11, 2011, by Fugro EarthData, Inc. (2011) and post processed by DJ&A, P.C.

During field mapping, the extents of distinct vegetation communities were delineated over aerial photographs of the Project Area. Vegetation communities are 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 2-4. 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 20 vegetation communities were mapped in and around the Project Area. Photographs of representative vegetation communities are provided in Figure 2-27. Approximately 531.5 acres were mapped of which 310.1 acres were within the limits of the soil pit investigation (Project Area) (Table 2-4, Figure 2-28 and Figure 2-29). The most extensive vegetation communities within Phases 3 and 4 are Willow/Birch (72.9 acres), Upland Herbaceous (66.0 acres), Meadow (53.8 acres) and Willow/Birch-Slickens (43.7 acres).

The elevation of each vegetation community relative to the 2-year flow WSE was evaluated to determine the range of elevations that would need to be created to support desirable vegetation communities post remediation actions. 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 10.1 (ESRI, 2011) to generate a raster representing the depth of contamination where the summed concentration of 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 mapped existing vegetation communities.

Figure 2-30 and Figure 2-31 and Table 2-4 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 (-0.3 ft), and Islands (-1.2 ft). All other vegetation communities have average elevations above the 2-year WSE, ranging from 0.1 ft for the Depositional community to 5.0 feet for the Cottonwood Stand community.

Table 2-4 Existing Vegetation Community Descriptions.

Vegetation Community Type	Vegetation Community Type Description	Elevation (feet) Relative to 2 year WSE			Depth of Contamination >1,400mg/kg (feet)			Hydrologically Connected Area (acres)	Geomorphic Feature	Land Management Effects
		Min	Max	Ave	Min	Max	Ave			
Willow/Birch (72.9 acres)[2]	Willow and/or birch dominated canopy. Understory can include upland vegetation such as gooseberry and rose, or wetland herbaceous vegetation such as sedges.	-3.3	11.2	1.5	0.0	6.0	2.1	8.2	Generally within the meander belt width, along side channels or low areas in the floodplain; along ditches; occasionally small patches further from the channel.	Often grazed with some shrubs browsed and some areas with soil pugging.
Upland Herbaceous (66.0 acres)	Dominated by upland species such as wild rye, redtop, and wheat grasses. Lacks shrubs and trees. Weed species often present.	-2.4	6.8	2.0	0.0	7.0	1.6	3.3	Outer meanders and high terraces; occasionally elevated areas on inside of meander bends.	Often hayed or grazed.
Meadow[2] (53.7 acres)	Dominated by both wet and dry species that are more typical of pastures areas such as redtop and a minor component of rush	-2.3	11.2	2.2	0.0	7.0	1.5	1.3	Typically irrigated hayfields located away from the channel.	Primarily hayed and sometimes grazed.
Willow/Birch-Slickens (43.7 acres)	Willow and/or birch dominated canopy. Understory is dominated by slickens with minimal herbaceous vegetation.	-2.8	10.8	1.4	0.0	6.4	2.6	4.0	Commonly found on inside of meander bends.	Some grazing impacts, but degraded condition primarily from contamination.
Willow/Birch-Grazed (24.8 acres)	Willow and/or birch dominated, however shrubs stand only 3 or 4 feet high due to grazing and understory is bare ground or minimal vegetation.	-2.4	9.7	1.7	0.2	5.0	1.9	4.3	Primarily on the west side of the channel where cattle use is heavy.	Heavily grazed.
Slickens (18.3 acres)	Bare ground characterized by contaminated sediment. Vegetation is often not present or a fringe of redtop.	-1.8	4.5	1.2	1.0	6.5	3.2	2.6	Most often found on inside meander bends. Occasionally located further from the channel within Willow/Birch communities.	Areas on inside meander bends have often been bermed to prevent contamination from entering the river.

Vegetation Community Type	Vegetation Community Type Description	Elevation (feet) Relative to 2 year WSE			Depth of Contamination >1,400mg/kg (feet)			Hydrologically Connected Area (acres)	Geomorphic Feature	Land Management Effects
		Min	Max	Ave	Min	Max	Ave			
Wet Meadow (12.3 acres)[2]	Dominated primarily by wetland species and typically temporarily or seasonally flooded wetlands.	-1.6	5.5	1.3	0.0	7.0	2.2	2.4	Abandoned meander channels and low elevation areas in floodplain.	Often hayed or grazed.
Infrastructure (5.1 acres)	Berms, rail road grades, water gaps, old roads and rip rap.	-2.1	12.6	4.7	0.0	4.5	2.1	0.2	None	N/A
Open Water (3.3 acres)[2]	Ponded or flowing water with no or some aquatic vegetation.	-2.9	5.1	-0.3	0.5	3.9	1.9	2.4	Ditches and old meander scrolls.	Often man-made and maintained. Otherwise deeper water within wetlands.
Emergent Marsh (2.7 acres)[2]	Dominated by wetland species and typically semi-permanently to permanently flooded wetlands.	-3.3	4.0	0.4	0.0	6.7	1.9	1.1	Low areas of the floodplain, along abandoned oxbows, along open water features.	Occasionally grazed.
Upland Herbaceous - Slickens (2.0 acres)	Characterized by more vegetation than Slickens with dead willow stumps and drier herbaceous species.	-0.2	4.1	2.0	2.0	7.0	4.1	0.1	Along the left bank of the river upstream of the bridge near the center of the Project Area.	Hayed in the past.
Low Shrub (1.4 acres)[2]	Dense low growing shrubs including snowberry, Wood's rose, and currant. Limited herbaceous understory. Lacks willow/birch in the overstory.	-2.0	4.1	2.3	0.0	3.9	0.9	0.0	Generally located further from the main channel.	Often grazed.
Colonizing Willow (1.1 acres)[2]	Depositional areas that are dominated by colonizing sandbar willow.	-2.6	2.8	0.4	0.0	4.4	2.5	0.6	Point bars and some low elevation streambanks.	Occasionally grazed.
Vegetated Bar (1.1 acres)[2]	Recently deposited sediment, now vegetated with wetland plants and often colonizing willows.	-2.7	2.5	-0.3	0.5	4.0	2.5	0.9	Point bars.	Often grazed.
Willow/Birch - Depression (0.6 acres)[2]	Willow and/or birch dominated canopy. Understory dominated by wetland species such as sedges.	-0.9	2.7	0.3	1.0	4.0	2.8	0.4	Floodplain depressions and along abandoned oxbow features.	Occasionally grazed.

Vegetation Community Type	Vegetation Community Type Description	Elevation (feet) Relative to 2 year WSE			Depth of Contamination >1,400mg/kg (feet)			Hydrologically Connected Area (acres)	Geomorphic Feature	Land Management Effects
		Min	Max	Ave	Min	Max	Ave			
Cottonwood Stand (0.3 acres)[2]	Black cottonwood stand with an understory dominated by upland herbaceous vegetation.	1.2	9.3	5	0.0	2.5	0.7	0.0	One stand is present on the east side of the river near irrigation ditches.	Heavily grazed with most trees decadent.
Depositional (0.3 acres)[2]	No vegetation, fine to coarse substrate recently deposited.	-2.7	1.7	0.1	0.6	4.5	2.6	0.1	Point bars and mid-channel islands.	None observed.
Willow/Birch - Decadent (0.3 acres)	High percentage of decadent willows and/or birch.	-0.1	4.2	2.0	0.0	3.8	1.4	0.0	Various areas of the floodplain, often between Willow/Birch community and Slicken communities.	Often grazed.
Island (0.1 acres)[2]	Vegetated island in or within active river channel. Often characterized by vegetated bars and willow/birch communities.	-2.0	0.3	-1.2	0.0	4.0	2.7	0.1	Vegetated islands in channel.	None observed.
Bare Ground (0.1 acres)	Areas of exposed substrate with minimal vegetative cover. When present, species include salt grass.	-0.7	1.9	1.0	2.0	4.0	3.5	0.0	One depositional area along the right bank of the river.	None observed.

[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.

[2] Indicates this existing vegetation community is a desirable vegetation community that will be replicated in the vegetation design.

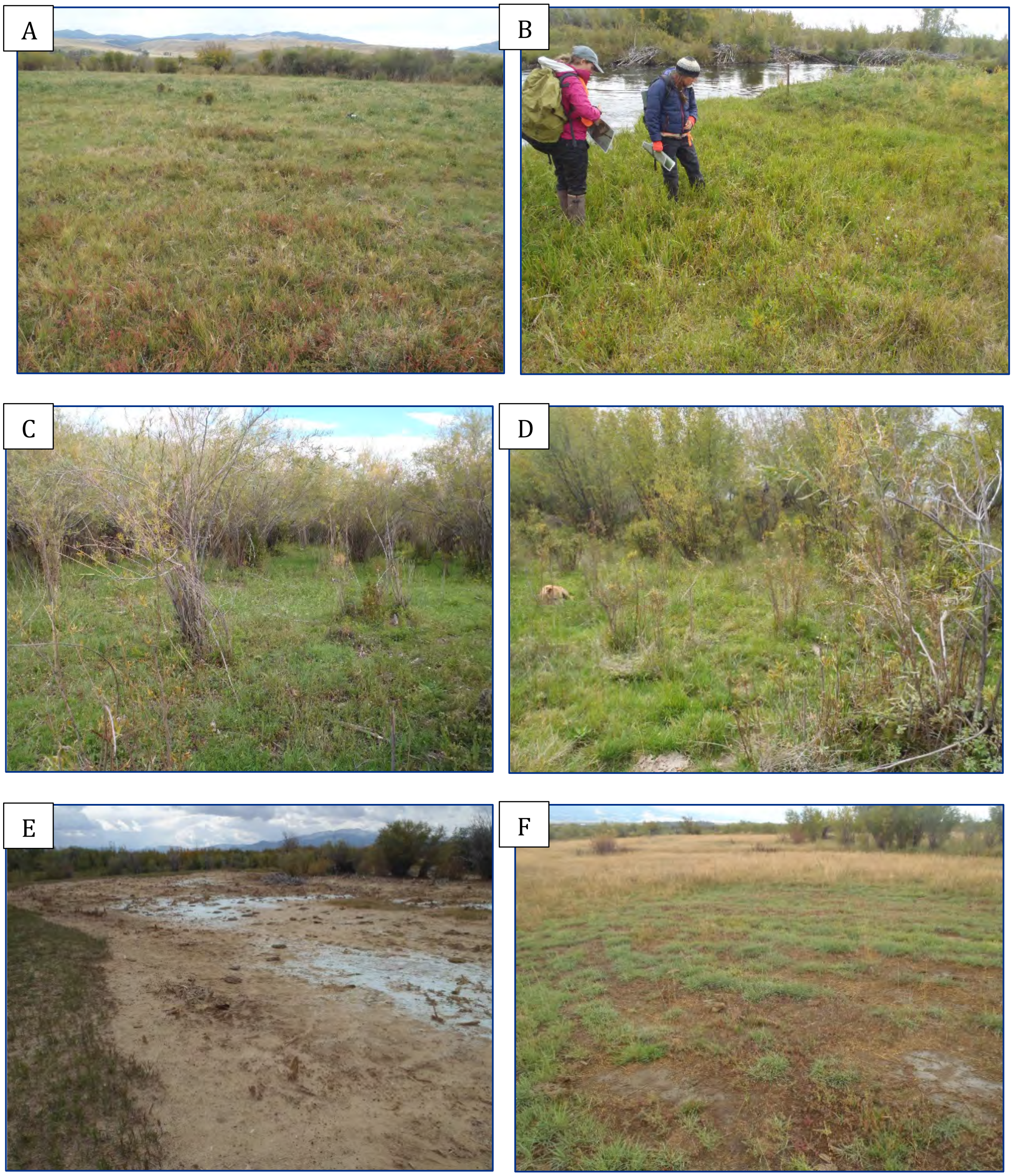


Figure 2-27 Photographs of Vegetation Communities in Phases 3 and 4.
A = Upland Herbaceous; B = Emergent Marsh; C = Willow Birch; D = Willow Birch – Depression; E = Slickens; F = Slickens – Upland Herbaceous.

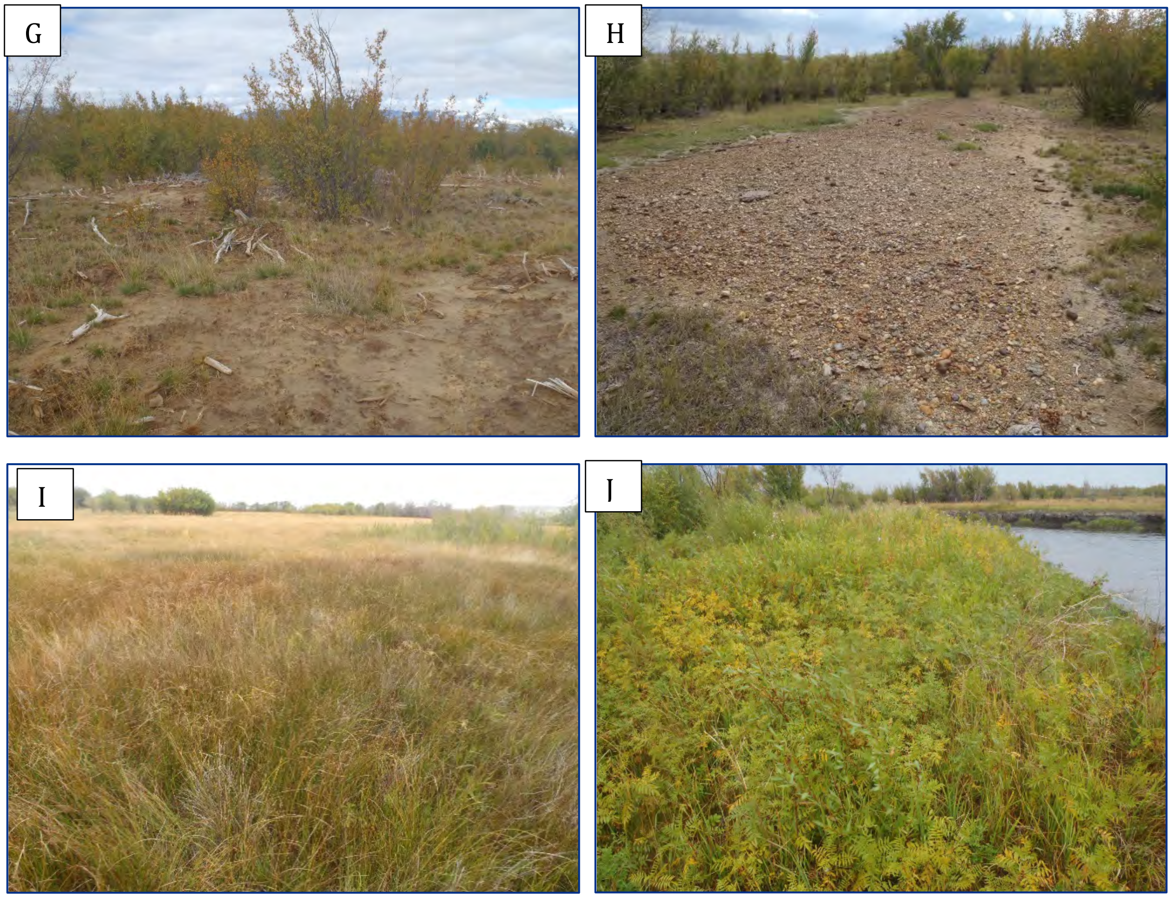


Figure 2-27 Photographs of Vegetation Communities in Phases 3 and 4 continued.
G = Slickens – Willow Birch; H = Bare Ground; I = Wet Meadow; J = Colonizing Willow.

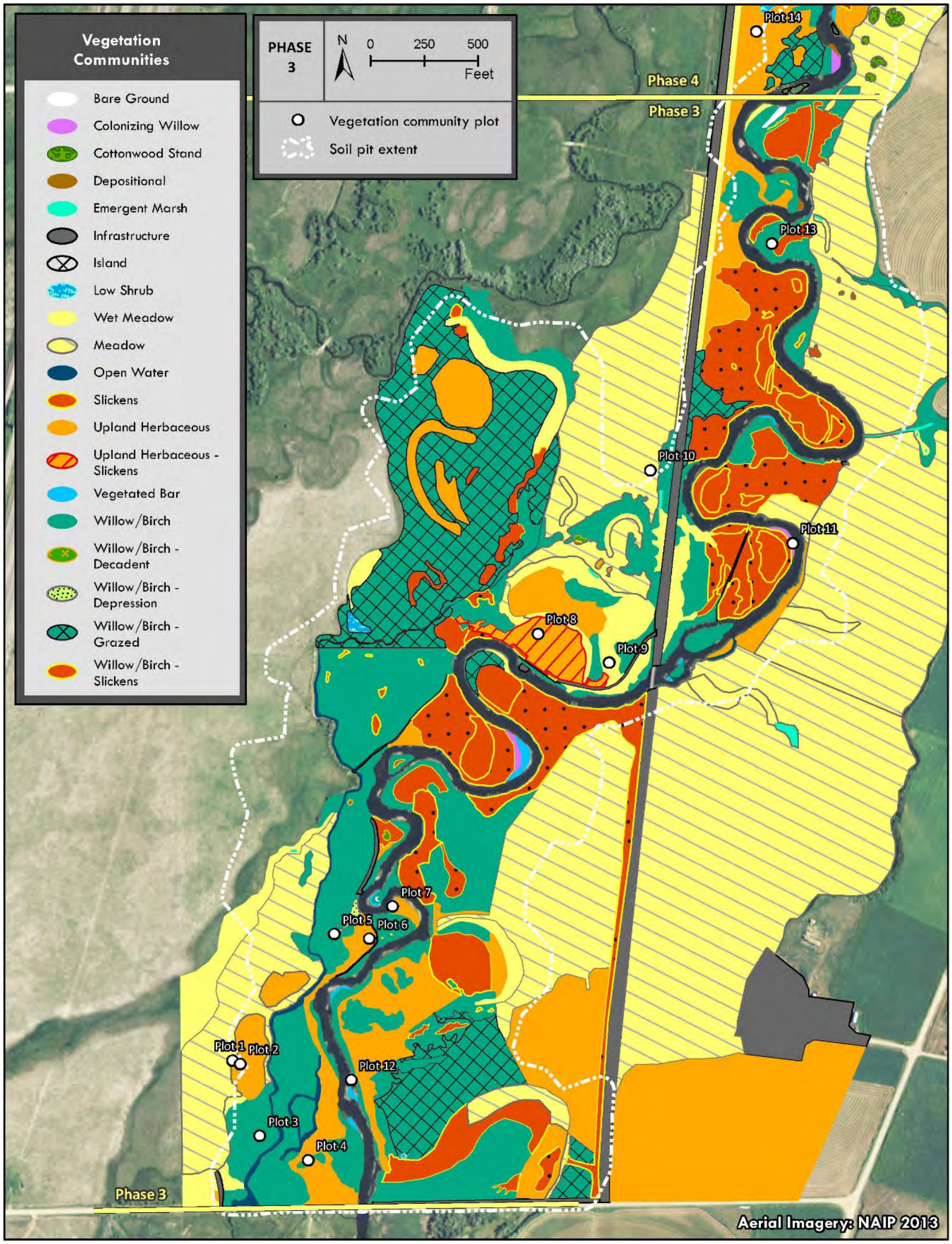


Figure 2-28 Phase 3 Existing Vegetation Community Distribution.

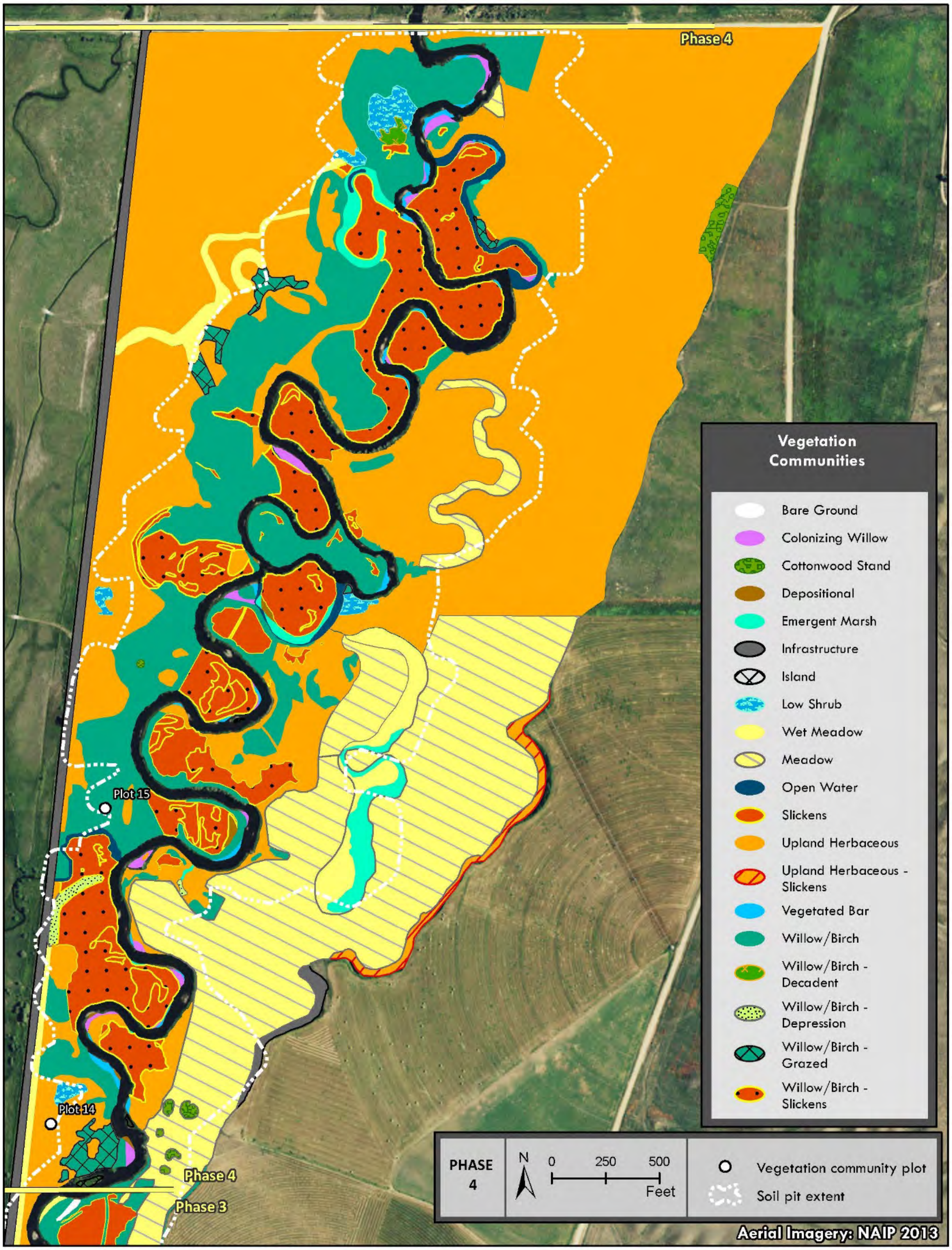


Figure 2-29 Phase 4 Existing Vegetation Community Distribution.

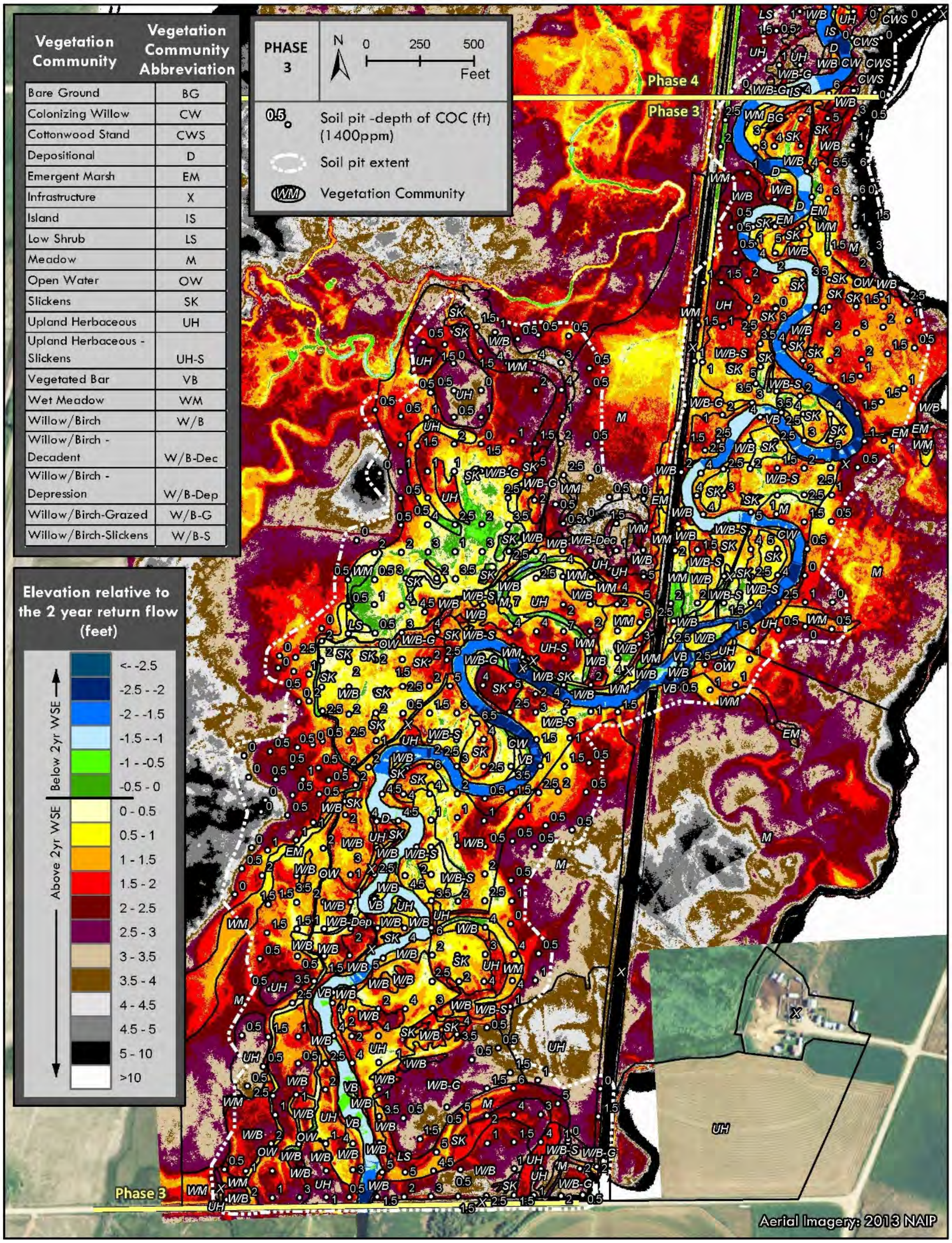


Figure 2-30 Phase 3 Existing Vegetation Communities, Existing Ground Elevation Relative to the 2-Year Water Surface Elevation and Soil Test Pits with Depth of Contamination in feet.

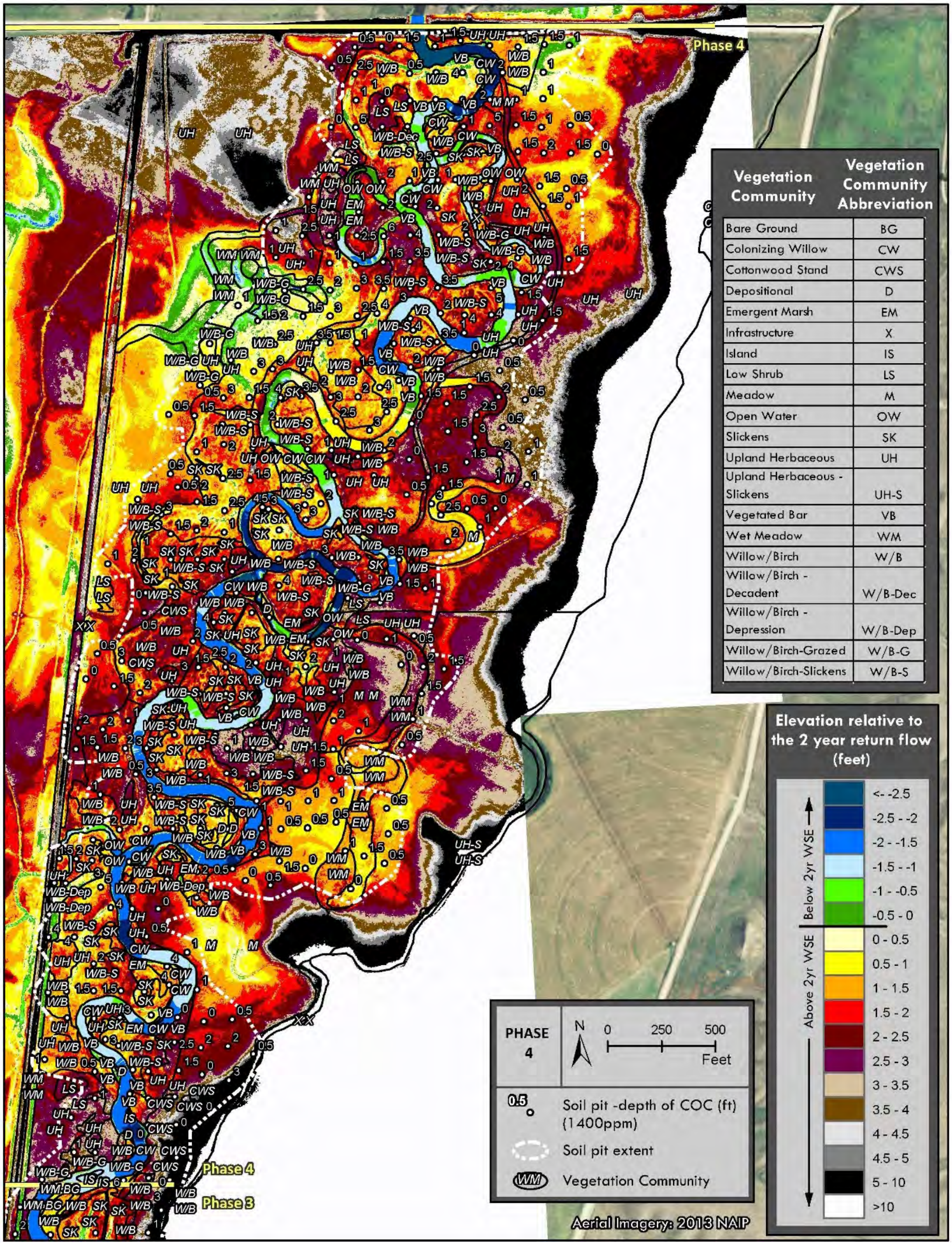


Figure 2-31 Phase 4 Existing Vegetation Communities, Existing Ground Elevation Relative to the 2-Year Water Surface Elevation and Soil Test Pits with Depth of Contamination in feet.

Table 2-4 provides the results of the analysis overlaying existing vegetation communities with soil contamination thickness. The Upland Herbaceous - Slickens had the greatest average depth of contamination (4.1 feet), followed by Bare Ground (3.5 feet), Slickens (3.2 feet) and Willow/Birch – Depression (2.8 feet). The Slickens communities (Slickens, Upland Herbaceous – Slickens and Willow/Birch – Slickens) are generally on the inside of meander bends and along old meander scrolls or oxbows. These areas are where flood deposition in 1908 was likely concentrated. The Slickens community is also found along ditches where contaminated soil material has been dredged. The Slickens community has no or sparse vegetation. The Upland Herbaceous – Slickens vegetation community has higher cover of herbaceous vegetation. The Willow/Birch – Slickens community has decayed willow stumps and supports sporadic decadent willows indicating it may have supported tall shrub vegetation prior to contaminated sediment deposition in these areas. The Willow/Birch – Depression communities are located in low areas such as oxbows are close to the main channel. These area may have acted as sediment sinks during higher flow events resulting in high metals concentrations. The Bare Ground community is present in one location in the Project Area. This type is represented by depositional material rather than visibly contaminated material however soil pit data indicate 2 to 4 feet of contamination.

Each vegetation community was also evaluated for hydrologic connectivity with the CFR. Hydrologic connectivity is defined as an elevation occurring at half a foot above the 2-year WSE or lower. Based on previous floodplain restoration 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 (necessary conditions to meet vegetation performance standards). 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 2-32 and Figure 2-33).

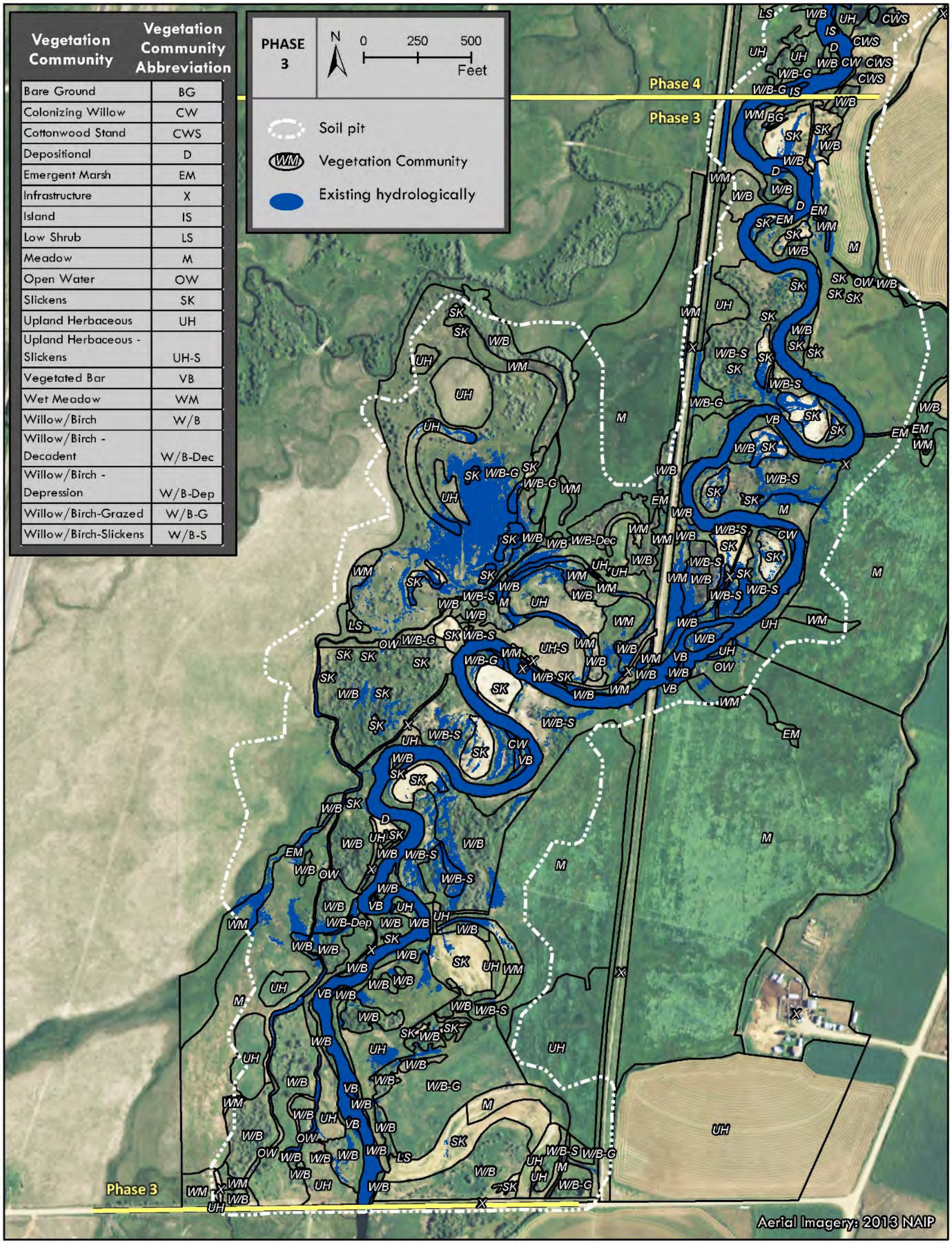


Figure 2-32 Phase 3 Current Floodplain Areas Connected to Clark Fork River Hydrology.

.

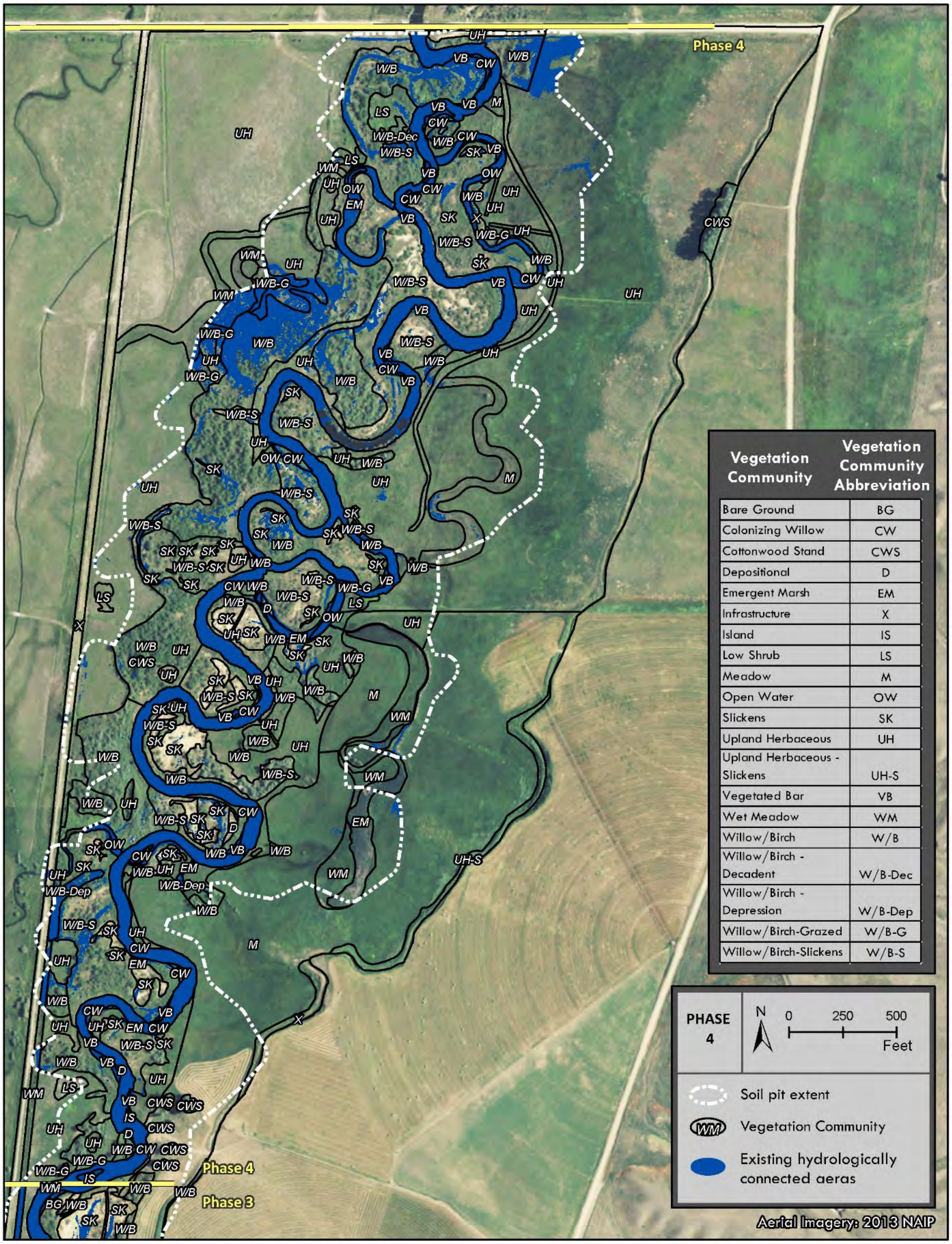


Figure 2-33 Phase 4 Current Floodplain Areas Connected to Clark Fork River Hydrology.

This analysis shows that only 32.2 acres (10.4 percent) of the mapped vegetation communities within the Project Area are hydrologically connected to the CFR. This is reflected in the area being largely dominated by drier vegetation communities such as Upland Herbaceous (66.0 acres, 21.3 percent of mapped vegetation communities) and Meadow (53.7 acres, 17.3 percent of mapped vegetation communities). Dominant vegetation communities (including Upland Herbaceous, Meadow, and Willow/Birch as well as Willow/Birch communities with an understory of Slickens and Willow/Birch communities that have been heavily grazed) only have a small percentage of area considered hydrologically connected to the river. Other vegetation communities, that do not occupy large areas such as the Vegetated Bar, Willow/Birch-Depression, Colonizing Willow, Depositional, and Emergent Marsh, communities 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 has caused these areas of the floodplain to aggrade and become hydrologically disconnected. The Willow/Birch community is characterized in 5 different ways; normal, decadent, depression, grazed and slickens. If these communities are combined, only 17.0 acres (12.0 percent of the Willow/Birch area) are hydrologically connected to the CFR. Existing willows and birches are likely the result of vegetative regrowth from live roots and branches buried under deposited tailings. New plants are unable to colonize many of these areas from seed because the elevated geomorphic position results in a lack of river flows that scour and deposit substrate needed for willow and cottonwood regeneration.

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 the Vegetated Bar, Willow/Birch- Depression, Colonizing Willow, Depositional, and Emergent Marsh, are able to perform ecological functions including sediment and nutrient transport and storage, flood water storage, food web support, and support aquatic habitat functions. These areas provide higher levels of ecological function despite often having a greater depth of contamination due to their connection with the river. 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 (necessary conditions to meet vegetation performance standards).

Variations in plant community composition and structure are 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.

2.8 Aerial Mapping

DEQ contracted with DJ&A consultants of Missoula, MT, for aerial mapping services on Reach A. 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 Phases 3 and 4, 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

Phases 3 and 4 are located within three ownerships: Lampert Ranch, Deer Lodge River Ranch (Hadley's), and Kelley Ranch. The Lampert Ranch constitutes the majority of the Phases 3 and 4 Project Area and extends from Perkins Lane downstream 3 river miles (1.5 miles due north). The Deer Lodge River Ranch is at the north east portion of the Project Area and extends from the Lampert Ranch 1 river mile (0.5 miles due north) downstream and ending at Galen Road. The Kelley property is a small section on the west side of the Project Area beginning at Perkins Lane. Discussions were held between members of the design team and Lamperts on their current and projected land uses on July 21 and November 13, 2015. The design team met with the Hadley's on July 29 and November 12, 2015. Figures 2-34 and 2-35 show current land ownership and land use.

2.9.1 Lampert Ranch

The Lampert Ranch is used for pasturing cattle, primarily heifers in the Phases 3 and 4 area. Cattle grazing occurs on most areas of the property within the Project Area. Irrigated hayfields also are located within the Project Area and are irrigated with pivots and wheel lines. The source for sprinkler irrigation is pumped water from the CFR. There are numerous fences on the property within the Project Area that generally correspond with the boundaries of irrigated hayfields or grazing pastures.

The Lamperts plan to continue their current land use for the foreseeable future. They would like to continue grazing in the pasture areas after vegetation is reestablished. A corridor along the river will be protected from grazing to allow newly planted vegetation to establish. Fences will be installed either where they were previously located or to protect establishing vegetation. Water gaps or off-site water sources will be established to maintain grazing practices. Where impacted, hayfields will be re-built. The Lamperts are hoping to reestablish their unirrigated hay fields east of the river after the area is remediated. Pivot lines will be maintained in their current locations.

2.9.2 Deer Lodge River Ranch

A significant portion of the Deer Lodge River Ranch within the Project Area is under easement with Montana Fish Wildlife and Parks (FWP). The easement is managed for public recreation use, including fishing and hunting, and wildlife and is part of the FWP Region 2 Block Management Program. Outside of the fenced easement area, land is used primarily as cattle pasture. There is a cattle river access located on the east side of the channel. The Hadleys are open to alternative water options but want to maintain water access in this general location. The Hadleys would like

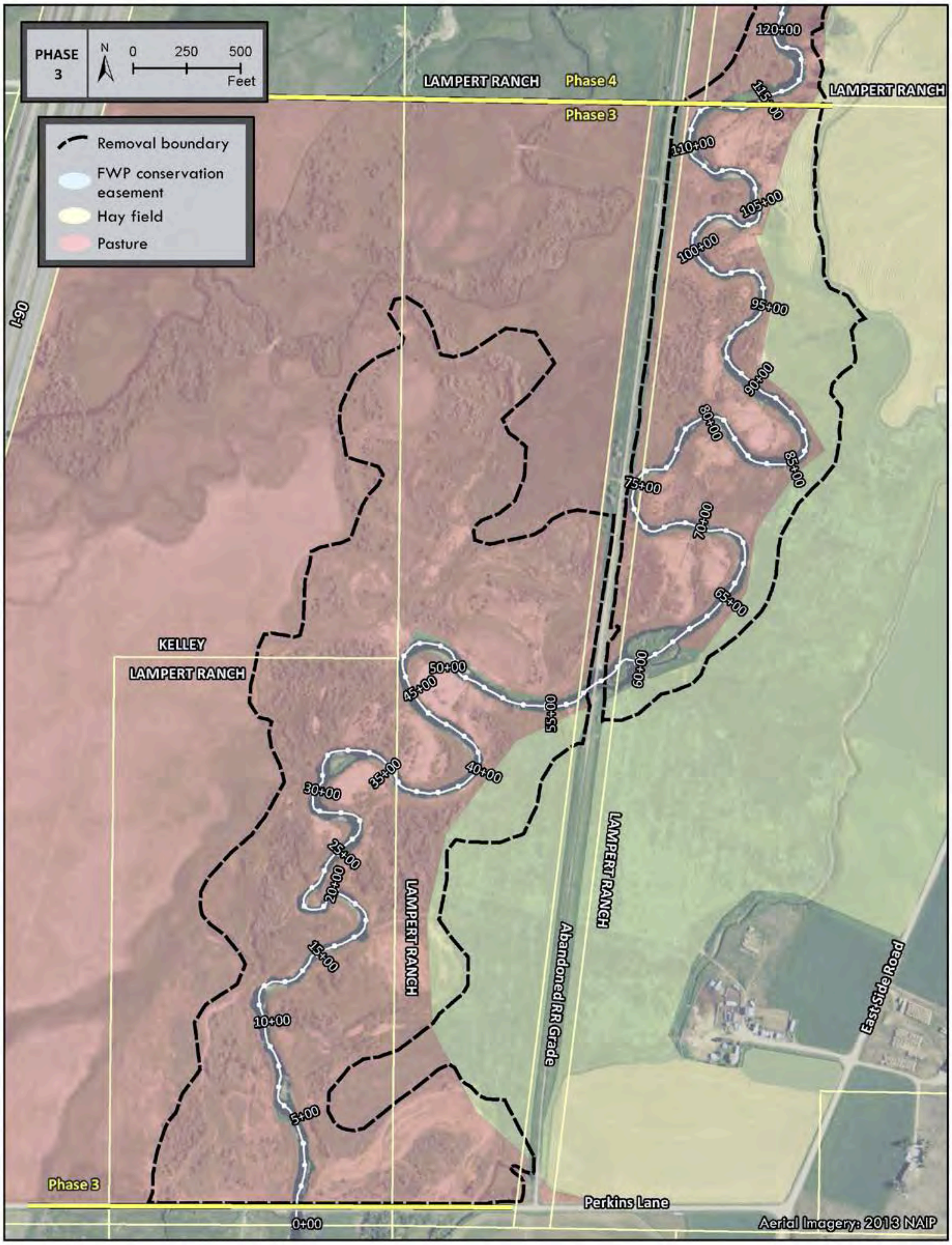


Figure 2-34 Land ownership and land use in Phase 3.

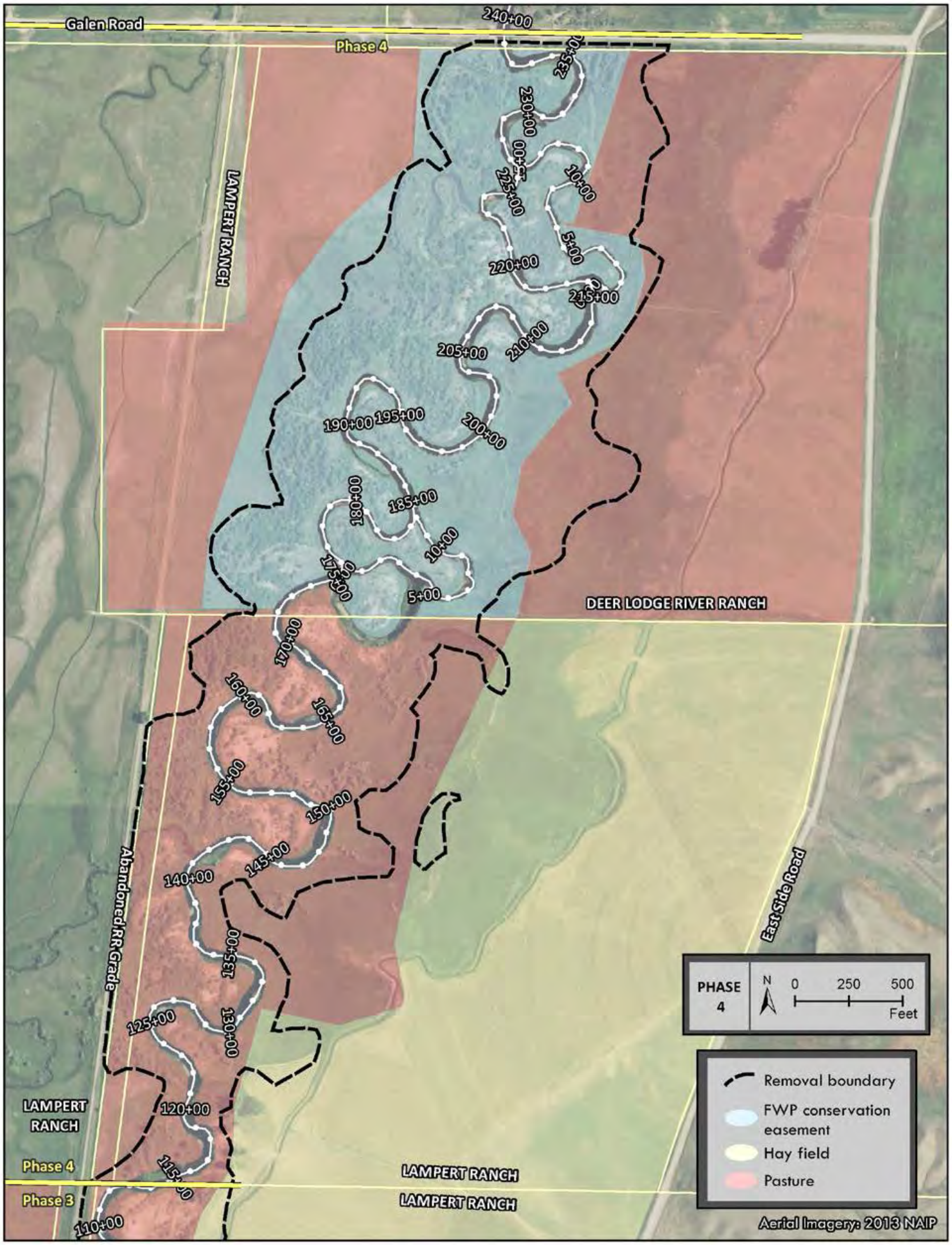


Figure 2-35 Land ownership and land use in Phase 4.

to see this area recover from remediation work as quickly as possible which can be achieved via more extensive planting and use of larger plant material.

2.9.3 Kelley Ranch

This property was previously owned by Rosamarie Silzly and is now owned by the Kelley Ranch. The property is currently used for grazing and it is expected that grazing will continue on the property, and all fences will need to be re-built in their current locations.

This page intentionally left blank.

Section 3

Design Criteria

This section presents the design criteria for CFR Reach A, Phases 3 and 4 Remedial Action Project on the Clark Fork Site. 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. The ROD defines areas of impacted soils and vegetation, and determined that slickens would be removed, but assumed that in most instances, areas of impacted soils and vegetation would be treated in place, using lime addition and other amendments as appropriate, soil mixing, and revegetation. 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. The ESD (DEQ and EPA, 2015) clarifies the design criteria as applied to determine the needed remedial component at specific locations.

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.

Strategies were developed to address the various impacts in the Project Area. Those strategies include stabilizing eroding, contaminated streambanks and the adjacent floodplain; removal of tailings/impacted 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/impacted soils within the CMZ 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 tailings/impacted soils contamination:
    - Remove the severely impacted areas from the floodplain
    - Dispose wastes 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 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, recontouring and revegetation strategies.

    - Preserve those streambanks that have stabilizing vegetation and are at a lower risk of accelerated erosion.

    - Stabilize actively eroding streambanks as necessary with bioengineered treatments designed to manage erosion and streambank migration during the period of floodplain vegetation establishment.

In Phases 3 and 4, studies have shown that most tailings/impacted soil deposits extend greater than 24-inches below ground surface (see Sheets C7 to C11 of the PDP plan set). Because it is not technically feasible to incorporate lime at depths greater than 24-inches, these areas will require excavation of the tailings/impacted soils and removal to the B2.12 cell at Opportunity Ponds.

According to the contaminant characterization data (CDM Smith, 2015a), approximately 95 percent of the total area of tailings/impacted soils within the Project Area may be 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 approach to remove tailings/impacted soils in the Project Area.

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

3.1.1 Contamination Benchmark

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/impacted soils 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. As a remedial design assumption, DEQ has set a numeric threshold for identification of the presence of tailings/impacted soils contaminated by mining activities and, when combined with other remedial design criteria, determines the severity of such impacts. This numeric threshold is 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. The following is a description of the numeric threshold assumption:

> Tailings/impacted soils are considered 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 mg/kg action level is not used as a risk-based screening level or cleanup level. Instead, the sum of the COC's > 1,400 mg/kg is used to 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 of the vegetation to hold the contamination in place. The use of 1,400 mg/kg as a remedial design assumption of contamination will not be viewed in isolation, but in conjunction with other design criteria. Documentation of the basis for this remedial design assumption is found in the *Basis for Remedial Design Assumption: Contamination Benchmark* (DEQ, 2014).

3.1.2 Removal Criteria

DEQ will analyze test pit data to determine the base of contamination. This analysis shall use the Remedial Design Assumption that tailings/impacted soil materials at a site-specific location are contaminated if the sum of the total soil metal concentrations (As+Cd+Cu+Pb+Zn) is greater than 1,400 mg/kg. The design team will analyze the severity of contamination, thickness of contamination, the Channel Migration Zone (CMZ), likelihood of contamination to be re-entrained via bank erosion or avulsion, and the capability the vegetation to hold the contamination in place. The final Remedial Design determinations (including the decision to remove, treat or leave tailings/impacted soil materials in place) will depend upon application of other Remedial Design Considerations described in the ESD such as groundwater, riparian vegetation, geomorphic stability, ownership, infrastructure, land use and site-specific remedy requirements. Consideration will be given to an over excavation depth in addition to the base of contamination depth. Contaminated tailings/impacted soils material will be removed under the following conditions:

1. Arsenic levels exceed the human health standard in the surface interval as discussed in Section 3.1.3.
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,
    - The contamination lies within the Channel Migration Zone (CMZ),
    - Arsenic exceeds the human health standard at the surface and the sum of COCs exceeds 1,400 mg/kg at an interval shallower than 24 inches, or

- In areas where floodplain connectivity is desired, the removal surface is lower than the floodplain connectivity elevation (Section 3.1.5).

3. Limited areas where contaminated material is shallower than 24 inches but that are contiguous to removal areas for construction efficiency.

4. Areas of uncommon native vegetation may be preserved.

3.1.3 Surficial Arsenic Levels Exceed Human Health Standards

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 (6 inches) unless total metals concentrations exceed 1,400 ppm in the deeper intervals. The rancher/farmer limit applies to the private land in the Project Area although the recreational limit also applies within the public recreation easement on the Hadley property. The lower rancher/farmer limit (620 ppm) therefore applies to all of Phases 3 and 4.

3.1.4 Contamination within Channel Migration Zone

The ROD requires establishment of a riparian buffer zone approximately 50 feet on both sides of the Clark Fork River for Streambank and Floodplain stabilization, intended to slow the rates by which meander and erosion or avulsion releases contaminants back into the Clark Fork River. The design refers to this buffer zone as the Channel Migration Zone (CMZ). Contamination in excess of the Contamination Benchmark that lies within the CMZ will likely be removed, making the CMZ a key criterion for contaminant removal. This section describes the development of the CMZ for the Project Area.

Fluvial entrainment of contaminants on the Clark Fork River has been documented by Swanson (2002) and CDM Smith and AGI (2013). Between 2006 and 2011, 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 the Project Area. The CMZ was developed by evaluating measured migration rates in each of the two phases 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 CMZ was further modified to exclude areas of the modern floodplain that are not contaminated. The CMZ empirically addresses direct tailings entrainment hazards.

To develop the CMZ, migration was measured on all banklines that displayed in excess of 20 feet of migration between 1955 and 2011. Vectors were collected at approximately 20-foot station frequencies on eroding banks to capture the range of migration distances expressed at a given site. The results are summarized in Table**Error! Reference source not found.** 3-2. In developing a buffer, the 90^{th} percentile migration rate was extrapolated to a 100-year erosion buffer. This statistic was selected to ensure that over the next century, the vast majority of migrating banklines would not exceed the erosion buffer boundary. It is important to note, however, that projected migration rates are based on historic conditions, and that these values may change with remedy due to the introduction of new alluvial backfill material and, in many locations, a lower floodplain elevation.

The erosion 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 buffers applied in Phases 3 and 4 are 131 and 107 feet, respectively (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. The two large islands formed by split flows in Phase 4 were fully included in the CMZ.

Table 3-2 Results of Migration Rate Analysis.

Station		Phase 3	Phase 4
Number of Measurements		59	100
1954-2011 Migration Distance (ft)	Mean	42	39
	90^{th} Percentile	131	107
	Maximum	98	84
1954-2011 Migration Rate (ft/yr)	Mean	0.7	0.7
	90^{th} Percentile	1.3	1.1
	Maximum	1.7	1.5
100-Yr Migration Distance (ft)	Mean	73	69
	90^{th} Percentile	131	107
	Maximum	171	147
Basis of Buffer Selection		**90^{th} Percentile 100- year Migration Distance**	
100-Year Migration Buff		131	107

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 meander 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. Although most high risk avulsion paths are accommodated by the erosion buffer, some additional areas were added beyond that boundary. This topic is addressed in detail in Section 3.2.2. Once the CMZ was developed, areas where test pits show 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 corridors are shown in Figure 3-1 and Figure 3-2.

3.1.5 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 water surface elevation (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 to the base of 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 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 for colonization of the re-built floodplain, so preservation is consistent with remedial objectives. However, in this Project Area one of these preservation areas is outside the removal boundary and is identified only to ensure other construction activities do not disturb it.

3.1.6 Excavation Boundary

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/impacted soils 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, creating conditions to stabilize the floodplain and meet vegetative performance standards, while minimizing the need for backfill. However, not all areas will be left low. Landowners' needs such as retaining areas for grazing and hay production were also considered in determining the backfill requirements. Floodplain design criteria are discussed further 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, i.e., the CMZ.

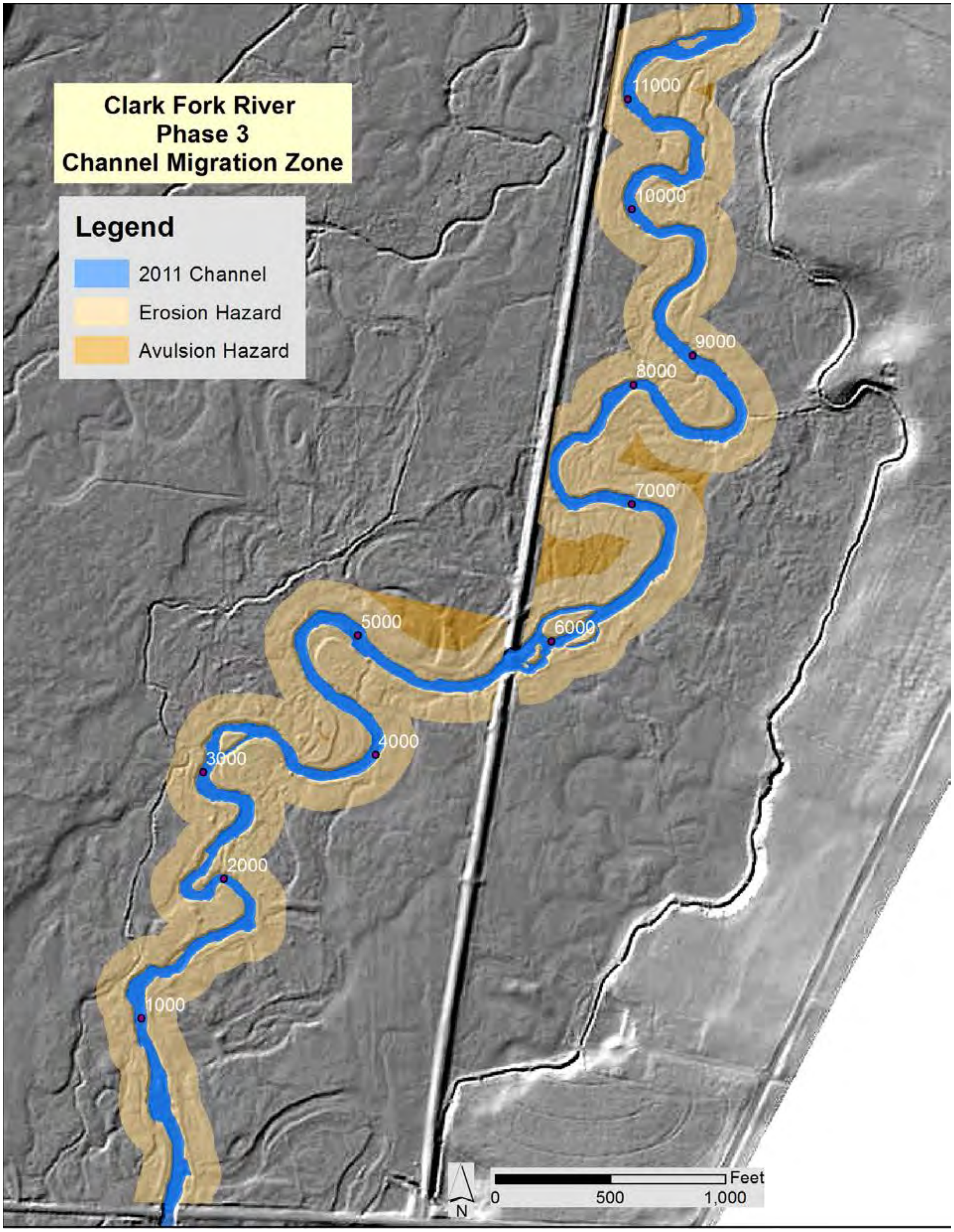


Figure 3-1 Channel Migration Zone boundary, Phase 3.

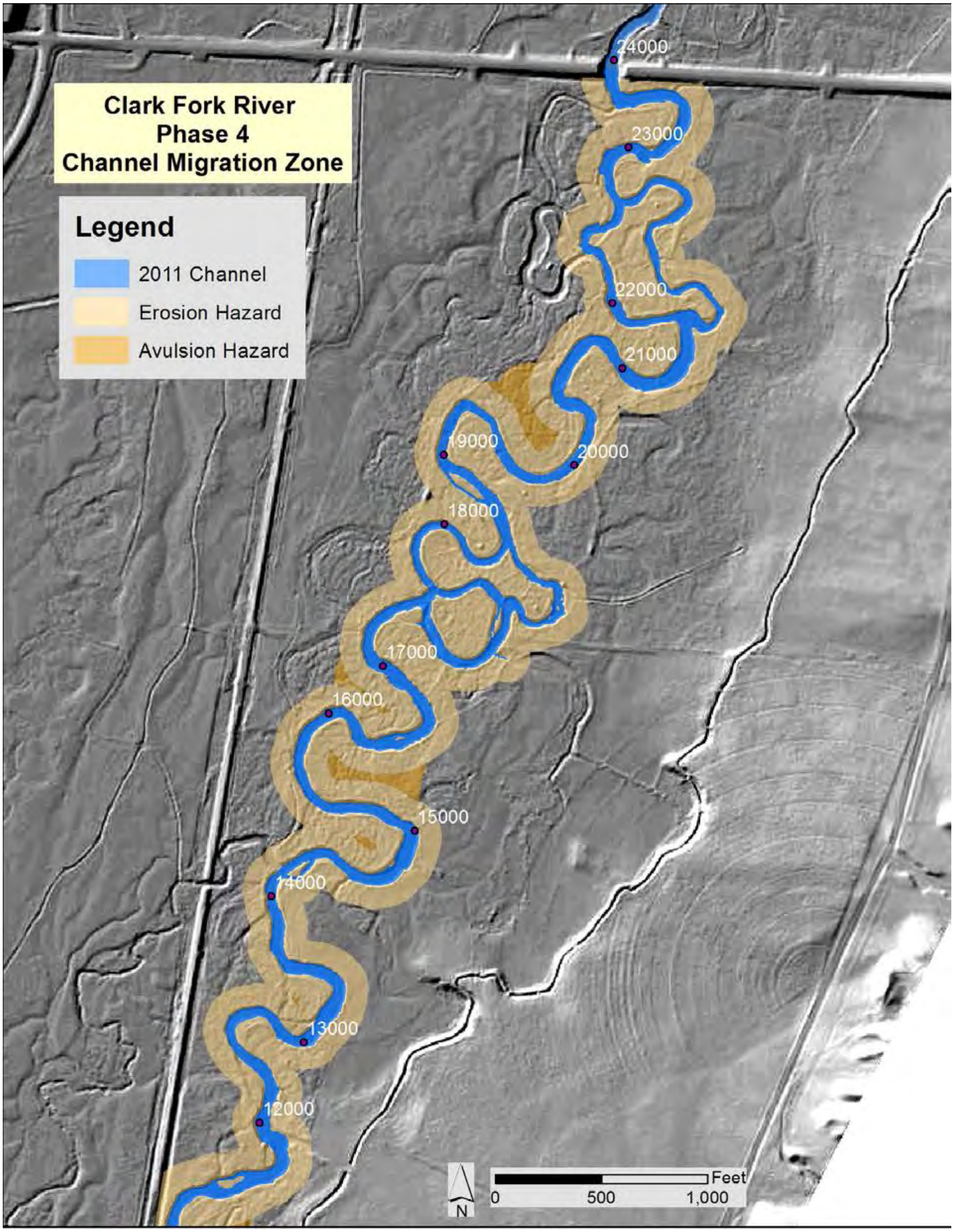


Figure 3-2 Channel Migration Zone boundary, Phase 4.

2. The excavation boundary will be expanded beyond the CMZ margin to include areas with over 24 inches of contamination or where connectivity to the river is desired.

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 Reconstruction

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

- Grassland Pasture –This land will be rebuilt either to the approximate existing elevation or slightly lower. This land will be left relatively flat with no surface roughness features. The surface will be planted with native grasses and forbs compatible with livestock grazing. It is possible these areas can be accessed within 3 years of construction completion if grasses become established by that time.

- Riparian pasture – The purpose of the riparian pasture is to allow use of some portions by livestock while still allowing woody vegetation to establish. The riparian pasture lies between riparian floodplain areas and existing higher ground, grassland pastures, or hayfields. It will generally be rebuilt to elevations slightly higher than the riparian floodplain and tie into adjacent riparian floodplain and existing ground surfaces. This land will be left relatively flat with no surface roughness or woody debris except in areas to be planted with woody vegetation. Portions of riparian pasture will be planted to create riparian shrub habitats similar to what currently exists in these areas. Planting areas may consist of small depressions, approximately 30 feet wide, 20 feet long and 2 feet deep or may be linear features of varying size. The linear features will function as corridors linking the riparian floodplain along the river with adjacent upland areas. Riparian shrub plantings will be planned in a manner that allows them to be fenced until established while still allowing cattle to use the remainder of the riparian pasture after grasses have established. Outside of riparian planting areas, the surface will be planted with native grasses and forbs compatible with grazing.

- Hayfield – Irrigated hayfields will be rebuilt in their present locations to the approximate existing elevation as required by irrigation equipment and planted for hay production. Subirrigated fields that are not irrigated with sprinklers will be rebuilt to an elevation that on the average floods every-other year or slightly higher.

- Riparian floodplain – Riparian floodplain will be rebuilt to an elevation that on average may become saturated or inundated every other year by overbank flood waters. The riparian floodplain will generally be built within 100 feet of the channel although it will be narrower in areas where it is constrained by hayfields or where no contaminant removals are needed. 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. Small depressions, approximately 30 feet long, 20 feet wide and 2 feet deep will be constructed in riparian floodplain areas to facilitate establishing woody vegetation. In addition, larger wetland features will be constructed to increase floodplain diversity and promote establishment of riparian vegetation. These features will be designed to mimic existing wetland conditions and will include a mix of open water, emergent wetland and riparian shrub habitats. The riparian floodplain will be fenced to exclude both cattle and wildlife such as deer and elk for a minimum of 5 years to allow vegetation time to establish.

- Conservation easement – This land will be treated the same as the riparian floodplain land use type; however, because the primary purpose of this land use is to provide public recreation opportunities and provide habitat for wildlife, additional actions may occur in this area that support this desired use. For example, more wetlands will be constructed in this land use type. More woody vegetation planting areas will be installed and mature shrubs will be transplanted into this area to increase cover of woody vegetation as quickly as possible. Additional habitat features to provide short-term cover for wildlife while vegetation establishes may also occur in this area.

As described in Section 2.1.2, the Clark Fork River floodplain is elevated above the stream to a degree that rarely allows overbank flows and greatly reduces suitable conditions for riparian vegetation. The objective of rebuilding a lower floodplain where land use permits is to provide connection of the river channel 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. 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

Removal of tailings from the Project Area floodplain provides an opportunity to reconnect the floodplain hydrologically to the river channel, which will benefit river function and native plan communities. 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 can be associated with a flow of a certain recurrence interval. When applied to stable alluvial streams, bankfull discharge usually has a recurrence of 1 to 2.5 years (Copeland *et al.,* 2000; Shields *et al.*, 2003). However, the range of recurrence floods can be wider than this as discussed by Williams (1978). The 2-year flow selected for the Clark Fork River falls within the conservative end of this typical range provides a 50% probability of overbank flows and floodplain inundation in any given year, and is therefore the logical bankfull flow criterion e to create 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. The selection of the 2-year flow over more frequent flows 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. 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 surface 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 to establish the appropriate final surface.
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 Minimizing Avulsion

When flows of significant depth occur on the floodplain, the force of the flowing water 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 elongated bend, establishes a straighter channel with a steeper grade, and reestablishes sediment transport capacity. This type of cutoff occurred in Phase 4 in 2010. 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 may cause rapid and severe erosion, which will adversely affect local channel grade stability, riparian recovery, and aquatic habitat.

Research has shown that a common cause of avulsion occurs when meander lengthening causes a reduction in channel slope (Sc) 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 threshold to categorize high avulsion risk. Since site remediation will include tailings removal and floodplain reconstruction with coarser alluvium, this can be considered a relatively conservative estimation of risk. That said, a conservative estimate is appropriate, especially during the first several years post-construction when the floodplain vegetation is not fully established.

A total of 10 meander bends have been identified in the Project Area as having an Sa/Sc ratio in excess of 5, and, therefore, have been categorized as having a high avulsion hazard. An additional 16 bends exhibit a moderate avulsion hazard defined by an Sa/Sc ratio of 3 to 5. These avulsion hazard locations are summarized in Table 3-3 and shown in Figures 3-3 and 3-4.

Table 3-3 Sa/Sc Ratios for Meander Bends and Associated Avulsion Risk Category.

Station	Phase	Maximum Sa/Sc	Risk
1900	3	3.7	Moderate
2100	3	7.6	High
3100	3	4.2	Moderate
4000	3	3.9	Moderate
4800	3	5.2	High
7500	3	4.7	Moderate
8600	3	5.8	High
10000	3	3.6	Moderate
10500	3	4.2	Moderate
12800	4	4.6	Moderate
13200	4	4.3	Moderate
14800	4	5.8	High
15800	4	4.4	Moderate
16500	4	4.0	Moderate
17500	4	5.6	High
18500	4	4.9	Moderate
19000	4	7.7	High
20000	4	3.3	Moderate
20700	4	3.7	Moderate
21500	4	11.1	High
22700	4	7.5	High
23300	4	4.9	Moderate
000 Hadley B	4	6.7	High
700 Hadley A	4	13.4	High
900 Hadley B	4	4.7	Moderate
1000 Hadley A	4	4.7	Moderate

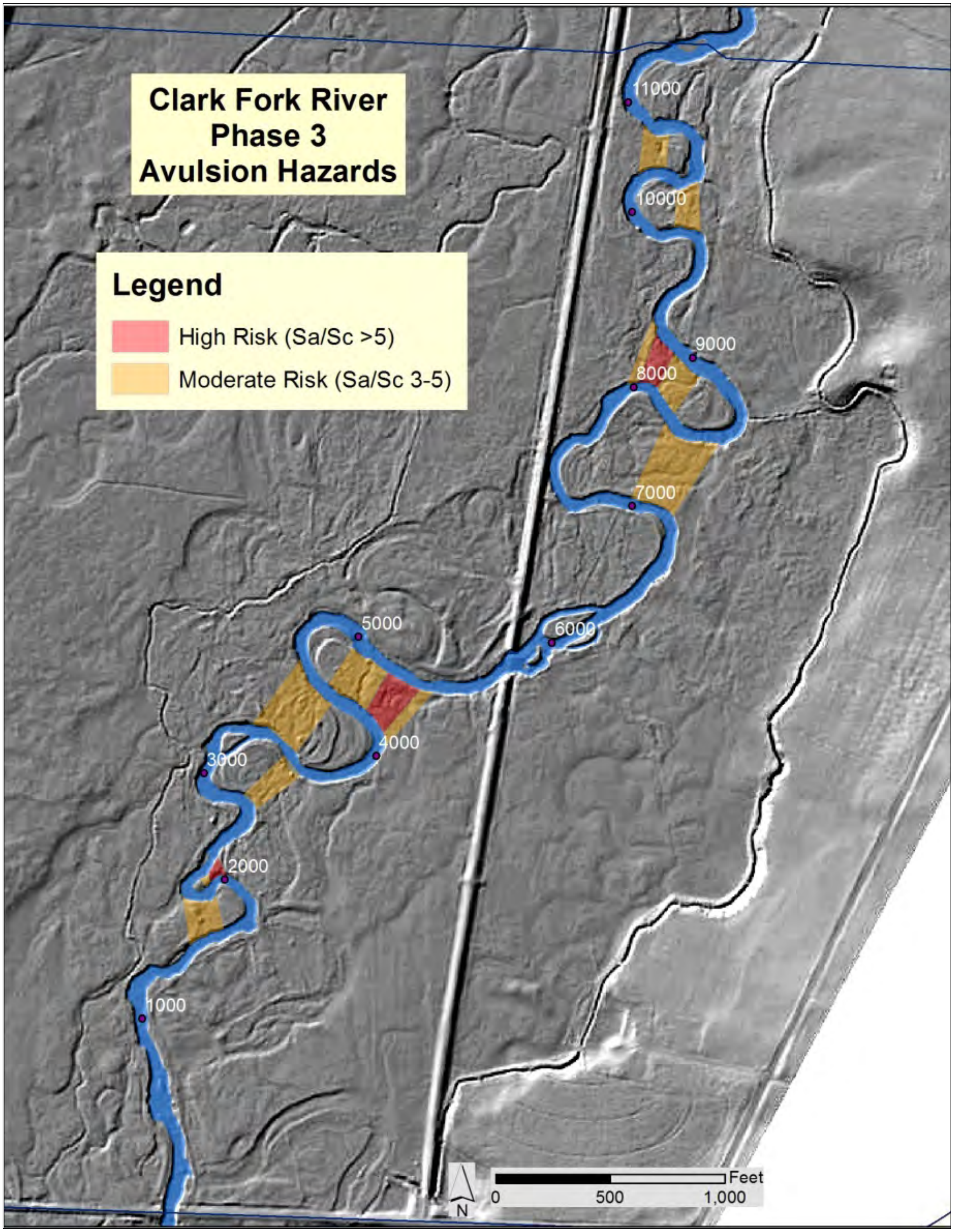


Figure 3-3 Mapped Areas at Risk of Avulsion, Phase 3.

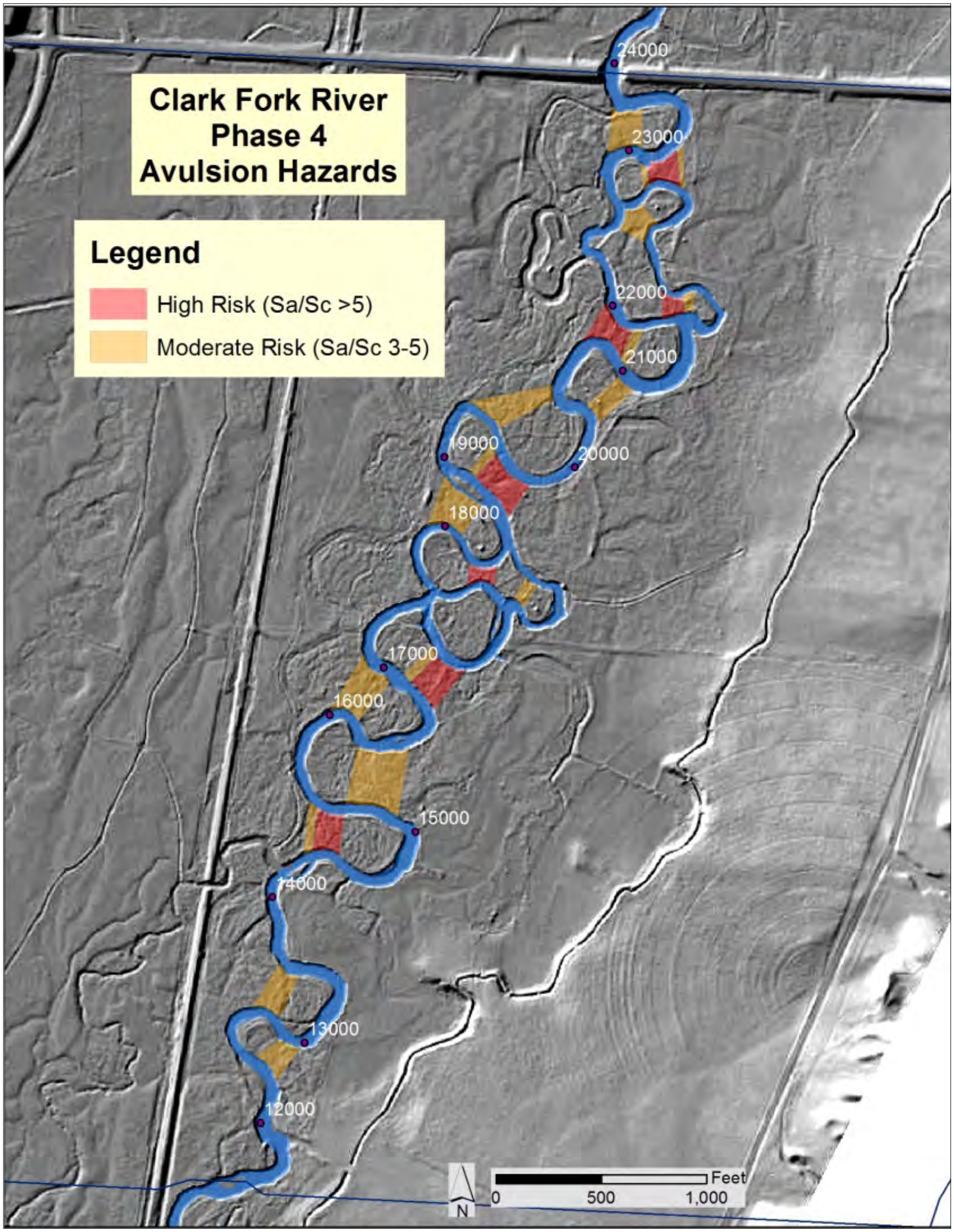


Figure 3-4 Mapped Areas at Risk of Avulsion, Phase 4.

Because avulsions are undesirable during the period that vegetation is established on the floodplain, several design criteria have been developed to minimize the formation of avulsions on bendways identified as having a moderate to high risk. These criteria include the following:

1. To reduce the potential for avulsion on bends identified as having a moderate to high avulsion hazard, a subtle topographic high will be constructed through most meander cores to reduce the risk of immediate avulsion. This high ground will take the form of a broad berm with minimal height (typically 0.5 feet or less). This criterion will be applied on a case-by-case basis to address both inundation frequency and slope through the avulsion path.

2. Meander cores and other potential avulsion paths will be treated with roughness elements (e.g., buried wood) and planted with shrubs within the predicted avulsion pathway. High risk avulsion paths will receive double the typical density of buried woody debris.

3. Outside bends may be elevated up to 0.5 feet above the 2-year WSE, and inside bends may be lowered up to 0.5 feet below the 2-year WSE to reduce the frequency and duration of overflow through the avulsion paths (see Figure 3-5).

4. Point bars will be constructed on the opposite side of the river from avulsion overflow points to reduce water surface elevations through the bend.

5. Appropriate bank treatments at avulsion path return flow locations will be utilized to minimize head-cutting potential.

6. 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).

7. Wetlands will 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 in a manner that minimizes potential for hydraulic connections that could form new channels during floods. Wetlands should also be placed away from other potential avulsion paths such as those across meander cores.

Although identified at-risk meander cores are being treated with a series of measures to reduce the likelihood of an avulsion in the short-term, there are some sites in the Project Area where this will be challenging without highly aggressive treatments that may adversely affect long-term riparian recovery and river function. As the bank design criteria require stability for up to the 10-year flow, this flow was evaluated to predict meander core erosion potential. Figure 3-6 shows the relationship between Phases 3 and 4 meander tab backslopes (down-valley slope along the avulsion path) and anticipated inundation depth at the 10-year flow. These two parameters allow the calculation of the estimated particle size that would mobilize under those conditions. The plot shows that for the majority of bends, the mobilized particle size is less than about 2.5 inches. In several sites where either the backslope is especially steep and/or the inundation depths especially deep (circled sites on Figure 3-6), the mobilized particle size is 3 inches or larger. This creates a challenge, in that minimizing the risk of avulsion at these sites will require the inclusion

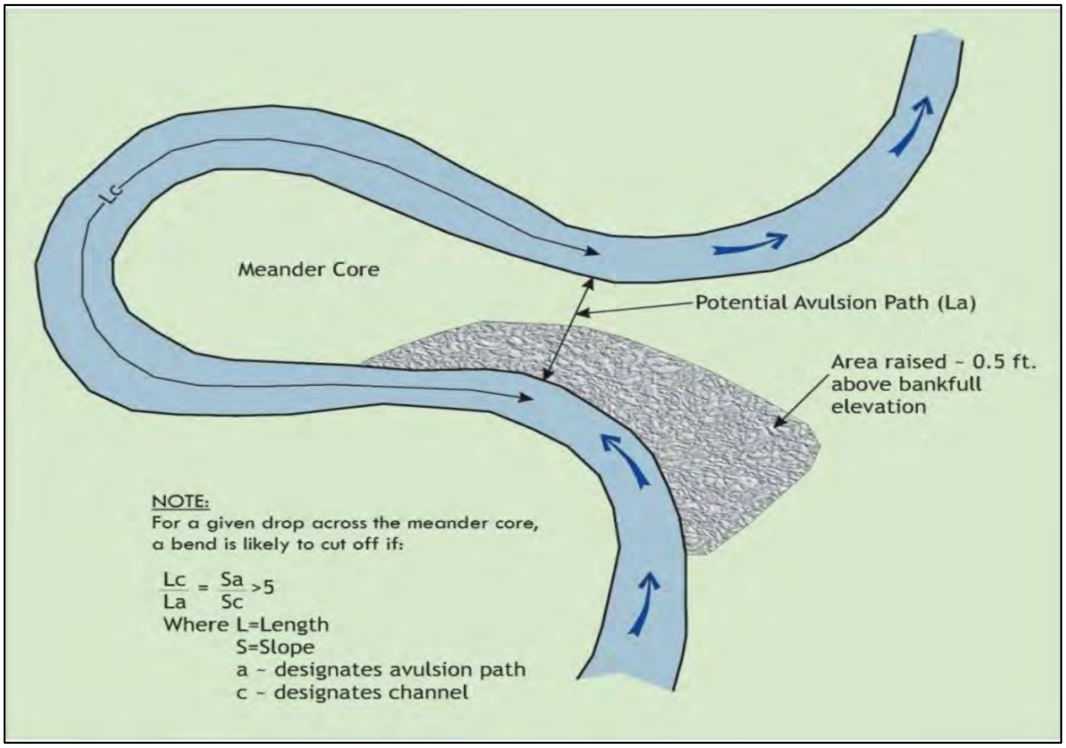


Figure 3-5 Schematic example of avulsion protection on meander bend.

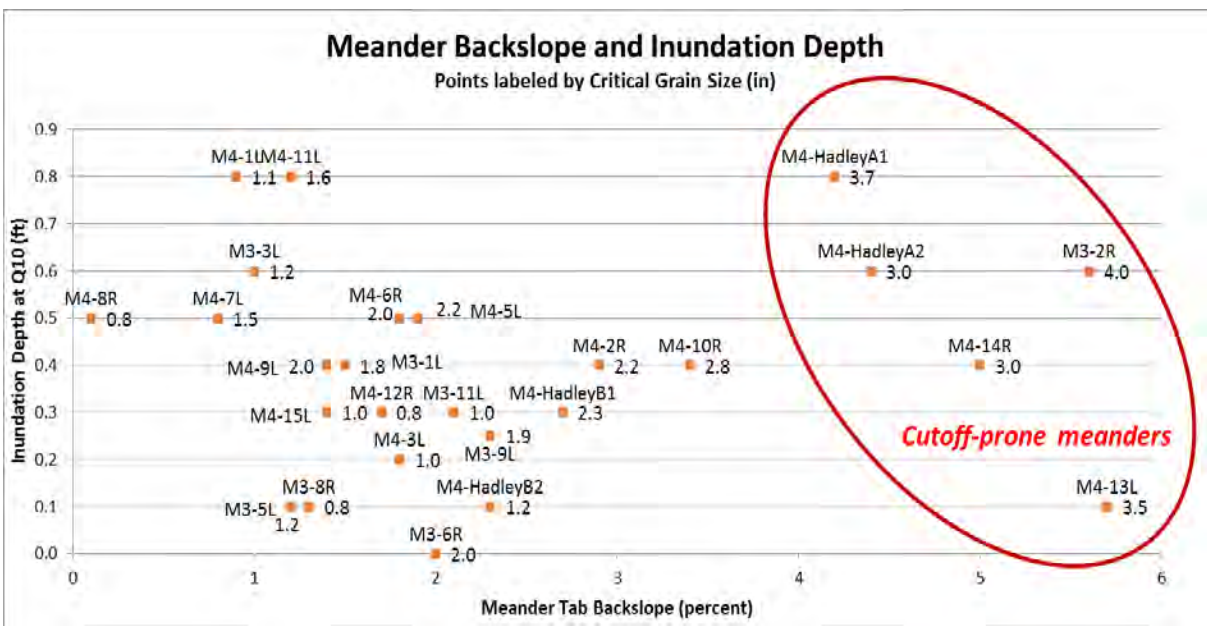


Figure 3-6 Relationship between meander tab backslope and inundation depth at Q10 for Phase 3 and 4 meander tabs; points are labeled with estimated particle size mobilized at that condition.

of very large alluvial backfill in the avulsion paths. This in turn may create problems with vegetation reestablishment on those paths, which is a critical component of managing long-term avulsion risk. To address these issues, each pathway was carefully evaluated in terms of inundation depth, slopes, and associated particle mobility, and adjustments were made to the grading plan to balance outcomes. The results show that the circled sites in Figure 3-6 will remain at a somewhat higher risk of avulsion than the remaining meanders due to the inherent planform-based risks that they pose now. This approach is consistent with design objectives that minimize the use overly aggressive floodplain treatments that will limit or largely preclude riparian recovery.

Phase 3 has another avulsion hazard that is quite different from the situations described above. The conditions that pose an avulsion risk in this location are shown in Figure 3-7 where the abandoned railroad grade bisects the Clark Fork River floodplain as it trends northward along the stream corridor. At station 58+00, the river flows under the railroad bridge (Figure 3-8) from the west to the east side of the embankment. River overflows must also pass through the bridge opening or will continue northward on the west side of the railroad grade (Figure 3-7). The bridge capacity is adequate to pass flows larger than the 100-year flow, but the backwater created by the narrowed bridge opening could cause flows to follow the path on the west side of the embankment. Any floodwaters that flow northward behind the railroad grade are trapped by the approximately 4,000 foot long embankment before returning to the river through Lost Creek or potentially continuing further north. This poses an avulsion risk to the Clark Fork River especially if conveyance through the bridge is somehow compromised. To minimize this risk, the grading plan will prevent overflows to extend northward behind the railroad grade at anything below a 10-year flow. Historic aerial imagery indicates that overflows have taken this path historically, and there is also evidence that sometime around 1950 the river was realigned to improve its orientation to the bridge (Section 2.1.1).

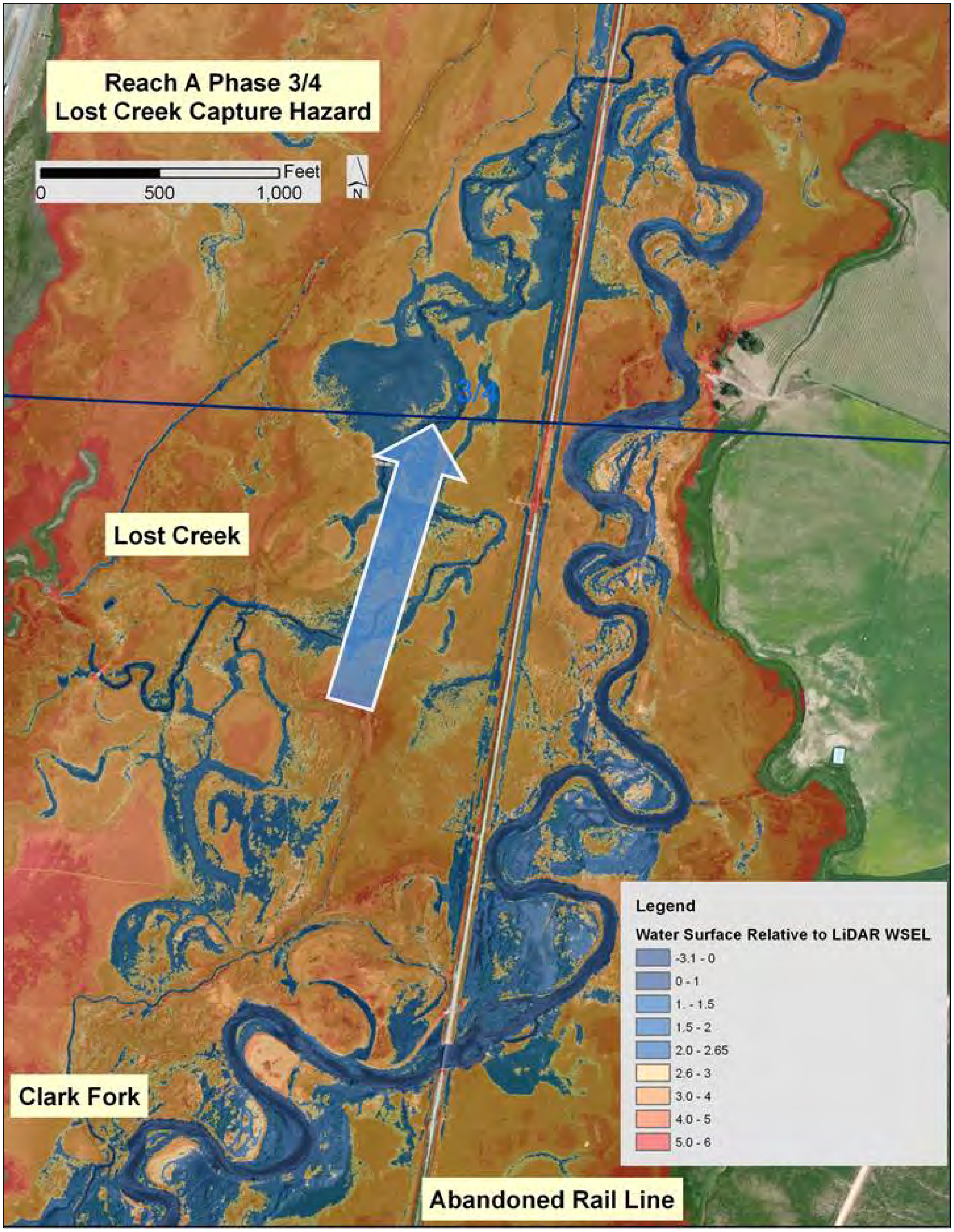


Figure 3-7 Inundation mapping showing avulsion hazard at Lost Creek, Phase 3.

Figure 3-8 View upstream of abandoned railroad bridge, Station 58+00.

3.2.3 Floodplain Grading

The objective of floodplain grading is to establish a surface that supports the expected land use. Five land uses are anticipated in Phases 3 and 4, grassland pasture, riparian pasture, hayfields, riparian floodplain, and conservation easement. This section discusses the criteria for preparation of the final surface for planting. Revegetation criteria are presented in Section 3.5.

Grassland Pasture

The objective of grassland 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.

3. This land will be left relatively flat with no surface roughness features to facilitate rapid grass establishment.

Riparian Pasture

The objective of riparian pasture floodplain grading is to develop a relatively smooth surface that is easily planted with suitable forage for grazing while still providing riparian shrub cover for wildlife and livestock and promote revegetation of the floodplain. The following design criteria apply to grading for riparian pastures:

1. This land will be rebuilt to elevations slightly higher than the riparian floodplain and that tie into adjacent riparian floodplain and existing ground surfaces. The final 0.5 feet of cover shall be vegetative backfill.

2. Materials used to build subgrade shall be non-impacted material or alluvial backfill. In portions of the removal area 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. In general, riparian pasture areas will be left relatively flat to facilitate rapid grass establishment. However, portions of riparian pastures will be planted with woody vegetation. Planting features will include linear bands of cottonwoods, willows or other shrubs to provide a passage corridor for wildlife between the riparian corridor along the river and adjacent uplands and to provide livestock shelter. These corridor 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. Planting features will also include 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). Within planting areas, (small swales, ridges) will be included with variation of up to one vertical foot from the grading plan. Woody debris will also be buried into the surface or scattered over the surface within areas to be planted with woody vegetation.

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

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 (0.3% to 2% slope).

3. Backfill of the uppermost 1.5 feet will be vegetative backfill. Subgrade will be constructed of alluvium or non-impacted material.

Riparian Floodplain and Conservation Easement
Riparian floodplain is designed is defined as a surface generally close to or in contact with groundwater that supports diverse riparian vegetation. The objective of riparian floodplain design is to develop a complex surface that supports a diverse mixture of riparian native vegetation communities. This surface will also support 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 no higher than one-foot above the 2-year WSE. Some areas, such as meander cores and transition areas are slightly higher.

2. Point bar features will be incorporated into the riparian floodplain areas. Point bars occur at the inside of channel 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 naturally 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 at an elevation 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 such as benches along the channel.

4. Backfill of the uppermost 0.5 feet of riparian areas, excepting point bars, will have sufficient amendment to support vegetation. Subgrade will be constructed of non-impacted or alluvial material.

5. Low features such as wetlands 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. 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 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.

7. Wetlands can imitate oxbow bends on an abandoned channel. These wetlands can be connected to the river and its secondary channels by alcoves that allow backwater from the river to inundate them.

8. 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 as described in Section 4.2.3.

9. 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. In

addition, a higher density of woody debris will be placed in high risk avulsion paths as described in Section 4.2.3.

The above criteria for Riparian Floodplain grading also apply to Conservation Easement land. The primary purpose of conservation easement land is to provide public recreation opportunities and provide habitat for wildlife and additional actions may occur in this area that support this desired use. For example, more wetlands will be constructed in this land use type and constructed according to the above criteria. More woody vegetation planting areas will be installed and mature shrubs will be transplanted into this area to increase cover of woody vegetation as quickly as possible. Additional habitat features to provide short-term cover for wildlife while vegetation establishes may also occur in this area. Grading and other criteria for additional habitat features will be developed as needed through the design process.

3.3 Streambank Reconstruction

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 the Project Area 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 flows during flood events. Reconstructed banks will have a top bank elevation equivalent to the elevation of the 2-year WSE plus up to 0.5 feet as described in Section 3.2.2. The design criteria described in this Section guide the identification of banks that need reconstruction and determine how the banks are to be rebuilt.

If contaminated sediments are not present in the adjacent floodplain, no streambank treatment is required. For those banks that require treatment due to the presence of contamination, banks were classified in three 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 3-9 is a flow chart describing how design criteria are applied to determine the type of bank treatment needed at specific locations.

3.3.1 Streambank Treatment

Design criteria for bank treatments reflect the need to completely reconstruct some banks that are contaminated and/or destabilized as well as preserve banks that are well vegetated with woody vegetation and supporting 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 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.

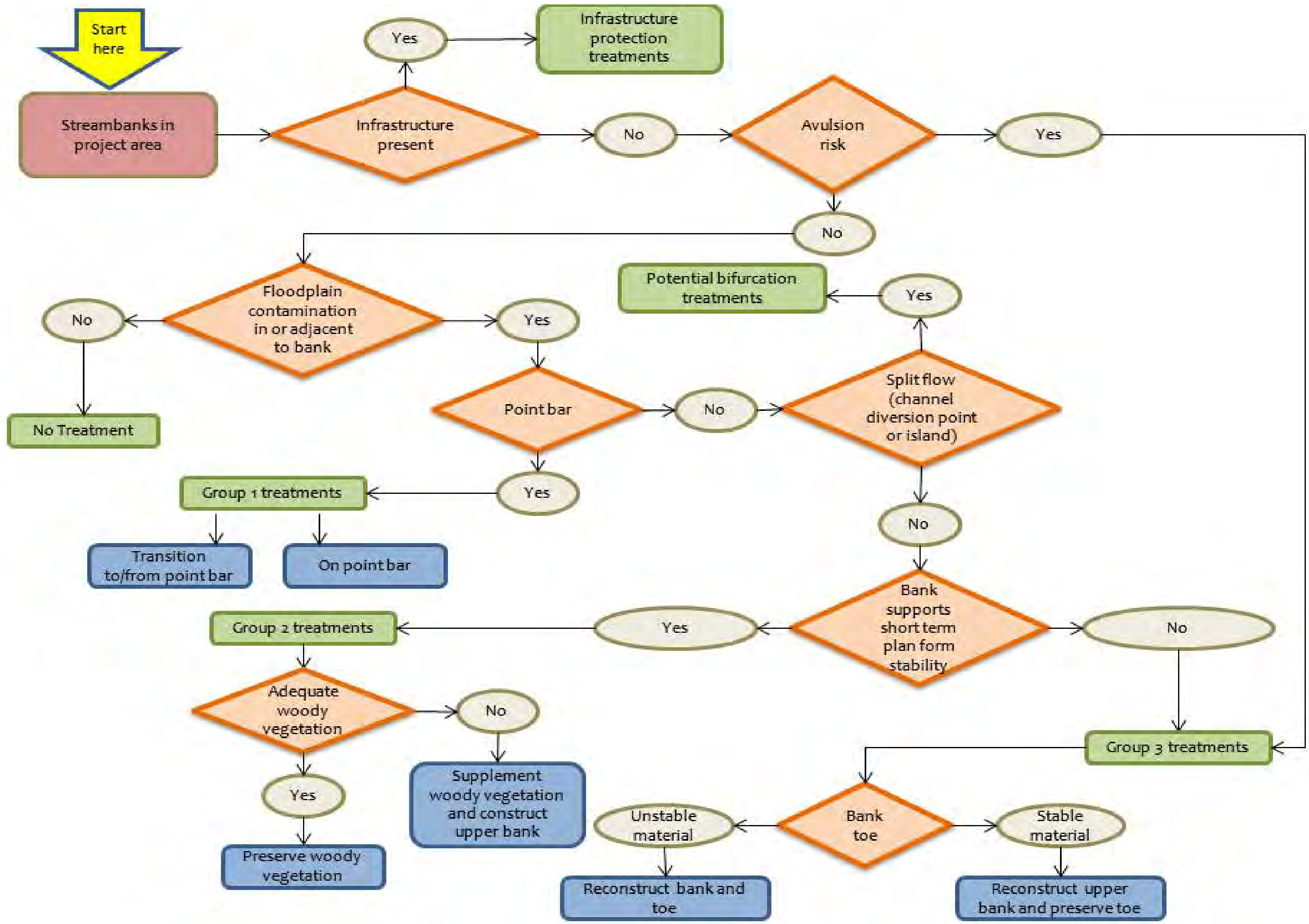


Figure 3-9 Application of design criteria in the decision process for streambank reconstruction.

2. If infrastructure is present, banks that are adjacent to or approaching infrastructure (particularly bridges) will be treated to provide stability as needed. This may require a higher level of protection armoring to withstand the predicted boundary shear stress. Typical infrastructure needing protection includes irrigation diversions, roads, bridges, or utility crossings.

3. Group 3 bank treatments will be reconstructed to be minimally deformable under most flows. Group 3 bank treatments should therefore only be constructed on stable toe materials, which are defined as being 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 foundation is constructed as part of the bank treatment.

4. 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.

5. 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.

6. Group 2 bank treatments have stabilizing woody or dense herbaceous vegetation 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. Banks located at split flow locations, such as an island or entrance to a secondary channel, may receive a bifurcation treatment.

7. 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).

3.3.2 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 Group 3 banks will be designed to withstand the shear stresses and forces associated with the 10-year flow at the time of installation.

2. Reconstructed banks for protection of infrastructure will be designed to withstand the shear stresses and forces associated 100-year flow.

3. Streambank designs should use native vegetation and organic materials to the extent practicable.

4. Where native, desirable woody bank vegetation exists below the design floodplain elevation (Group 2 treatments), excavation of the bank will only extend to the designed top of bank elevation.

3.3.3 Streambank Toe Construction

The bank toe investigation described in Section 2.4 indicates that only 18 to 40% of the Group 3 locations excavated had suitable bank toe material close to the desired elevation. The remaining locations will 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 D50 of the toe gravel should not be mobile under the 10-year recurrence flow at that location.

3.4 Backfill Materials

Backfill materials will be needed to reconstruct the floodplain in the Project Area. 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.

3.4.1 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 4.5.1.

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	Certified weed-free

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

There is no requirement that imported material have organic matter since the soil will be amended. Organic matter will be added to target a total composition of 1.5% to 2%. The amount of organic matter required to amend the imported soil with will be determined after a compost source has been identified for the project.

3.4.2 Alluvial Gravel

Alluvial gravel is needed for construction of bank toes, point bars, 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 (Table 3-4).
2. Gravel and cobble fractions will be rounded and not crushed or angular.
3. The D50 of the bank toe material will not be mobilized at flows less than a 10-year flow 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 D50 of about 0.25 inches with gravel sizes no larger than three inches. It shall have a soil fraction less than 10 percent.

3.4.3 Type A Material

Type A Material is a 1:1 mixture of floodplain alluvium and vegetative backfill to be used where increased resistance to erosion is desirable yet the ability to establish vegetation is paramount. One application is the backfill for soil lifts in DVSL Bank construction. Another is avulsion paths where the relatively steep slope across the bend requires additional short-term erosion protection while vegetation becomes established.

3.5 Floodplain Vegetation

As described in Section 3.2, five types of land use have been identified for the Project Area: grassland pasture, hay field, riparian pasture, riparian floodplain, and conservation easement. Within grassland pasture and hay field areas, vegetation design criteria focus on establishing conditions necessary to support grazing and hay production operations. Within the riparian pasture areas, vegetation design criteria focus on establishing grasses suitable for grazing with areas of concentrated woody vegetation to provide riparian habitat. 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 river channel. 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 the Project Area, floodplain cover types include:

- Land use cover types:
  - Grassland pasture
  - Riparian Pasture
  - Hayfield
  - Conservation Easement
- Riparian floodplain cover types:
  - Exposed Depositional (non-vegetated),
  - Colonizing Depositional (vegetated),
  - Emergent Wetland
  - Riparian Wetland

- Floodplain Riparian Shrub
- Outer Bank Riparian Shrub

Design criteria for each land use and riparian 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 dynamics including extent, frequency and duration of inundation within the cover type
- Estimated depth to groundwater
- Elevation relative to the 2-year flow WSE
- Soil texture: Range of soil textures that can support development of desired plant communities within the cover type
- Soil depth: depth of soil (vegetative backfill) before alluvium is reached
- Floodplain roughness

Table 3-5 provides ranges for each of these design criteria by 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 3.4). The following discussion explains some of the rationale for riparian floodplain vegetation design criteria within the Project area. Land use cover type design criteria aim to create conditions necessary to support the desired future land use.

Creating hydrologic connectivity between the channel and floodplain is necessary for floodplain cover types and related plant communities to develop so they can support a wide range of floodplain functions and processes. Reconstructing the floodplain at the range of elevations specified in the design will result in the targeted degree of hydrologic connectivity between the floodplain and channel. As a result, flows exceeding the 2-year flow will deposit nutrients, sediment, and seeds on the floodplain, thereby creating and sustaining riparian vegetation. The designed floodplain topography also allows for surface connection to ground water 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.

Table 3-5 Design Criteria for Floodplain Cover Types.

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)	Floodplain Roughness
Land Use Cover Types							
Grassland Pasture	Higher terraces	>2 years-	2+	1+	Silt loam to sandy loam (vegetative backfill)	6	No
Riparian Pasture	Bankfull Floodplain to higher terraces	>2 years	2-4	0+	Silt loam to sandy loam (vegetative backfill)	6	In areas planted with woody vegetation
Hay field	Higher terraces	>2 years	2+	2+	Silt loam to sandy loam (vegetative backfill)	18	No
Conservation Easement	Equivalent to Riparian Floodplain Cover Types	Equivalent to Riparian Floodplain Cover Types	Equivalent to Riparian Floodplain Cover Types	Equivalent to Riparian Floodplain Cover Types	Equivalent to Riparian Floodplain Cover Types	Equivalent to Riparian Floodplain Cover Types	Yes, in priority areas
Riparian Floodplain Cover Types							
Exposed Depositional (Non-vegetated)	Non-vegetated portion of point bars	< 1 year	0 to 1	-2.5 to -1.0	Sand, fine to coarse gravel or cobble (alluvium)	0	No
Colonizing Depositional (Vegetated)	Vegetated portion of point bars	1 to 2 years	0 to 2	-1.0 to 0	Sand, fine to coarse gravel or cobble (alluvium)	0	No
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	Yes
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)	12	Yes
Floodplain Riparian Shrub	Bankfull floodplain; low terrace	2 to 10+ years	2 to 4	-0.5 to 2.5	Silt loam to sandy loam (vegetative backfill) overlying alluvium	6	Yes, in priority areas
Outer Bank Riparian Shrub	Streambanks along outer meanders	2 to 10 years	2 to 4	0 to 2.0	Silt loam to sandy loam (vegetative backfill)	6	Yes

As with other natural floodplain processes, riparian soil development and related nutrient exchange also depends on the floodplain and channel being hydraulically 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 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 and coated soil particles (as described above). Deeper vegetative growth media will be placed in wetland depressions because floodplain depressions with no outlets trap more sediment, resulting in the formation of 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.

3.5.1 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. Riparian floodplain areas of the designed 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 hay field elevations also require specific elevations to minimize damage from flooding and support land management goals.

3.6 Restoration in Lieu of Remedy

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

3.7 Restoration Components

DEQ has coordinated with NRDP regarding implementation and integration of restoration components into the Work. The design reflects the addition of 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 and Bid Package as restoration components.

This page intentionally left blank.

Section 4

Proposed Design

This section presents the design basis for the CFR Phases 3 and 4, Remedial Action Project. Major elements of the design are developed and presented based on the identified design criteria and project objectives. Design assumptions are explained and references are made to supporting documents. The primary elements of the design include:

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

Supporting design elements such as dewatering and transportation are also described. Finally, construction sequencing and construction Best Management Practices (BMPs) are presented for the Phases 3 and 4 Remedial Action.

4.1 Contaminant Removal Design

Contaminant removal is planned for the Project Area because in-situ treatment is not feasible given the depth and saturation of tailings. Tailings/impacted soils depths range up to at least four feet with an average depth within the removal boundary of 2.59 feet. Drawings C17 to C21, Excavation Plan, in the preliminary Drawings identify the expected excavation depths. Because it is difficult to amend soil at depths greater than two feet and because a high percentage of the tailings/impacted soils area is saturated during high groundwater water periods, removal is a key component of remedial design for the Project. Limited areas within this boundary have tailings depths less than 24 inches, but these areas have been included within the excavation boundary for ease of construction and cost-effectiveness.

4.1.1 Tailings Removal Depth

The tailings/impacted soils depth, which is defined here to include tailings mixed with soil as well as soil impacted by contaminant migration, is determined based on laboratory data for arsenic and metals concentrations. Tailings/impacted soils are contaminated when the sum of the Contaminants of Concern (COCs) (As, Cd, Cu, Pb, Zn) concentrations exceeds 1,400 mg/kg (parts per million). The 1,400 mg/kg concentration is not used as a risk-based screening level or cleanup level. Instead, the sum of the COC's > 1,400 mg/kg is used as a Remedial Design Assumption in the design process to help identify areas of contamination in site-specific locations. The design criteria for removal are presented in Section 3.1.

The concentrations used in this determination are taken from test pit sample intervals of 0.5 vertical feet so the accuracy of the depth of tailings is about 0.5 feet (Tetra Tech, 2010). To allow for this uncertainty and variability in the tailings surface, an additional 0.5 feet of depth will be excavated in areas without a clear demarcation between overlying contaminated materials and deeper, uncontaminated materials. Table 4-1 summarizes the estimated extent of excavation based on these data. The total excavated volume is estimated to be 1,111,000 cubic yards.

Table 4-1 Summary of Project Area Excavation Extents.

Excavation Area	266 Acres
Total Excavation	1,111,000 Cubic yards
Average Removal Depth	2.59 feet

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 CMZ, and opportunities to increase streambank and floodplain stability though reconnection with surface flows and groundwater. Tailings/impacted soils will be removed according to the design criteria presented in Section 3.1.

Removing tailings and rebuilding the floodplain at a lower elevation will increase areas of hydraulically 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 increase the stability of 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 grassland pasture, riparian pasture, hayfields, conservation easement, 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 water surface elevation (WSE). To meet this objective and the design criteria that derive from it, a number of features have been incorporated in the floodplain design. This section discusses the floodplain backfill concept, avulsion risk reduction measures, 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 an elevation appropriate for the planned land use. As discussed in Section 4.1, tailings will be removed to a depth based on the sum COCs plus a six-inch over excavation depth in selected areas. Floodplain design will also affect the excavation depth at some locations where 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.

Grassland pasture and hay fields will generally be established at higher elevations than the riparian floodplain to avoid frequent flooding of these areas. Riparian pasture provides a transition between the riparian floodplain and grassland pasture in many areas. Transitional slopes will be needed between the riparian areas and these higher terrace-like areas. These transitional 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 river banks may need additional erosion protection such as coir fabric 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 Avulsion Risk Reduction

As discussed in Section 3.2.2, meander bends with avulsion paths that are significantly steeper than the channel path are susceptible to channel relocation through the flow path. Within most of these potential cutoff paths, a broad, low elevation berm has been 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 portion of the meander bend normally found upstream of the meander core (Figure 3-5). This results in a broad section of elevated ground across the potential avulsion path. The outside bank elevation has been raised up to 0.5 feet on the upstream end of avulsion paths to reduce the frequency and duration of overflows in those areas. To reduce the stress on the outer bank in these situations, the inner bank is designed as a broad point bar, which permits the flow to spread out on the floodplain on the inside of the bend. In some cases, the elevated berm resulted in very steep (>5%) avulsion paths; in these cases the grading was developed on a case-by-case basis to balance the slope configuration through the avulsion path with the overtopping frequency and depth.

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 woody debris 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 shrub clumps and branches in the floodplain backfill. Drawing D9 in the plan set 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 sub-grade backfill and compacted in areas of potential avulsion. Finally, on moderate and high risk avulsion paths a 1:1 mix of vegetative backfill and floodplain alluvium Type A Material, see Section 3.4.3) will be placed to maintain a coarse material at the surface (upper 6 inches), which will allow vegetation to reestablish rapidly.

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 erosion, the streambanks 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.

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. 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 floodplain features. A general design goal for all riparian floodplain features is to provide increased complexity in the floodplain that provides increased roughness and minimizes floodplain erosion potential as well as increases habitat variability.

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). Additional groundwater data are being collected to further evaluate the seasonal groundwater fluctuations and help refine wetland grading.

Small depressional features called floodplain swales are included throughout the floodplain and in some areas of riparian pasture 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 and are intended to facilitate the establishment of floodplain revegetation and trap sediment, nutrients and organic matter. These floodplain swales will contain buried wood as well as plants and will increase floodplain roughness along with other microtopographic features. 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) in many areas of the floodplain whose purpose 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. Woody debris will consist of willow and birch salvaged during clearing and grubbing activities within the excavation boundary. The following are priority areas for placement of woody debris: all areas within the channel migration zone and all swale and wetland features, and all areas planted with woody vegetation.

4.2.4 Floodplain Hydraulic Model

A hydraulic model of the proposed design condition was developed using HEC-RAS Version 4.1 (USACE, 2008). The purpose of the design hydraulic model was to determine bank-full elevations, floodplain inundation at various flow levels, 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. The final grading surface was used to develop the overbank portions of the cross sections. Manning's n (roughness coefficients) values for the channel remained 0.036 as in the existing condition, while the Manning's n values 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 value of 0.11 assuming the fully developed land use includes mature shrubs.

The model was run using a steady state 2-year flow of 569 to 592 cfs and the 10-year flow of 1,169 to 1,221 cfs (Table 2-3). The higher values were used downstream of the Lost Creek confluence and account for the additional flow from Lost Creek. The model boundary condition was based on a normal depth calculation at the most downstream surveyed cross-section located about 600 feet downstream of Galen Bridge. The flow is predicted to remain subcritical throughout the modeled reach. Split flows were modeled for the 2-year flow at the two secondary channels, Hadley A and Hadley B. However, at the 10-year flow the islands between the secondary and main channels are inundated and the combined flow was modeled. Table 4-2 summarizes the flows in the secondary channels and the mainstem. Model section locations and inundation maps of the proposed condition are located in Appendix A as well as model outputs for the 2-year and 10-year flows.

Table 4-2 Design Flows for Phases 3 and 4 Stream Reaches, Design Conditions.

	2-Year Flow (cfs)	10-year Flow (cfs)
Main Stem at Perkins Lane	569	1,169
Main Stem at Lost Creek	592	1,221
Main Stem at Hadley A	349	NA
Secondary Channel at Hadley A	243	NA
Main Stem at Hadley B	394	NA
Secondary Channel at Hadley B	198	NA

NA- Not Applicable. The 10-year flow inundates the islands between channels and a split flow condition no longer applies.

Floodplain inundation mapping was performed for the 2-year and 10-year flows. 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 flow elevation to promote flow expansion onto the floodplain at this and higher water surface elevations (WSEs). The inundation map shows that under proposed Project Area conditions the 2-year flow is normally within and only occasionally outside the banks, generally meeting this criterion. The 10-year flow will inundate 57% of the reconstructed floodplain indicating that considerable floodplain connectivity has been achieved.

Table 4-3 Modeled Inundation areas for 2-Year and 10-Year Flow Events, Design Conditions.

	2-yr. Flow	10-yr. Flow
Reconstructed Floodplain Area (acres)	262.5	262.5
Inundated Area (acres)	10.0	150
Percent Floodplain Inundation	3.8%	57%

Note: Calculations exclude area of river channel.

4.3 Streambank Design

Streambank elevations in the Project Area will be lower 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 WSE. 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 meander bends require reconstruction, they will be constructed in a point bar configuration with appropriately sized alluvial gravels. This reduction of the inside bend elevations will reduce shear stress on the outer bank during high flow events.

Design criteria require protection of infrastructure, which can require hard bank protection to ensure no bank erosion at the design flow. However, no banks are required to be built to protect infrastructure in the Project Area. The only on-stream infrastructure on-stream at this site are three bridges, all of which are adequately protected at this time, and two irrigation pump intakes on Lampert property. The irrigation pump houses will be left in place and streambanks will be built to accommodate the intake structures.

4.3.1 Upper Bank Design

After streambank elevations are lowered to the floodplain elevation, the height of the bank from typical base flow (80 cfs) elevation to the floodplain will average 2.3 feet with a minimum height of 1.4 feet and a maximum height of 3.0 feet. Reconstructed banks are designed to resist shear stresses at the 10-year flow. Resistance to higher design flows is not desirable because it could result in formation of a minimally deformable channel that will not support natural geomorphic processes. The 10-year flow is estimated to be 1,169 cfs upstream and 1,221 cfs downstream of Lost Creek, respectively.

Shear stress is the 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) and 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. Shear stress is also amplified on meander bends. Proposed conditions modeling predicted that the average channel shear stress during the 10-year flow in the Project Area is 0.37 lb/ft^2 and the maximum value is 1.06 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 flow (Fischenich, 2001).

Several bank treatment approaches are proposed for the Project Area. The following bank treatments are applied, listed in order of increasing resistance to shear stress:

- **Group 1 Bank Treatments** are applied in areas of low shear stress and include regrading inside meander bends 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 bank to reinforce bank material and vegetation. When placed for continuous lengths, the brush mattress construction is referred to as a Brush Matrix.

- **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 primarily applied on the outsides of meander bends where higher shear stresses are expected.

All of these bank treatments that involve reconstruction make use of dormant woody vegetation cuttings, primarily willows, to provide the binding root mass needed to increase bank strength. Dormant woody vegetation cuttings typically root and increase bank strength within 3 to 4 years.

Group 1 Bank Treatments (Point Bar/Lateral Bar, Regrading/Brush Trench)
Passive margins, such as insides of meander bends (point bars/lateral bars) and other low velocity depositional areas will be left untreated or regraded into point bar/lateral bar configurations and 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 and Figures 4-1 and 4-2. 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.

Figure 4-1 Reconstructed Point Bar.

Figure 4-2 Brush Trench bank treatment on a Point Bar.

Meander 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 WSE to indicate the landward extent of these bars although the brush trench may not be continuous on the longer point bars. Meander 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.

- Meander 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 WSE to indicate the landward extent of these bars although the brush trench may not be continuous on the longer point bars.
- Meander 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, Brush Matrix 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 alluvium layered together as shown on Drawings D2 and D3. Where bank material alone is preserved, a brush trench is installed behind the bank as shown on Drawing D2. In areas with low shear stress but where no desirable vegetation or bank material is present, brush matrix treatments are installed. Brush Matrix banks are brush and alluvium mattresses with some brush overhanging the stream for habitat benefits. These banks are only appropriate in areas with moderate shear stresses such a straight runs. Floodplain alluvium is placed behind Group 2 bank treatments for a distance of 10 feet. Figure 4-3 shows a Preserve Vegetation bank treatment, and Figure 4-4 shows a Brush Matrix bank treatment.

Figure 4-3 Preserve Vegetation bank treatment.

Figure 4-4 Brush Matrix bank treatment.

Group 3 Bank Treatments (Double Vegetated Soil Lifts)

Group 3 bank treatments are double vegetated soil lifts (DVSLs) that contain two soil wrapped lifts with cuttings placed above and between the lifts as shown in details contained in Drawings D2 and D3. Soil lifts are filled with a mix of floodplain alluvium and vegetated backfill. These are considered the strongest bank treatment to be used on outer meander bends and other high shear stress locations. Floodplain alluvium is placed behind Group 3 bank treatments for a distance of 10 feet. Plantings will also be installed behind some Group 3 bank treatments, particularly where they are located on outer meander bends. There is also an option to add additional cuttings in a trench about ten feet behind these banks as shown in Drawing D2. The vegetation design for banks is described in more detail in Section 4.6. Figure 4-5 shows a DVSL bank treatment.

Figure 4-5 Double Vegetated Soil Lift bank treatment.

No Treatment Banks

In Phases 3 and 4 there are two short no treatment streambanks. One is located where the river's left bank is formed by the abandoned railroad grade embankment at Station 75+00 on Drawing C-44. It is not certain if the embankment is uncontaminated but the railroad embankment needs to be maintained in place and will not be disturbed. The other no treatment streambank is on the Hadley property where the oxbow connects to the right bank of the main channel at Station 175+00 on Drawing C-46, and the objective is to maintain the existing entrance of the oxbow to preserve the current overflow condition into the abandoned channel.

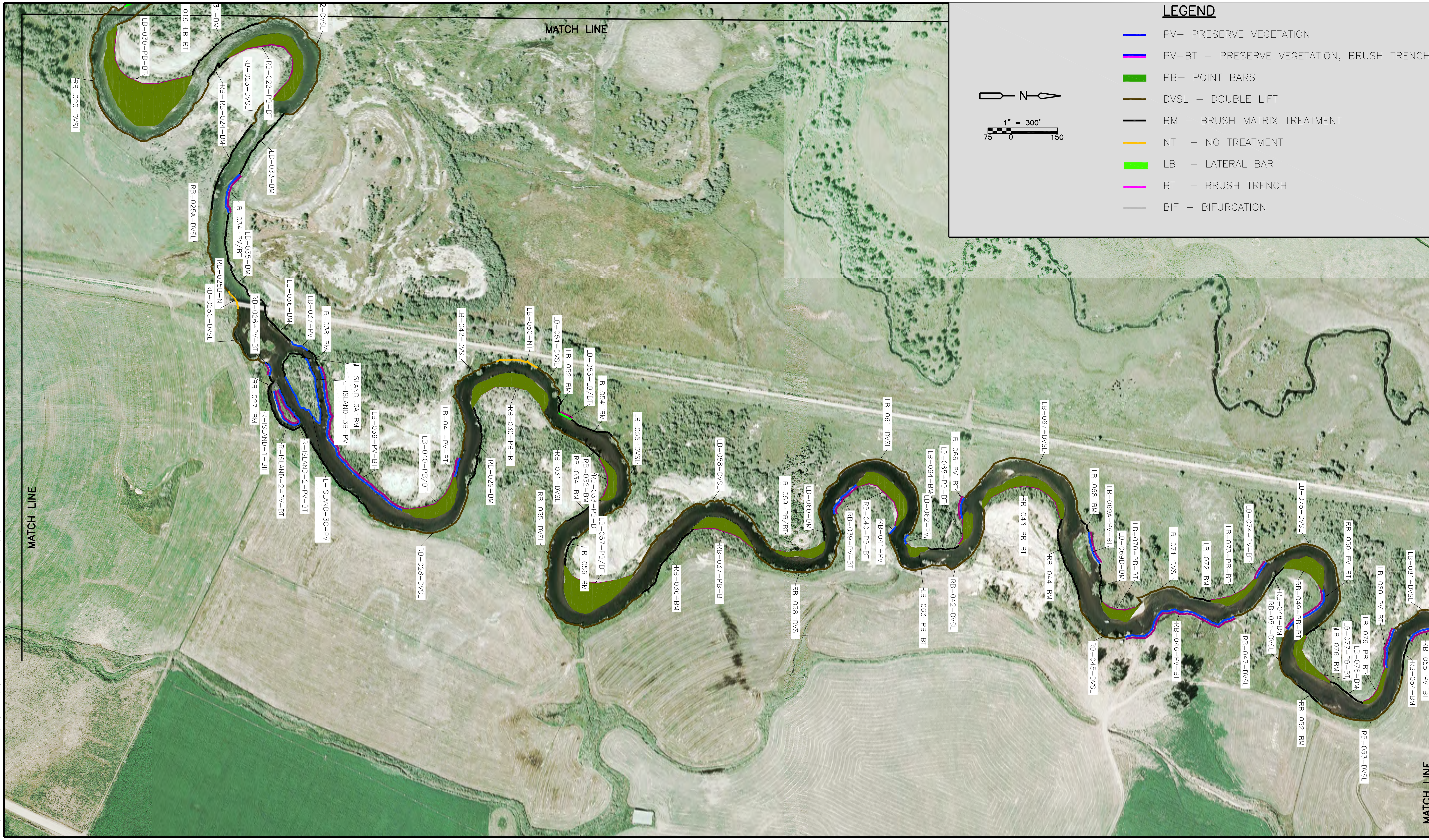
Bank Treatment Layout

Figures 4-6 through 4-8 show proposed streambank treatments as identified in the field by the design team. A memorandum to Katie Garcin at DEQ dated May 15, 2015, (CDM Smith, 2015c) transmitted these figures to DEQ as well as the data tables that support the selection of the treatments. Table 4-4 summarizes the expected lengths of the various bank treatments.

K:\CFR- PHASES 3 AND 4\Dwg PDP\Figures Streambanks27_29.dwg SAVED: 2/2/16 BY: MAINZHAUSENK

CDM Smith

Figure 4-6
PROPOSED STREAMBANK TREATMENT TYPES
JANUARY 2016

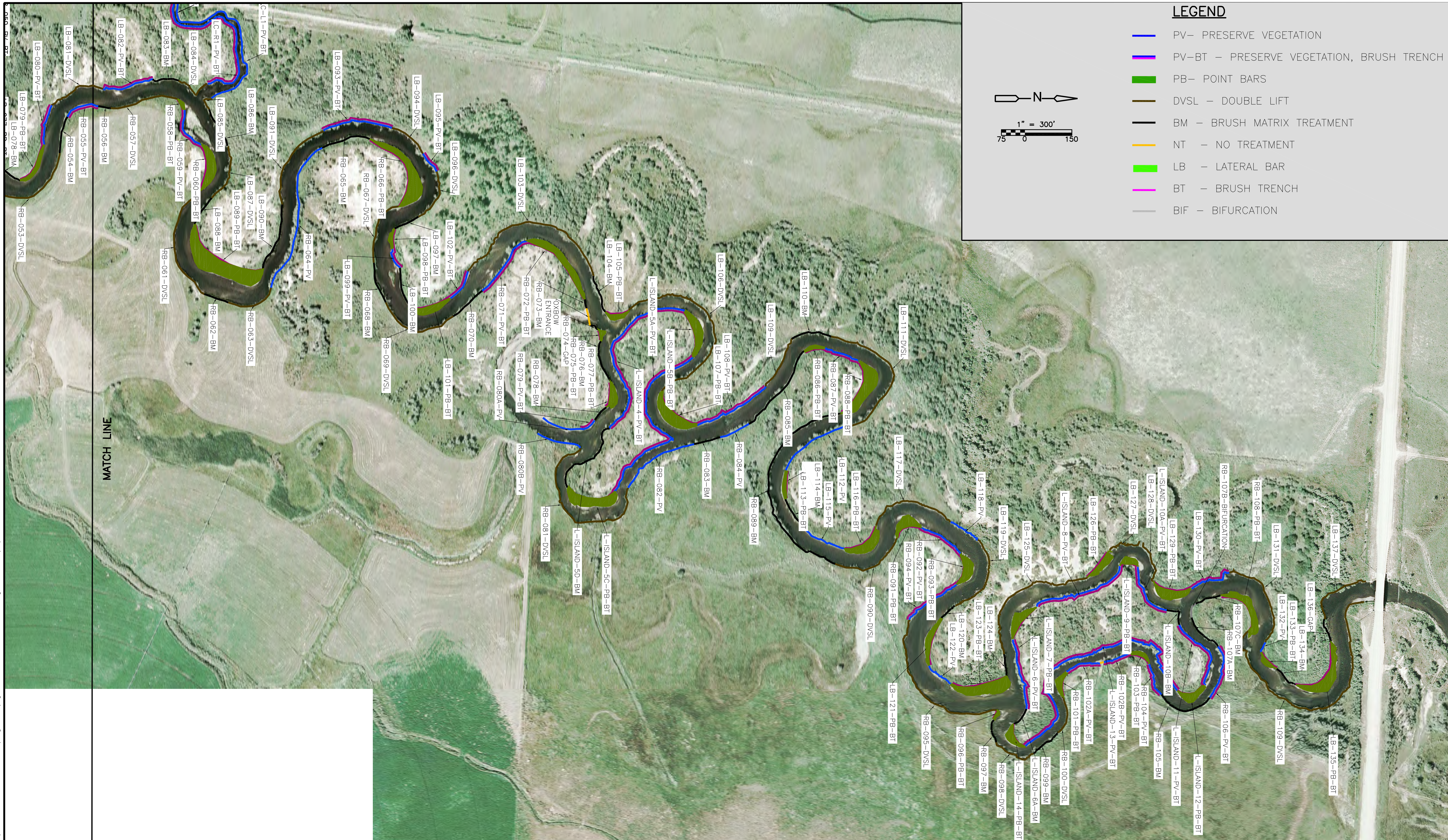


K:\CFR– PHASES 3 AND 4\Dwg PDP\Figures Streambanks27_29.dwg SAVED: 2/2/16 BY: MAINZHAUSENK

CDM Smith

Figure 4-7
PROPOSED STREAMBANK TREATMENT TYPES
JANUARY 2016

K:\CFR- PHASES 3 AND 4\Dwg PDP\Figures Streambanks27_29.dwg SAVED: 2/2/16 BY: MAINZHAUSENK



CDM Smith

Figure 4-8
PROPOSED STREAMBANK TREATMENT TYPES
JANUARY 2016

Table 4-4 Proposed Lengths of Bank Treatments, Phases 3 and 4 Design.

Bank Treatment Type	Length (feet)
Group 1 (Brush trench behind point and lateral bars)	8,962
Group 2 (Brush Matrix)	10,796
Group 3 (Double Vegetated Soil Lift)	21,039
Preserve Vegetation no Brush Trench	3,241
Preserve Vegetation with Brush Trench	9,049
Bifurcation Treatment	98
No treatment	283
TOTAL BANK LENGTH	**53,468**
Estimated extent of Group 3 banks requiring toe construction(1)	12,623

Note: (1) Based on 60% of DVSL treatments needing bank toe.

About 8,406 feet of passive margins (point bars and lateral bars) require construction of a brush trench (Group 1). Another 12,290 feet of bank will be lowered but not rebuilt to preserve intact vegetation that provides good bank strength; these are referred to as Preserve Vegetation (PV) banks. All other banks will be treated with Group 2 or Group 3 treatments. In addition, there will be no treatment on approximately 283 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 Phases 3 and 4 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. A total of 12, 623 linear feet of bank toe protection is estimated for Group 3 bank treatments.

4.3.2 Bank Toe Design

The terms "bank toe" or "bank toe material" as used in this report are defined as the location of the inflection point at the base of the streambank and the material that is found at this location including the material below the bank toe to the predicted scour depth. The predicted scour depth for the 10-year flow at this Project Area is generally five-feet below the top of the reconstructed bank. This design requires the reconstruction of the bank toe under certain conditions when suitable materials are not already present at this location.

As described in Section 2.4, analysis of the bank toe materials based on test pits adjacent to the planned DVSL locations suggests that alluvial gravel was present below the upper bank in 18% of the investigated locations. Thus, for the remaining 82% of the DVSL bank lengths, some bank toe material may need to be placed to support and protect the constructed upper bank. 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 below the bank, thereby maintaining bank stability. Dense, highly cohesive clay at the bank toe can also fulfill the same purpose. If suitable bank toe material is not present, a bank may be prone to failure especially at erosive locations such as the outside banks of meander 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 Phases 3 and 4 is alluvial material that generally meets the gradation for floodplain alluvium described in Section 4.5.4 (Table 4-8). If suitable bank toe material is not present, the bank toe should be constructed as shown on the drawings and schematically in Figure 4-9. 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 flow has been calculated to range from about two feet below the upper bank for straight reaches to 5 feet below the bank toe for outsides of tight meander 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 the Project Area are on the outside of meander bends where shear stresses can be high due to the deflection of the flow by the bend. Meander bends with small radii of curvature that require Group 3 bank treatments have been selected and analyzed for critical shear stress using Shield's Equation (Shields, 1936) for the 10-year flow conditions. Table 4-5 shows the calculated increase in shear caused by meander bend shape as defined by the ratio of Bend Radius to Width (Rc/W). The Rc/W correction coefficient increases the median particle size mobilized, referred to as the critical D50 (FHWA, 1988). All of the calculated critical D50 values that are greater than the average D50 for alluvium of 1.7 inches are shown in Table 4-4. Processing of the floodplain alluvium will be needed to produce suitable bank toe conditions at these locations if the existing toe material is not suitable. Suitable bank toe material in Phases 3 and 4 is alluvial material that generally meets the gradation for floodplain alluvium described in Section 4.5.4 (Table 4-8). If suitable bank toe material is not available at these locations, a gradation with the D50 shown in Table 4-5 should be installed. Figure 4-6 shows the general configuration of a reconstructed streambank that requires additional toe material.

The bank toe should be constructed of floodplain alluvium as shown in the drawings. The gradation for floodplain alluvium is given in Table 4-8 and is applicable for the toe reconstruction at all locations except for those locations identified in Table 4-5. 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. The preferred method of sediment control is placement of coffer dams around the work area.

Table 4-5 Proposed Design Critical Shear Stress Analysis for Bank Toe Material at a 10-Year Flow.

Cross Section	River Station	E.G. Slope (ft/ft)	Velocity Channel (ft/s)	Grain Shear(1) (lb/sq ft)	Shear Channel (lb/sq ft)	CL Radius (ft)	Width (ft)	R/W	Correc-tion	Corrected Shear(2) (lb/sq ft)	Critical D50(3) (in)
XS 43	48+37	0.0013	3.53	0.18	0.29	110	50	2.20	1.96	0.57	2.22
XS 58	59+66	0.0013	3.21	0.16	0.26	110	40	2.75	1.87	0.49	1.89
XS 77	97+02	0.0013	3.92	0.22	0.35	70	45	1.56	2.08	0.73	2.83
XS80	103+07	0.0014	4.01	0.23	0.36	70	40	1.75	2.04	0.74	2.87
XS 83	106+81	0.0015	4.30	0.26	0.41	95	50	1.90	2.01	0.83	3.22
XS 85	109+54	0.0022	4.02	0.26	0.41	130	50	2.60	1.89	0.78	3.03
XS 90	118+17	0.0018	3.76	0.22	0.36	100	55	1.82	2.03	0.73	2.85
XS 95	126+20	0.0017	3.82	0.22	0.35	80	45	1.78	2.04	0.71	2.78
XS 101	133+48	0.0012	3.67	0.19	0.31	90	50	1.80	2.03	0.63	2.46
XS 122	161+29	0.0016	3.77	0.21	0.34	85	45	1.89	2.02	0.69	2.67
XS 126	166+18	0.0014	3.94	0.22	0.36	80	50	1.60	2.07	0.74	2.90
XS 148	192+11	0.0010	3.46	0.17	0.27	65	50	1.30	2.12	0.57	2.24
XS 155	202+45	0.0011	3.47	0.17	0.27	110	50	2.20	1.96	0.53	2.07
XS 156	204+17	0.0018	3.96	0.24	0.38	75	60	1.25	2.13	0.81	3.16
XS 159	208+48	0.0017	4.03	0.24	0.39	80	45	1.78	2.04	0.79	3.10
XS 185	234+56	0.0011	3.33	0.16	0.26	90	40	2.25	1.95	0.51	1.98

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. Shields coefficient is 0.030.

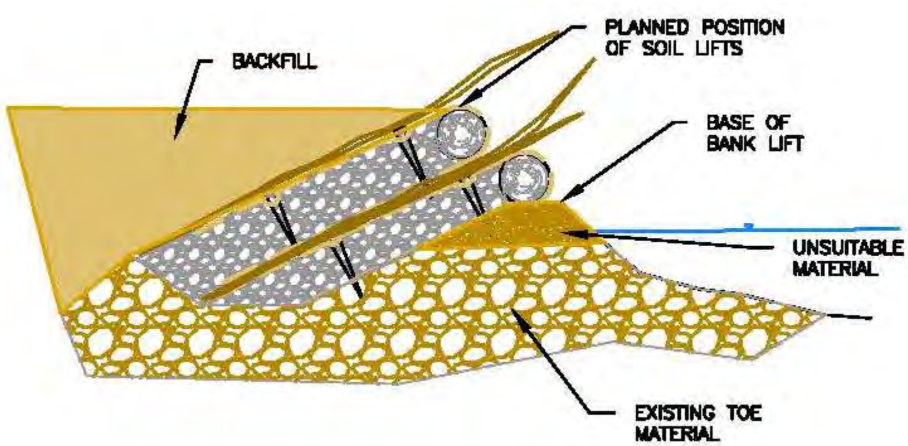


Figure 4-9 Schematic of bank toe requirements.

4.4 Channel Stability and Design

The designed channel was analyzed using the HEC-RAS proposed condition hydraulic model to provide verification of the stability of the channel bed and bank toe design. The Project Area channel design was vetted using the hydraulic model to determine if there were any areas that might compromise the stability of the channel.

4.4.1 Channel Stability Analysis

The proposed condition HEC-RAS model was used to evaluate the behavior of the channel/floodplain system under different flow conditions. In particular, the 2-year flow was modeled to evaluate the design criterion that the channel should hold the approximate 2-year flow, and the 10-year flow was modeled to evaluate the design criterion that the channel should become deformable at the approximate 10-year 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 proposed design condition differs from the existing condition of the channel, because the banks have generally been lowered allowing out-of-bank flow at the approximate 2-year flow. The designed condition was modeled assuming full floodplain vegetation reestablishment. Pasture lands were assumed to have a Manning's n value of 0.035 and riparian areas planted with riparian shrubs and trees were assumed to have a Manning's n value of 0.15. Other n value assumptions are listed in Table 4- 6. The floodplain was divided into regions with similar mixes of land types and composite values were calculated for each region. The 2-year flow did not have much effect on overbank conditions but the 10-year flow had considerable effect on the overbank condition because there was significant out-of-bank flow as discussed in section 4.2.4. In general, the 10-year flow generates higher channel shear stresses than the 2-year flow, and this discussion of channel stability centers on the 10-year flow.

The output of the 10-year flow HECRAS 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 exerted on 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 4-7 and fall within reasonable values when related to total shear. Then Shields' equation used the grain shear stress to estimate the median

Table 4-6 Manning's n Values used in Proposed Conditions HECRAS Models.

Land Use	Manning's N Value
Riparian Floodplain	0.15
Riparian Pasture	0.035
Riparian Shrub Planting Area	0.06
Riparian Wetland	0.15
Emergent Wetland	0.1
Open Water/Lost Creek	0
Irrigation Ditch/Swale/Oxbow	0.15
Grassland Pasture	0.035
Irrigated Hay Field	0.04

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 of 0.001 to 0.006. The slope of the Clark Fork River in Phases 3 and 4 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 4-7 presents critical particle size calculations for incipient motion in the main channel bed in Phases 3 and 4. This table was generated 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 1.7 inches found from pebble counts in the Project Area. The averaged pebble count gradation values for the Project Area may not reflect the site-specific bed sediment at the cross sections shown in Table 4-7; as such, the cross-sections identified in Table 4-7 are identified only as potential locations of channel instability.

The areas of relatively high grain shear in Table 4-7 are often associated with areas of high velocity caused by steepening of the main channel. This is true at the upper end of the reach (cross sections 4 through 16) where the channel was historically straightened and routed through Perkins Lane bridge. High shear stresses become less frequent in the downstream reaches and especially below Lost Creek where gradients are the flattest and split flows distribute the stress. However, there is another relatively steep reach of river just downstream of Lost Creek from cross section 116 to 119 that shows shear stresses in the 0.60 to 0.70 lb/ft^2 range.

Table 4-7 Ten-Year Event Critical Shear Stress Analysis for Main Channel Bed, Phases 3 and 4.

Cross-section	Station	E.G. Slope	Velocity Channel	Grain Shear	Shear Chan	Critical D_{50}
	(ft)	(ft/ft)	(ft/s)	(lb/sq ft)	(lb/sq ft)	(in)
XS-4	3+55	0.0032	5.52	0.45	0.73	1.77
XS-5	4+65	0.0039	5.85	0.52	0.83	2.02
XS-9	8+88	0.0035	5.42	0.45	0.72	1.76
XS-16	15+17	0.0048	6.63	0.66	1.06	2.57
XS-24	23+32	0.0030	5.44	0.44	0.70	1.70
XS-36	35+36	0.0033	5.82	0.50	0.79	1.93
XS-46	53+53	0.0027	5.70	0.46	0.73	1.78
XS-82	105+77	0.0049	6.31	0.61	0.99	2.40
XS-117	153+81	0.0029	5.46	0.44	0.70	1.70
XS-119	156+88	0.0029	5.57	0.45	0.72	1.75
XS-146	187+62	0.0031	5.99	0.51	0.82	1.99

Notes: D_{50} is 1.7 inches and D_{84} is 2.7 in. for riffles in Phases 3 and 4.
Shield's Coefficient = 0.030

In summary, it appears that many of the potentially unstable locations on the main channel at the 10-year 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 experience 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 channel failure.

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 construction 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 232,000 cubic yards of vegetative backfill and 635,000 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. Physical and chemical requirements for vegetative backfill are found in Table 3-4.

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 Phases 3 and 4. The vegetative borrow area location is shown on Drawing C50 (the Transportation Plan) and the development plan is shown on Drawing C47 of the plan set.

At the Beck Ranch Borrow Area, soils generally meet the criteria for vegetative backfill of Table 3-4. The results of soil analysis at the Beck Ranch 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 placed to a greater depth on some areas to support the development of wetlands or other land uses. 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.

The soil at the Beck Ranch 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 3-4, 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. Because the material is subsoil, it is generally low in organic matter. Organic matter content is not a limiting factor because it can be adjusted using compost additions. The amount of organic matter to amend the imported soil with will be determined after a compost source has been identified for the project. Organic matter will be added to target a total composition of 1.5% to 2%.

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 the Vegetative Backfill Borrow Area Plan on Drawing C47 of the plan set. Field adjustments or changes to the borrow area limits may be needed during construction. Once the top one-foot of soil is stockpiled, the borrow material will be excavated to the elevations shown on Drawing C47. 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, and new point bar construction. Alluvial materials are generally sand, gravels and cobbles that have been transported by water.

Floodplain Alluvial Backfill

Besides being used for reconstruction of the floodplain, floodplain alluvium will also be used to construct soil lifts. Floodplain backfill materials are designed to be similar to existing floodplain alluvium. With the exception of avulsion paths, no incipient motion calculations have 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 4-10). 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 D80 of about 3 inches.

The design 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 at least 60% 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 Phases 3 and 4 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.

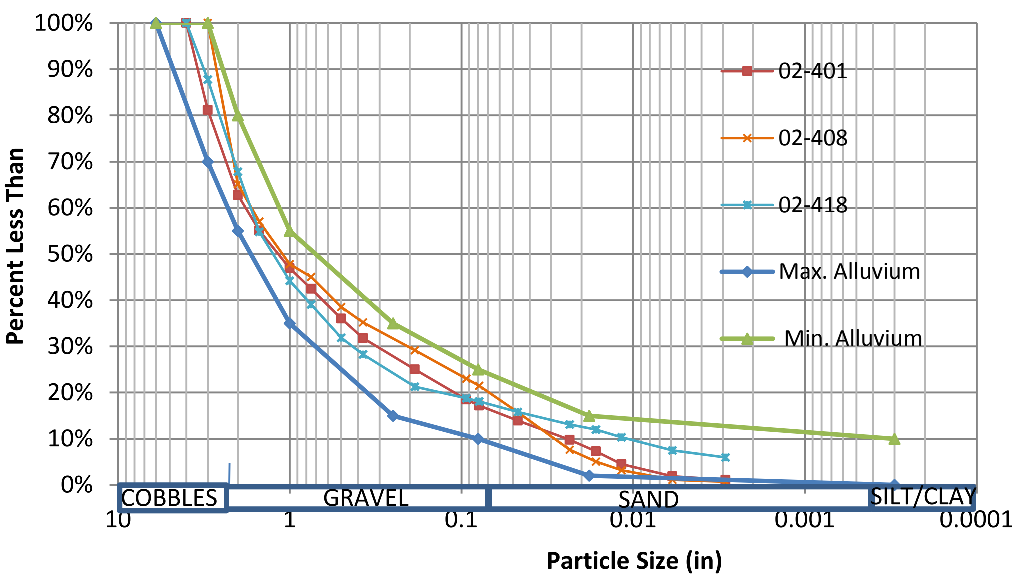


Figure 4-10 Proposed Floodplain Alluvium Gradation.

Table 4-8 Alluvium Material Gradations.

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

Point Bar Alluvium
The gradation for point bars is based on observed deposition of point bars in the Project Area. 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% 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.

4.5.5 Alluvial Borrow Area Availability and Quality

Investigations are on-going for borrow sources, but sampling of test pits to date indicates that suitable alluvial borrow materials should be available in large quantities at this site. Material samples were analyzed for gradations and samples was analyzed for soil pH, electrical conductivity and metals to ensure material would be chemically suitable as borrow.

The gradation 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. 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 avulsion paths. This material should meet the specifications shown in Table 3-4 except for texture and coarse fragments.

Although general backfill could be taken from a number of sources, in Phases 3 and 4 it may be excavated from small portions of Lampert's property. There is high ground near the Helen Johnson ditch that the Lamperts would like leveled. (Drawing C48 of the plan set). There is also a meander core northwest of this location that is outside the removal boundary that will generate some material when it is lowered to match adjacent ground in the meander corridor

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;
- 3.8% of the constructed floodplain surface will be inundated at the average 2-year WSE and 57% at the 10-year WSE;
- 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 Riparian Floodplain cover type and land use type described in Section 3.5. The Conservation Easement land use types receives the same revegetation treatments as the Riparian Floodplain cover types. Figures 4-11 and 4-12 show the distribution of design floodplain cover types in Phases 3 and 4 based on the preliminary grading plan. Figure 4-13 shows an example floodplain cross-section comparing existing, design and future floodplain vegetation and substrate. Appendix B provides additional details including revegetation treatment descriptions and plant species that will be used to revegetate the site.

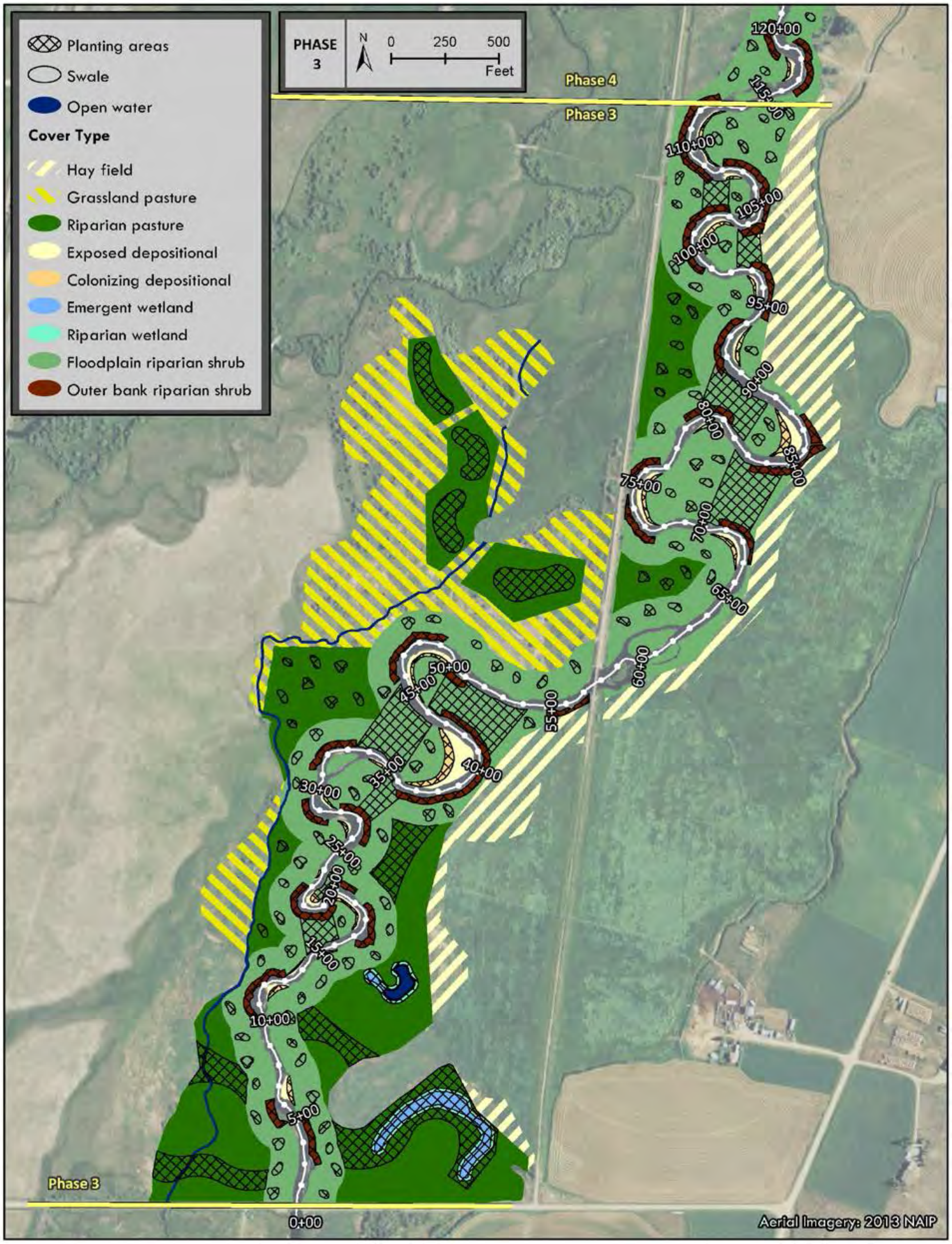


Figure 4-11 Phase 3 Design Cover Types, Planting Areas, and Swale Features.

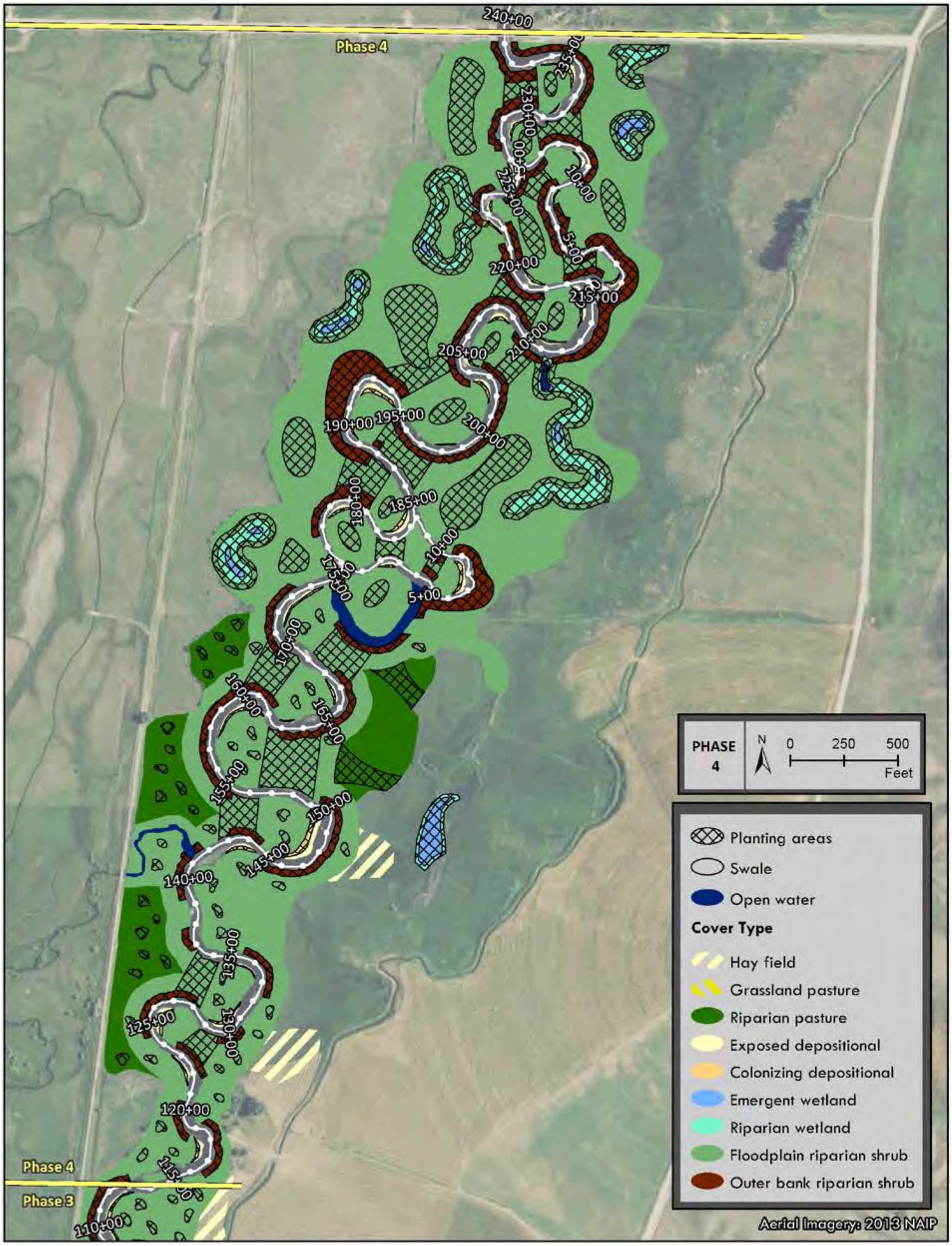


Figure 4-12 Phase 4 Design Cover Types, Planting Areas, and Swale Features.

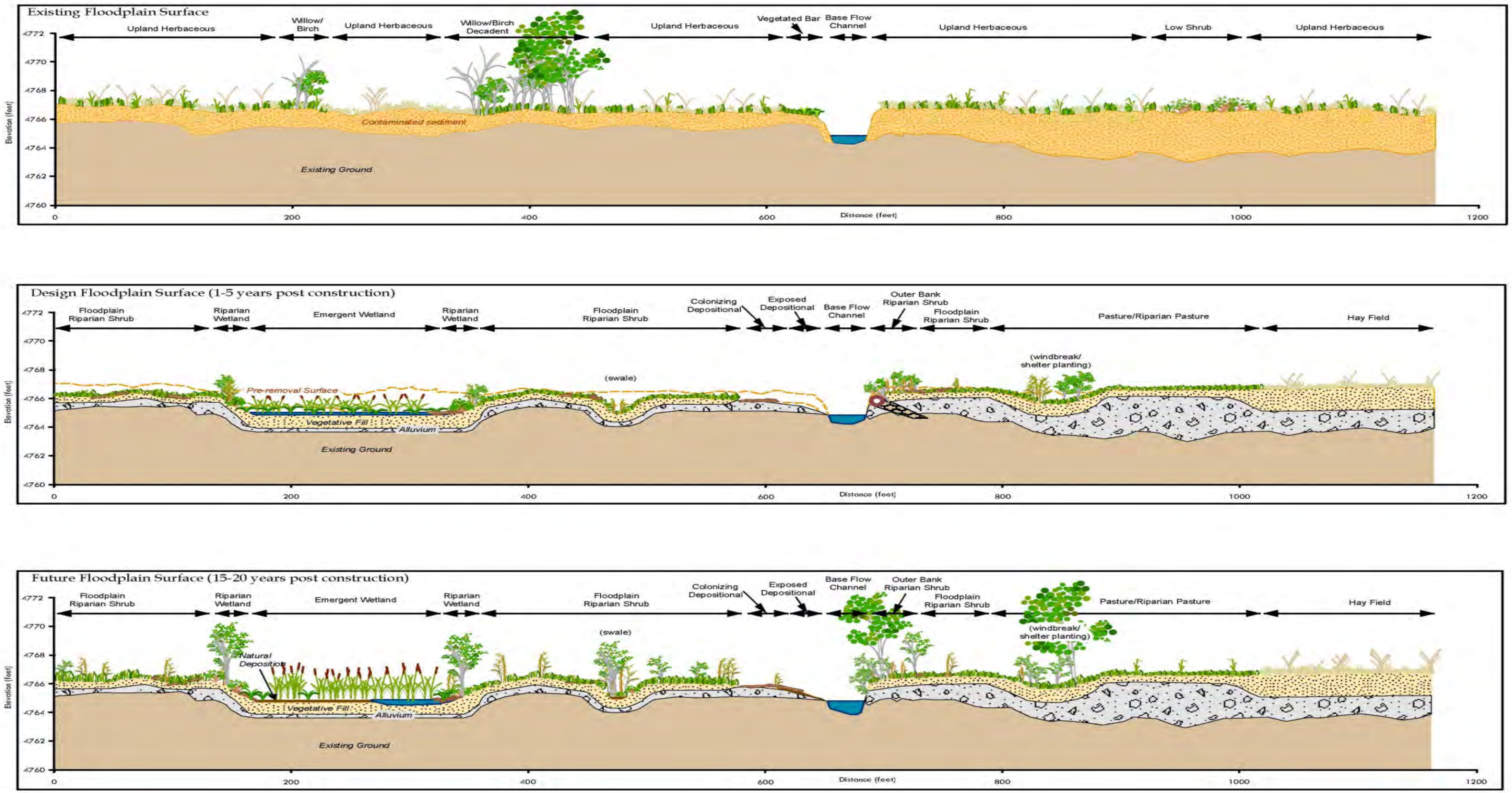


Figure 4-13 Example Cross-Section of the Existing, Design and Future Floodplain Surface.

This page intentionally left blank.

4.6.1 Exposed Depositional

4.6.1.1 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 processes, 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 habitats 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.

4.6.1.2 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 4-9 summarizes the revegetation criteria and treatments for the Exposed Depositional cover type.

Table 4-9 Exposed Depositional Cover Type Criteria and Revegetation Treatments.

Exposed Depositional Cover Type	Total Area = 2.6 acres Percent of Total Area = 1.0%	
Treatment	Criterion/Description	Treatment Area
Grading	-2.5 to -1.0 feet relative to 2-year water surface elevation	2.6 acres
Soil Texture	Sand, fine to coarse gravel or cobble (alluvium)	2.6 acres
Vegetative Backfill Depth	No vegetative backfill	N/A

4.6.2 Colonizing Depositional

4.6.2.1 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.

4.6.2.2 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.
- Planting of herbaceous wetland plugs and small willows or cottonwoods to encourage development of desired plant communities along the channel margins.
- 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 = 2.4 acres Percent of Total Area = 0.9%	
Treatments	Criterion/Description	Treatment Area
Grading	-1 to 0 feet relative to 2-year water surface elevation	2.4 acres
Soil Texture	Sand, fine to coarse gravel or cobble (alluvium)	2.4 acres
Vegetative Backfill Depth	No vegetative backfill	N/A
Containerized Planting: Shrubs and Trees	Small 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

4.6.3 Emergent Wetland

4.6.3.1 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 WSE. 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.

4.6.3.2 Strategy

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

- Grading, including microtopographic enhancements, and substrate placement in association with floodplain shaping to provide 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. Figure 4-14 shows an example of microtopography with wood debris placement.
- 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.

Figure 4-14 Micotopography with wood debris placement.

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

Emergent Wetland Cover Type	Total Area = 2.2 acres Percent of Total Area = 0.8%	
Treatment	Criterion/Description	Treatment Area
Grading	-2.5 to -1.0 feet relative to 2-year water surface elevation	2.2 acres
Soil Texture	Silt to sandy loam (vegetative backfill)	2.2 acres
Vegetative Backfill Depth	12 inches (over alluvium)	2.2 acres
Microtopography (surface roughness and woody debris placement)	Surface will have undulations +/- 0.5 feet and large and coarse woody debris will be partially buried into the surface up to the edge of open water.	2.2 acres
Containerized Planting: Herbaceous Plugs	Herbaceous plugs installed according to appropriate hydrologic zones	2.2 acres
Seeding	Seed with diverse native mix of grasses and forbs	2.2 acres

4.6.4 Riparian Wetland

4.6.4.1 Description

The goal of the Riparian Wetland cover type is 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 ecological functions. This cover type will occupy floodplain areas that are 0 to 1.0 feet below the 2-year WSE and often represents a transition area between Emergent Wetland cover types and drier cover types. 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.

4.6.4.2 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.

4.6.5 Floodplain Riparian Shrub

4.6.5.1 Description

The Floodplain Riparian Shrub cover type will occupy the largest percentage of floodplain area within the 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.

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 = 5.2 acres Percent of Total Area = 2.0%	
Treatment	Criterion/Description	Treatment Area
Grading	-1.0 to 0 feet relative to 2-year water surface elevation	5.2 acres
Soil Texture	Silt to sandy loam (vegetative backfill) overlying gravel or cobble (alluvium)	5.2 acres
Vegetative Backfill Depth	12 inches	5.2 acres
Microtopography (surface roughness and woody debris placement)	Surface will have undulations +/- 0.5 feet and large and coarse woody debris will be partially buried and scattered throughout floodplain and within connected wetland complexes as grade control features	5.2 acres
Containerized Planting: Shrubs and Trees	Shrubs and trees will be installed in all areas of this cover type; features include off-channel wetlands	5.2 acres
Browse Protection	Exclosure fence where possible; individual protectors where not	TBD
Seeding	Seed with diverse native mix of grasses and forbs	5.2 acres

4.6.5.2 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, high risk avulsion paths and other areas to promote the establishment of the vegetation community and provide a long-term seed source. Within the Conservation Easement land use type, additional areas will be planted to increase cover for wildlife and support conservation uses in this area.
- 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 4-13 summarizes revegetation criteria and treatments for the Floodplain Riparian Shrub cover type.

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

Floodplain Riparian Shrub Cover Type	Total Area = 134.8 acres Percent of Total Area = 50.7%	
Treatment	Criterion/Description	Treatment Area
Grading	-0.5 to 2.5 feet relative to 2-year WSE	134.8 acres
Soil Texture	Silt loam to sandy loam	134.8 acres
Vegetative Backfill Depth	6 inches	134.8 acres
Microtopography (surface roughness)	Undulating surface +/- 0.5 feet	134.8 acres
Microtopography (woody debris placement in high priority areas)	Partially buried large and coarse woody debris scattered throughout floodplain	115.3 acres
Containerized Planting	Shrubs and trees installed in swales, potential meander cut-off areas and along the Clark Fork River	32.7 acres
Browse Protection	Exclosure fence where possible; individual protectors where not	TBD
Seeding	Seed with diverse native mix of grasses and forbs	134.8 acres

4.6.6 Outer Bank Riparian Shrub

4.6.6.1 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.

4.6.6.2 Strategy

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

- Grading and substrate placement in association with streambank treatments to create suitable growing conditions for native vegetation.
- Floodplain shaping 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 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.

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

Outer Bank Riparian Shrub Cover Type	Total Area = 16.6 acres Percent of Total Area = 6.2%	
Treatment	Criteria/Description	Treatment Area
Grading	0 to 2.0 feet relative to 2-year water surface elevation	16.6 acres
Soil Texture	Silt loam to sandy loam (vegetative backfill)	16.6 acres
Vegetative Backfill Depth	6 inches	16.6 acres
Microtopography (surface roughness and woody debris placement)	Surface will have undulations +/- 0.5 feet and partially buried large and coarse woody debris scattered throughout floodplain	16.6 acres
Containerized Planting: Trees and Shrubs	Planted in all areas throughout the cover type	16.6 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	16.6 acres

4.6.7 Hay Field

4.6.7.1 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. Treatments in this cover type aim to create conditions needed to support grass, legumes or other herbaceous species. This cover type will be constructed to mimic approximate pre-removal elevations and conditions.

4.6.7.2 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 4-15 summarizes revegetation criteria and treatments for the Hay Field cover type.

Table 4-15 Hay Field Cover Type Criteria and Revegetation Treatments.

Hay Field Cover Type	Total Area = 21.3 acres Percent of Total Area = 8.0%	
Treatment	Criterion/Description	Treatment
Grading	Similar to pre-removal elevations	21.3 acres
Soil Texture	Silt to sandy loam (vegetative backfill)	21.3 acres
Vegetative Backfill Depth	18 inches	21.3 acres
Seeding	Seed with hay crop species as determined by land owner	21.3 acres

4.6.8 Grassland Pasture

4.6.8.1 Description

The Grassland Pasture cover type occurs in Phase 3 on the west side of the Clark Fork River within the removal boundary. Grassland 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 cover type will consist of native grass and forb species suitable for grazing.

4.6.8.2 Strategy

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

- Grading and substrate placement in association with floodplain shaping to create suitable growing conditions for native herbaceous vegetation.
- Seeding with native grasses suitable for grazing.

Table 4-16 summarizes revegetation criteria and treatments for the Grassland Pasture cover type.

Table 4-16 Grassland Pasture Cover Type Criteria and Revegetation Treatments.

Grassland Pasture Cover Type	Total Area = 26.7 acres Percent of Total Area = 10.0%	
Treatment	Criterion/Description	Treatment
Grading	2.0+ feet relative to 2-year water surface elevation	26.7 acres
Soil Texture	Silt to sandy loam (vegetative backfill)	26.7 acres
Vegetative Backfill Depth	6 inches	26.7 acres
Seeding	Drill seed with pasture grasses	26.7 acres

4.6.9 Riparian Pasture

4.6.9.1 Description

The Riparian Pasture cover type occurs at various locations within the removal boundary. Riparian Pasture occurs 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. In some areas planting of trees and shrubs will occur within swales and linear corridors to restore shrub cover similar to existing conditions; provide connectivity between the river riparian corridor and upland areas and increase wildlife habitat. Within areas to be planted, microtopography including surface roughness and woody debris placement will occur. The Riparian Pasture cover type will consist of native grass and forb species suitable for grazing except in planted areas which will consist of native riparian shrub and trees species.

4.6.9.2 Strategy

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

- Grading and substrate placement in association with floodplain shaping to create suitable growing conditions for native herbaceous vegetation.

- Floodplain shaping and microtopographic enhancements in planting areas to provide suitable growth media and microsites for better germination and plant survival.
- Installation of large and coarse woody debris (microtopography) in planting areas to create niches and microsites for vegetation development and promote soil development.
- Installation of containerized plant material in 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 Riparian Pasture cover type.

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

Riparian Pasture Cover Type	Total Area = 51.6 acres Percent of Total Area = 19.4%	
Treatment	Criterion/Description	Treatment
Grading	2.0+ feet relative to 2-year water surface elevation	51.6 acres
Soil Texture	Silt to sandy loam (vegetative backfill)	51.6 acres
Vegetative Backfill Depth	6 inches	51.6 acres
Microtopography (surface roughness and woody debris placement)	Surface will have undulations +/- 0.5 feet and partially buried large and coarse woody debris scattered throughout floodplain	12.0 acres
Containerized Planting: Trees and Shrubs	Shrubs and trees installed in windbreaks/shelter planting areas	12.0 acres
Browse Protection	Exclosure fence around planting areas	TBD
Seeding	Drill seed with pasture grasses	51.6 acres

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 will arrive free of weeds and weed seeds.
- Vehicle and equipment traffic will remain within designated construction limits and on designated access routes.
- Driving through existing weed infestations will be avoided to the greatest extent possible.
- Noxious weed infestations adjacent to construction limits will 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 will be noxious weed and noxious weed seed free to the extent practicable.

Preliminary vegetation mapping conducted during summer 2014 and subsequent site observations identified the state-listed noxious weed species listed in Table 4-18 within the Project Area. Most of the noxious weeds identified on the Clark Fork Site are listed as Priority 2b by the State of Montana (2015). Priority 2b weeds are abundant in Montana and widespread in many counties. Management criteria require eradication or containment where less abundant (State of Montana, 2015). Perennial pepperweed (*Lepidium latifolium)* is a Priority 2a species indicating it is common in isolated areas of Montana. Management criteria require eradication or containment where less abundant (State of Montana, 2013). There are also two Priority 3 species found in the Project Area, cheatgrass (*Bromus tectorum)* and Russian olive (*Eleagnus angustifolia*). Priority 3 species are regulated plants but are not Montana listed noxious weeds. These plants have the potential to have significant negative impacts and spread or sale of these plants is not allowed. Current management recommendations include research, education and prevention to minimize the spread of these plants.

Table 4-18 Phase I Noxious Weed Species found within the Project Area and their Listing Category.

Scientific Name	Common Name	Priority
Bromus tectorum	cheatgrass	3
Cardaria draba	whitetop	2b
Centaurea maculosa	spotted knapweed	2b
Cirsium arvense	Canada thistle	2b
Cynoglossum officinale	houndstongue	2b
Eleagnus angustifolia	Russian olive	3
Euphorbia esula	leafy spurge	2b
Lepidium latifolium	Perennial pepperweed	2a
Linaria dalmatica	Dalmatian toadflax	2b
Linaria vulgaris	yellow toadflax	2b

A long term weed management plan will be necessary to control weed infestations on the Clark Fork 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 and adjacent private landowners.

This page intentionally left blank.

Section 5

Supporting Plans

This Section describes supporting plans for the CFR Phases 3 and 4 Remedial Action Project. These plans are prepared by DEQ 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 (in consultation with EPA), has 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 DEQ's 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 (RAWP) 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 the Phases 3 and 4 construction.

5.2 Construction Erosion Control Plan

The Special Provisions for the draft and final CFR Reach A, Phases 3 and 4 Remedial Action Project will require the remedial action construction contractor to prepare and submit a site-specific Erosion Control Plan to DEQ's Engineer for review. The remedial action construction contractor will implement the Erosion Control Plan. The Erosion Control Plan will describe the Best Management Practices (BMPs) needed to implement the CFR Reach A, Phases 3 and 4 Remedial Action Project. 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 contaminated tailings/impacted soils material will be removed, construction roads, borrow areas, construction staging areas, streambanks, and areas where tailings/impacted soils material 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 for the draft and final CFR Reach A, Phases 3 and 4 Remedial Action Project 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 remedial action construction contractor will 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 for the draft and final CFR Reach A, Phases 3 and 4 Remedial Action Project will require the remedial action construction contractor to prepare and submit a site-specific Dust Control Plan to DEQ's Engineer for review. The remedial action construction contractor will 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 for the draft and final CFR Reach A, Phases 3 and 4 Remedial Action Project will require the remedial action construction contractor to prepare and submit a site-specific Weed Control Plan to DEQ's Engineer for review. The remedial action construction contractor will 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 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.

This page intentionally left blank.

Section 6
References

Bureau of Land Management (BLM), 2012. General Land Office Records Automation. Accessed from: http://www.glorecords.blm.gov

CDM Smith, 2014. Clark Fork River Reach A Phases 3 and 4 Draft Sampling and Analysis Plan Addendum. Clark Fork River Operable Unit, Milltown Reservoir/Clark Fork River NPL Site, Powell, Deer Lodge, Granite and Missoula Counties, Montana. Prepared for the Montana Department of Environmental Quality and the Montana Natural Resource Damage Program, December.

CDM Smith, 2015a. Clark Fork River Reach A Phases 3 and 4 Draft Data Summary Report, Clark Fork River Operable Unit, Milltown Reservoir/Clark Fork River NPL Site, Powell, Deer Lodge, Granite and Missoula Counties, Montana. Prepared for the Montana Department of Environmental Quality and the Montana Natural Resource Damage Program, May.

CDM Smith, 2015b. Memorandum: Peak Flow Hydrology for Phases 3 and 4 Design, Clark Fork River Site. Prepared for K. Garcin, Montana Department of Environmental Quality, May 20, 2015.

CDM Smith, 2015c. Memorandum: Clark Fork River Phases 3 and 4 Streambanks and Site Map. Prepared for K. Garcin, Montana Department of Environmental Quality, May 15, 2015.

CDM Smith, 2016a. Memorandum: Hydraulic Models of Existing Conditions for Phases 3 and 4 Design, Reach A, Clark Fork River Site. Prepared for K. Garcin, Montana Department of Environmental Quality, February, 2016.

CDM Smith, 2016b. Memorandum: Hydraulic Models of Design Conditions for Phases 3 and 4 Design, Reach A, Clark Fork River Site. Prepared for K. Garcin, Montana Department of Environmental Quality, February, 2016.

CDM Smith and AGI, 2013. Geomorphology and Hydrology of Reach A, Clark Fork River Operable Unit Milltown Reservoir/Clark Fork River Superfund Site, Powell, Deer Lodge, and Granite Counties. Prepared for the Montana Department of Environmental Quality. September.

CH2M-Hill, 2008. Clark Fork River RipES Website. http://www.cfrripes.com/.

Copeland, R.R., D.S. Biedenharn, and J.C. Fischenich; 2000. Channel Forming Discharge ERDC/CHL CHETN-VIII-5, U.S. Army Corps of Engineers. December.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe, 1979. Classification of Wetlands and Deepwater Habitats of the United States. FWS/OBS-79/31. U.S.D.I Fish and Wildlife Service. Washington, D.C.

Department of Environmental Quality. 1996. Montana Sediment and Erosion Control Manual. Revised May.

Department of Environmental Quality, 2008a. Construction Quality Assurance Plan. Remedial/Restoration Action, Clark Fork River Operable Unit of the Milltown Reservoir/Clark Fork River Superfund Site. Draft, May.

Department of Environmental Quality, 2008b. CFR OU Weed Control Plan for the Clark Fork River Operable Unit. Draft.

Department of Environmental Quality, 2009. Construction Storm Water Best Management Practices Plan Clark Fork River Operable Unit of the Milltown Reservoir/Clark Fork River Superfund Site. Missoula County, Montana. Prepared by CDM. February.

Department of Environmental Quality, 2014. Basis for Remedial Design Assumption: Contamination Benchmark. Memorandum from Brian Bartkowiak, DEQ Clark Fork River Project Officer, to Roger Hoogerheide, EPA Clark Fork River Support Agency Coordinator. March 19, 2014.

Department of Environmental Quality and USEPA, 2015. Explanation of Significant Differences, Clark Fork River Operable Unit (OU #3), Milltown Reservoir/Clark Fork River Superfund Site, CERCLIS Identification Number: MTD980717565. April.

Doyle, M.W., D. Shields, K.F. Boyd, P.B. Skidmore, and D. Dominick; 2007. Channel-forming Discharge Selection in River Restoration Design. *Journal of Hydraulic Engineering*. July 2007, pp. 831-837.

ESRI, 2011. ArcGIS Desktop, Release 10. Environmental Systems Research Institute, Redlands, California.

Federal Highway Administration (FHWA), 1988. HEC-15 - Design of Roadside Channels with Flexible Linings. P. 62, Chart 10. http://www.fhwa.dot.gov/engineering/hydraulics/pubs/hec/hec15si.pdf

Fischenich, C., 2001. Stability Thresholds for Stream Restoration Materials. USAE Research and Development Center, ERDC TN-EMRRP-SR29. Vicksburg, MS. May.

Fugro Earthdata, Inc., 2011. LiDAR mapping of reach A, Clark Fork River Operable Unit. Performed for Montana Department of Environmental Quality, August 9, 2011. Rapid City, SD.

Gordon, L., A. Dutton, and C. Gammons, 2010. Monitoring Groundwater in Remediated vs. Unremediated Floodplain Sediments along the Upper Clark Fork River. Prepared for Montana Natural Resource Damage Program and Montana Department of Environmental Quality by Montana Tech Geological Engineering Department. December 17, 2010.

Gregory, S. V., Swanson, F. J., McKee, W. A., & Cummins, K. W., 1991. An Ecosystem perspective of Riparian Zones: Focus on links between land and water. *BioScience , 41* (8), 540-551.

Griffin E.R. and J.D Smith, 2002. State of Floodplain Vegetation within the Meander Belt of the Clark Fork of the Columbia River Deer Lodge Valley, Montana. WRIR 02-4109. USDI Geological Survey, Boulder, Colorado. 20pp.

Hanson, P. L., Pfister, R. D., Boggs, K., Cook, B. J., Joy, J., & Hinckley, D. K. (1995, May). Classification and Management of Montana's Riparian and Wetland Sites. *Miscellaneous Publication No. 54*. Missoula, MT: School of Foresty, The University of Montana.

Jones, L.S. and S.A. Schumm, 1999. Causes of avulsions—an overview: Special Publications of the International Association of Sedimentologists, v.28, p. 171-178.

Kappesser, G.B., 2002. A riffle stability index to evaluate sediment loading to streams: Journal of the American Water Resources Association, v. 38, no 4, pp 1069-1081.

Maynord, S.T., 1996. Toe-Scour Estimation in Stabilized Bendways. Journal of Hydraulic Engineering, ASCE. August 1996, pp. 460-464.

Microsoft, 2011. Bing Maps aerial imagery in ArcGIS 10.1, imagery courtesy of the U.S. Geological Survey.

Mueller, E.R., J. Pitlick, and J.M. Nelson, 2005. Variation in the reference Shields stress for bed load transport in gravel-bed streams and rivers. Water Resources Research, Vol. 41. WW04006.

Quivik, F.R., 1998. Smoke and tailings: An environmental history of copper smelting technologies in Montana, 1880-1930. PhD Dissertation, University of Pennsylvania, Philadelphia, PA, 544p.

PBS&J, 2008. Beck Ranch Cover Soil Borrow Investigation, Clark Fork River Operable Unit of the Milltown Reservoir/Clark Fork River Superfund Site. Prepared for Montana Department of Environmental Quality. Missoula, October.

Rosgen, D.L., 2001. A practical method for computing streambank erosion rate: Proceedings of the Seventh Federal Interagency Sedimentation Conference, V2, PP II-9-15, March 25-29, Reno, NV.

Schafer and Associates, 1991. Final Report for the Clark Fork River Demonstration Project, Warm Springs Montana: Report submitted to the Office of the Governor, Helena Montana, April 30, 1991.

Shields, A., 1936. Application of Similarity Principles and Turbulence Research to Bed Load Movement. California Institute of Technology, Pasadena; Translation from German Original; Report 167.

Shields, F.D, R.R. Copeland, P.C. Klingman, MW. Doyle, and A. Simon, 2003. Design for Stream Restoration. Journal of Hydraulic Engineering, ASCE. August 2003, pp. 575-584.

Slingerman, R. and N.D. Smith, 1998. Necessary conditions for a meandering-river avulsion: *Geology*, v. 26, no.5, pp. 435-438.

Smith, J.D. and E.R. Griffin, 2002. Relation between geomorphic stability and the density of large shrubs on the flood plain of the Clark Fork River of the Columbia River in the Deer Lodge Valley, Montana. WRIR 02-4070. USDI Geological Survey, Boulder, Colorado. 25 pp.

Smith, J.D., J.H. Lambing, D.A. Nimick, C. Parrett, M. Ramey, and W. Schafer, 1998. Geomorphology, flood-plain tailings, and metal transport in the Upper Clark Fork Valley, Montana: USGS Water Resources Investigations Report 98-4170, 56p.

State of Montana, 2015. Montana Noxious Weed List effective July, 2015. Montana Department of Agriculture.

Swanson, B., 2002. Bank Erosion and Metal Loading in a Contaminated Floodplain System, Upper Clark Fork River Valley, Montana: MS Thesis, University of Montana, 195p.

Tabacchi, E., Correll, D. L., Hauer, R., Pinay, G., & Planty-Tabacchi, A. M., 1998. Development, maintenance and role of riparian vegetation in the river landscape. *Freshwater Biology*, *40*, 497-516.

Tetra Tech, 2011. Clark Fork River Operable Unit, Milltown Reservoir/Clark Fork River NPL Site, Powell, Deer Lodge and Granite Counties, Montana. Part 1, Data Summary Report – Reach A, Phase 2. Prepared for the Montana Department of Environmental Quality. January.

US Army Corps of Engineers, 2008. HEC-RAS, River Analysis System. Version 4.0. http://www.hec.usace.army.mil/software/hec-ras/hecras-download.html

U.S. Department of Agriculture Farm Service Agency (USDA FSA), 2013. Montana 2013 Color National Aerial Imagery Program, Digital Orthoimagery. Accessed from: https://gdg.sc.egov.usda.gov/

U.S. Department of Agriculture Natural Resource Conservation Service (USDA NRCS), 2012. Soil Survey Geographic (SSURGO) database for Powell County Area, Montana. Accessed from: http://www.ftw.nrcs.usda.gov/ssur_data.html.

USEPA, 1998. Baseline Human Health Risk Assessment for the Clark Fork River Operable Unit of the Milltown Reservoir Sediments National Priority List Site. Final. Prepared by Roy F. Weston, Inc. January.

USEPA/DEQ, 2004. Record of Decision, Clark Fork River Operable Unit of the Milltown Reservoir/Clark Fork River Superfund site. U.S. Environmental Protection Agency, Helena, Montana, with concurrence of Montana Department of Environmental Quality, Helena, Montana. April.

U.S. Fish and Wildlife Service (USFWS), 2005. National Wetlands Inventory Website. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. Upper Clark Fork Watershed, 2005. False color infrared, orthorectified photography. Accessed from: http://www.fws.gov/wetlands.

Vannote, R. L., Minshall, G. W., Cummins, K. W., Sedell, J. R., & Cushing, C. E., 1980. The River Continuum Concept. *Canadian Journal of Fisheries and Aquatic Sciences.*, *37*, 130-137.

Wilcock, P., J. Pitlick and Y. Cui, 2006. Sediment Transport Primer and BAGS user's Manual, Part 1: Sediment Transport Primer. Draft – February 26, 2006. Produced by USDA Forest Service, Washington, D.C.

Williams, G.P., 1978. Bankfull Discharge of Rivers. *Water Resources Research*, 14(6), 1141-1154.

Appendix A

Hydraulic Modeling of Existing and Proposed Conditions – Phases 3 and 4

PHASES 3 AND 4 HYDRAULIC MODEL
EXISTING CONDITIONS, 2-YEAR EVENT
WSE, VELOCITY AND SHEAR STRESS

Channel	Cross Section	River Station	Q Total (cfs)	W.S. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Vel Left (ft/s)	Vel Right (ft/s)	Shear Chnl (lb/sq ft)	Shear LOB (lb/sq ft)	Shear ROB (lb/sq ft)
REACH 1											
main stem		24762	Bridge								
main stem	XS-1	24735	569	4757.34	0.0010	2.95			0.21		
main stem	XS-2	24602	569	4756.56	0.0024	3.51			0.34		
main stem	XS-3	24564	569	4756.49	0.0012	2.62			0.19		
main stem	XS-4	24490	569	4756.29	0.0018	3.57			0.33		
main stem	XS-5	24380	569	4756.07	0.0023	3.58	0.37		0.35	0.02	
main stem	XS-6	24234	569	4754.91	0.0182	6.07			1.29		
main stem	XS-7	24184	569	4755.14	0.0003	1.43			0.05		
main stem	XS-8	24053	569	4754.86	0.0020	3.62			0.34		
main stem	XS-9	23957	569	4754.45	0.0049	4.48			0.59		
main stem	XS-10	23845	569	4754.33	0.0010	3.10			0.23		
main stem	XS-11	23766	569	4754.29	0.0008	2.50			0.16		
main stem	XS-12	23666	569	4754.11	0.0020	3.05			0.26		
main stem	XS-13	23557	569	4753.83	0.0015	3.52			0.31		
main stem	XS-14	23496	569	4753.81	0.0013	2.85			0.21		
main stem	XS-15	23408	569	4753.60	0.0018	3.55			0.33		
main stem	XS-16	23328	569	4753.31	0.0031	4.15			0.47		
main stem	XS-17	23208	569	4753.13	0.0013	3.43			0.28		
main stem	XS-18	23111	569	4753.17	0.0003	1.75			0.07		
main stem	XS-19	23037	569	4752.93	0.0019	3.79			0.36		
main stem	XS-20	22907	569	4752.63	0.0023	3.88			0.39		
main stem	XS-21	22830	569	4752.63	0.0006	2.49		0.47	0.14		0.01
main stem	XS-22	22757	569	4752.44	0.0034	3.56		0.80	0.38		0.03
main stem	XS-23	22652	569	4752.37	0.0006	2.33	0.12	0.48	0.13	0.00	0.01
main stem	XS-24	22513	569	4751.95	0.0031	4.30		0.52	0.49		0.01
main stem	XS-25	22440	569	4751.89	0.0014	3.13		0.51	0.25		0.01
main stem	XS-26	22308	569	4751.68	0.0023	3.11			0.28		
main stem	XS-27	22146	569	4751.67	0.0002	1.55			0.05		
main stem	XS-28	22057	569	4751.31	0.0035	4.42			0.53		
main stem	XS-29	21942	569	4751.40	0.0002	1.60			0.06		
main stem	XS-30	21777	569	4751.08	0.0024	3.79			0.39		
main stem	XS-31	21729	569	4751.14	0.0005	1.99			0.10		
main stem	XS-32	21606	569	4751.01	0.0008	2.95			0.20		
main stem	XS-33	21552	569	4750.62	0.0045	4.77			0.64		
main stem	XS-34	21501	569	4750.48	0.0026	3.82			0.40		
main stem	XS-35	21453	569	4750.43	0.0016	3.24			0.28		
main stem	XS-36	21309	569	4750.10	0.0022	3.68			0.36		
main stem	XS-37	21171	569	4749.99	0.0007	2.68			0.17		
main stem	XS-38	21004	569	4749.75	0.0016	3.39			0.29		
main stem	XS-39	20848	569	4749.55	0.0014	3.00			0.24		
main stem	XS-40	20694	569	4749.23	0.0017	3.36	0.16		0.30	0.00	
main stem	XS-41	20515	569	4748.98	0.0011	2.78		0.10	0.20		0.00
main stem	XS-42	20283	569	4748.69	0.0011	3.20			0.24		
main stem	XS-43	20008	569	4748.32	0.0013	3.22			0.26		
main stem	XS-44	19800	569	4747.94	0.0023	3.38			0.32		
main stem	XS-45	19692	569	4747.94	0.0003	2.08			0.10		
main stem	XS-46	19492	569	4747.58	0.0020	3.81			0.37		
main stem	XS-47	19319	569	4747.40	0.0008	2.81			0.19		
main stem	XS-48	19168	569	4747.28	0.0008	2.83			0.19		
main stem	XS-49	19098	569	4747.29	0.0004	1.94			0.09		
main stem		19077	Bridge								

PHASES 3 AND 4 HYDRAULIC MODEL
EXISTING CONDITIONS, 2-YEAR EVENT
WSE, VELOCITY AND SHEAR STRESS

Channel	Cross Section	River Station	Q Total (cfs)	W.S. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Vel Left (ft/s)	Vel Right (ft/s)	Shear Chnl (lb/sq ft)	Shear LOB (lb/sq ft)	Shear ROB (lb/sq ft)
REACH 1 SUMMARY			Slope	0.0018	Average	3.20	0.22	0.48	0.29	0.01	0.01
					Maximum	6.07	0.37	0.80	1.29	0.02	0.03
					Minimum	1.43	0.12	0.10	0.05	0.00	0.00
REACH 2											
main stem	XS-50	19058	569	4746.91	0.0003	1.84			0.08		
main stem	XS-51	19010	569	4746.69	0.0042	3.76			0.44		
main stem	XS-52	18974	569	4746.72	0.0009	2.32			0.15		
main stem	XS-53	18878	569	4746.68	0.0005	1.72			0.08		
main stem	XS-54	18709	569	4746.07	0.0045	4.55			0.59		
main stem	XS-55	18570	569	4745.81	0.0010	2.62			0.18		
main stem	XS-56	18353	569	4745.35	0.0018	3.54			0.32		
main stem	XS-57	18185	569	4745.08	0.0015	3.26			0.27		
main stem	XS-58	18039	569	4744.66	0.0029	4.07			0.45		
main stem	XS-59	17904	569	4744.37	0.0020	3.85	0.23		0.38	0.01	
main stem	XS-60	17706	569	4744.13	0.0011	3.01			0.22		
main stem	XS 61	17545	569	4744.02	0.0006	2.64			0.16		
main stem	XS 62	17398	569	4743.80	0.0014	3.40		0.58	0.28		0.01
main stem	XS-63	17304	569	4743.40	0.0040	4.67			0.60		
main stem	XS 64	17170	569	4743.28	0.0010	2.95		0.11	0.21		0.00
main stem	XS-65	17035	569	4743.00	0.0020	3.77			0.37		
main stem	XS 66	16877	569	4742.84	0.0010	2.88			0.20		
main stem	XS 67	16755	569	4742.76	0.0007	2.74			0.17		
main stem	XS 68	16610	569	4742.56	0.0015	3.31			0.28		
main stem	XS-69	16464	569	4742.35	0.0013	3.16			0.25		
main stem	XS 70	16295	569	4742.14	0.0012	3.00			0.23		
main stem	XS 71	16151	569	4741.87	0.0016	3.58			0.32		
main stem	XS 72	15978	569	4741.56	0.0021	3.41			0.32		
main stem	XS-73	15794	569	4741.24	0.0015	3.14			0.26		
main stem	XS 74	15608	569	4741.09	0.0007	2.55	0.21		0.15	0.00	
main stem	XS-75	15438	569	4740.83	0.0015	3.44			0.30		
main stem	XS 76	15276	569	4740.53	0.0022	3.83			0.38		
main stem	XS 77	15142	569	4740.27	0.0017	3.92			0.37		
main stem	XS 78	14996	569	4740.13	0.0013	3.40			0.28		
main stem	XS 79	14757	569	4739.70	0.0022	3.72			0.37		
main stem	XS80	14538	569	4739.40	0.0010	2.95			0.21		
main stem	XS 81	14395	569	4739.30	0.0010	2.56	0.70		0.17	0.03	
main stem	XS 82	14268	569	4738.92	0.0035	4.17			0.49		
main stem	XS 83	14164	569	4738.90	0.0007	2.67	0.25		0.17	0.01	
main stem	XS 84	14049	569	4738.77	0.0014	2.85	0.45		0.22	0.02	
main stem	XS 85	13891	569	4738.40	0.0020	3.40			0.31		
main stem	XS 86	13517	569	4737.38	0.0021	3.23			0.29		
main stem	XS 87	13387	569	4736.90	0.0032	3.65			0.39		
main stem	XS 88	13311	569	4736.80	0.0013	2.63			0.19		
main stem	XS 89	13128	569	4736.54	0.0006	2.23			0.12		
main stem	XS 90	13028	569	4736.32	0.0026	3.29			0.32		
main stem	XS 91	12913	569	4736.03	0.0024	3.04			0.28		
main stem	XS 92	12683	569	4735.61	0.0017	3.10			0.26		
main stem	XS 93	12601	569	4735.38	0.0027	3.65			0.37		
main stem	XS 94	12437	569	4735.05	0.0018	3.61			0.33		
main stem	XS 95	12225	569	4734.59	0.0024	3.89			0.40		
main stem	XS 96	12093	569	4734.39	0.0012	3.35			0.27		

PHASES 3 AND 4 HYDRAULIC MODEL
EXISTING CONDITIONS, 2-YEAR EVENT
WSE, VELOCITY AND SHEAR STRESS

Channel	Cross Section	River Station	Q Total (cfs)	W.S. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Vel Left (ft/s)	Vel Right (ft/s)	Shear Chnl (lb/sq ft)	Shear LOB (lb/sq ft)	Shear ROB (lb/sq ft)
main stem	XS 97	11927	569	4734.17	0.0016	3.25			0.28		
main stem	XS 98	11859	569	4734.07	0.0013	3.14			0.25		
main stem	XS 99	11775	569	4733.75	0.0041	4.25			0.52		
main stem	XS 100	11665	569	4733.45	0.0030	3.56			0.37		
main stem	XS 101	11496	569	4733.19	0.0011	2.88			0.21		
main stem	XS 102	11332	569	4732.72	0.0034	4.18			0.49		
main stem	XS 103	11262	569	4732.73	0.0007	2.37			0.14		
main stem	XS 104	11123	569	4732.64	0.0006	2.38		0.31	0.14		0.00
main stem	XS 105	11007	569	4732.35	0.0031	3.89			0.43		
main stem	XS 106	10868	569	4732.10	0.0014	3.34			0.28		
main stem	XS 107	10772	569	4732.08	0.0005	2.29			0.12		
main stem	XS 108	10701	569	4732.01	0.0018	2.38			0.18		
REACH 2 SUMMARY			Slope	0.0018	Average	3.22	0.37	0.33	0.29	0.01	0.00
					Maximum	4.67	0.70	0.58	0.60	0.03	0.01
					Minimum	1.72	0.21	0.11	0.08	0.00	0.00
REACH 3											
main stem	XS 109	10540	569	4731.80	0.0008	2.72			0.18		
main stem	XS 110	10435	569	4731.69	0.0010	2.98			0.21		
main stem	XS 111	10321	569	4731.44	0.0021	3.81			0.38		
main stem	XS 112	10108	592	4731.16	0.0010	2.70			0.19		
main stem	XS 113	9975	592	4730.93	0.0018	3.13			0.27		
main stem	XS114	9856	592	4730.75	0.0012	2.94			0.22		
main stem	XS 115	9780	592	4730.61	0.0013	3.46			0.29		
main stem	XS 116	9563	592	4730.20	0.0021	3.80			0.37		
main stem	XS 117	9464	592	4729.92	0.0029	4.16			0.46		
main stem	XS 118	9337	592	4729.70	0.0016	3.50			0.31		
main stem	XS 119	9157	592	4729.31	0.0020	3.90		1.69	0.38		0.08
main stem	XS 120	9018	592	4729.01	0.0025	3.86			0.40		
main stem	XS 121	8852	592	4728.74	0.0014	3.25			0.27		
main stem	XS 122	8715	592	4728.42	0.0022	3.99			0.40		
main stem	XS 123	8603	592	4728.37	0.0009	2.74			0.18		
main stem	XS124	8409	592	4728.12	0.0019	3.08			0.27		
main stem	XS 125	8339	592	4727.80	0.0036	4.22			0.50		
main stem	XS 126	8227	592	4727.63	0.0015	3.22			0.27		
main stem	XS 127	8075	592	4727.47	0.0009	2.93			0.21		
main stem	XS 128	7925	592	4727.48	0.0002	1.18			0.03		
main stem	XS 129	7850	592	4727.34	0.0011	2.79			0.20		
main stem	XS 130	7618	592	4726.99	0.0015	3.32			0.28		
main stem	XS 131	7537	592	4726.58	0.0046	4.78			0.64		
main stem	XS132	7468	592	4726.44	0.0021	3.87			0.38		
main stem	XS 133	7392	592	4726.40	0.0009	2.79			0.19		
main stem	XS 134	7319	592	4726.22	0.0018	3.59			0.33		
main stem	XS 135	7287	592	4726.21	0.0009	3.03			0.22		
REACH 3 SUMMARY			Slope	0.0017	Average	3.32		1.69	0.30		0.08
					Maximum	4.78		1.69	0.64		0.08
					Minimum	1.18		1.69	0.03		0.08
REACH 4											
main stem	XS 136	7239	365	4726.16	0.0014	2.90			0.22		
main stem	XS 137	7179	365	4725.96	0.0022	3.67			0.36		
main stem	XS 138	7132	365	4725.98	0.0009	2.29			0.14		

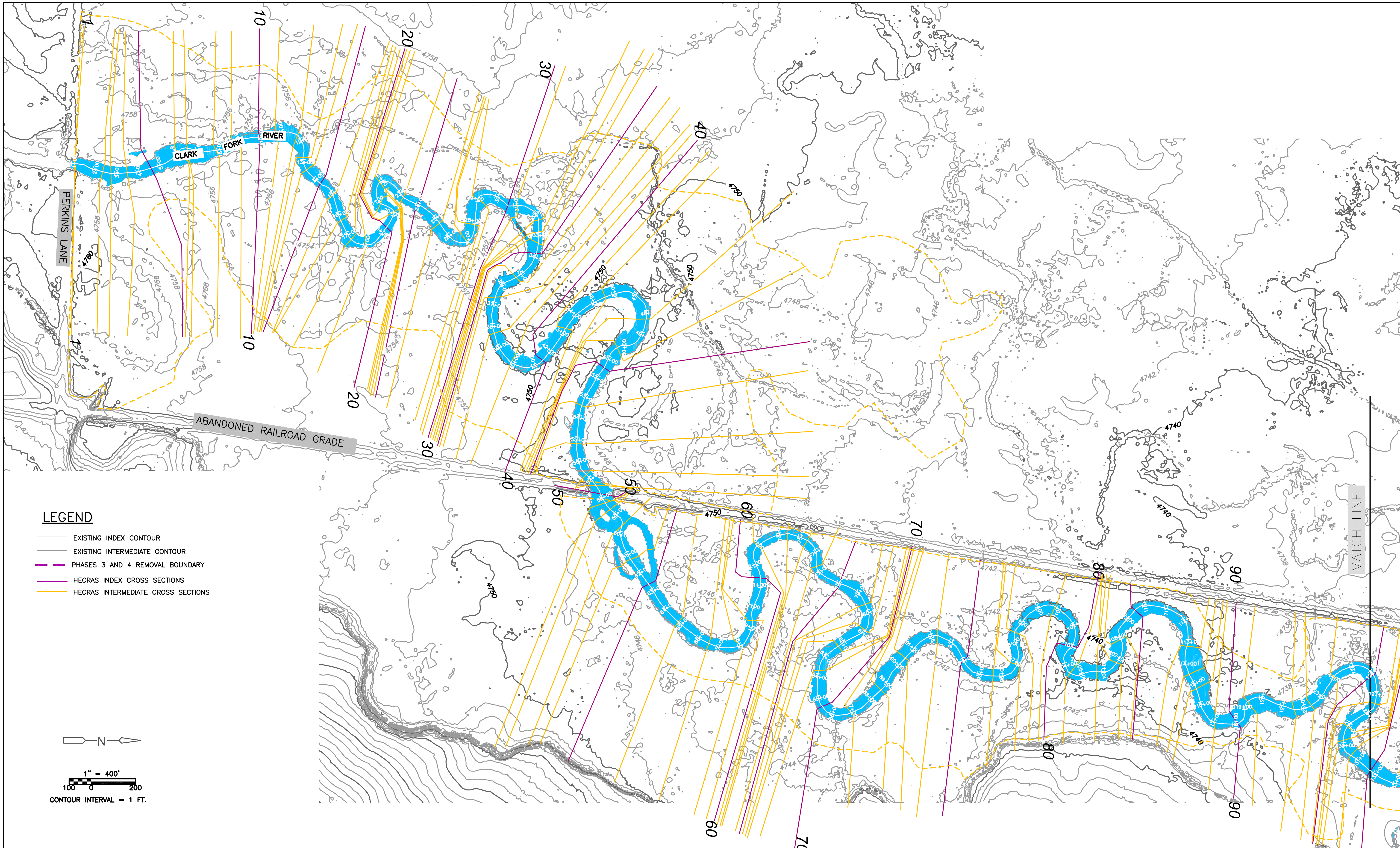
PHASES 3 AND 4 HYDRAULIC MODEL
EXISTING CONDITIONS, 2-YEAR EVENT
WSE, VELOCITY AND SHEAR STRESS

Channel	Cross Section	River Station	Q Total (cfs)	W.S. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Vel Left (ft/s)	Vel Right (ft/s)	Shear Chnl (lb/sq ft)	Shear LOB (lb/sq ft)	Shear ROB (lb/sq ft)
main stem	XS 139	7010	365	4725.68	0.0023	3.56			0.35		
main stem	XS 140	6906	365	4725.49	0.0018	3.33			0.29		
main stem	XS 141	6807	365	4725.34	0.0016	3.18			0.27		
main stem	XS 142	6627	365	4725.23	0.0005	2.22			0.12		
main stem	XS 143	6446	365	4724.98	0.0014	3.19	0.03		0.26		
REACH 4 SUMMARY			Slope	0.0015	Average	3.04	0.03		0.25		
					Maximum	3.67	0.03		0.36		
					Minimum	2.22	0.03		0.12		
REACH 5											
main stem	XS 144	6363	592	4724.87	0.0014	3.25			0.26		
main stem	XS 145	6255	592	4724.70	0.0016	3.19			0.27		
main stem	XS 146	6083	592	4724.32	0.0022	3.97			0.40		
main stem	XS 147	5888	592	4724.08	0.0009	2.86		0.25	0.20		0.00
main stem	XS 148	5634	592	4723.83	0.0011	2.89			0.21		
main stem	XS 149	5501	592	4723.53	0.0015	3.56			0.31		
main stem	XS 150	5334	592	4723.21	0.0014	3.40			0.29		
main stem	XS 151	5170	592	4723.00	0.0011	3.02			0.22		
main stem	XS 152	5040	592	4722.85	0.0011	3.12			0.23		
main stem	XS 153	4869	592	4722.54	0.0020	3.66			0.35		
main stem	XS 154	4699	592	4722.29	0.0013	3.27			0.27		
main stem	XS 155	4600	592	4722.18	0.0010	3.03			0.22		
main stem	XS 156	4427	592	4721.95	0.0023	3.27			0.30		
main stem	XS 157	4310	592	4721.66	0.0021	3.39			0.31		
main stem	XS 158	4158	592	4721.36	0.0018	3.36			0.30		
main stem	XS 159	3996	592	4721.16	0.0011	3.02	0.16	0.13	0.23	0.01	0.00
main stem	XS 160	3827	592	4720.88	0.0016	3.11			0.26		
main stem	XS 161	3691	592	4720.61	0.0013	2.98			0.23		
main stem	XS 162	3544	592	4720.30	0.0018	3.07			0.26		
main stem	XS 163	3402	592	4719.95	0.0022	3.56			0.34		
main stem	XS 164	3307	592	4719.68	0.0018	3.49		0.07	0.32		
REACH 5 SUMMARY			Slope	0.0017	Average	3.26	0.16	0.15	0.28	0.01	0.00
					Maximum	3.97	0.16	0.25	0.40	0.01	0.00
					Minimum	2.86	0.16	0.07	0.20	0.01	0.00
REACH 6											
main stem	XS 165	3183	394	4719.51	0.0014	3.14			0.25		
main stem	XS 166	3129	394	4719.45	0.0012	2.79			0.20		
main stem	XS 167	2971	394	4719.20	0.0012	2.89			0.22		
main stem	XS 168	2849	394	4719.07	0.0010	2.42			0.16		
main stem	XS 169	2779	394	4718.88	0.0013	2.99			0.23		
main stem	XS 170	2725	394	4718.64	0.0026	3.62			0.37		
main stem	XS 171	2618	394	4718.29	0.0020	3.45			0.32		
main stem	XS 172	2554	394	4718.04	0.0031	4.16	0.33		0.47	0.01	
main stem	XS 174	2451	394	4717.99	0.0011	2.64			0.18		
main stem	XS 175	2361	394	4717.86	0.0012	2.89			0.21		
main stem	XS 176	2308	394	4717.81	0.0014	2.55			0.18		
main stem	XS 177	2236	394	4717.37	0.0052	4.49			0.60		
REACH 6 SUMMARY			Slope	0.0023	Average	3.17	0.33		0.28	0.01	
					Maximum	4.49	0.33		0.60	0.01	
					Minimum	2.42	0.33		0.16	0.01	

PHASES 3 AND 4 HYDRAULIC MODEL
EXISTING CONDITIONS, 2-YEAR EVENT
WSE, VELOCITY AND SHEAR STRESS

Channel	Cross Section	River Station	Q Total (cfs)	W.S. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Vel Left (ft/s)	Vel Right (ft/s)	Shear Chnl (lb/sq ft)	Shear LOB (lb/sq ft)	Shear ROB (lb/sq ft)
REACH 7											
main stem	XS 178	2173	592	4717.20	0.0026	4.20			0.46		
main stem	XS 179	1983	592	4717.06	0.0009	2.64			0.17		
main stem	XS 180	1824	592	4716.82	0.0019	3.16			0.28		
main stem	XS 181	1710	592	4716.72	0.0012	2.89	0.12		0.22	0.00	
main stem	XS 182	1576	592	4716.51	0.0017	3.13			0.27		
main stem	XS 184	1494	592	4716.48	0.0010	2.64			0.18		
main stem	XS 185	1389	592	4716.35	0.0010	2.83			0.20		
main stem	XS 186	1239	592	4716.21	0.0012	2.61			0.18		
main stem	XS 187	1102	592	4716.15	0.0004	2.00			0.10		
main stem	XS 188	998	592	4716.11	0.0004	1.98			0.09		
main stem	XS 189	919	592	4716.06	0.0005	2.11			0.11		
REACH 7 SUMMARY			Slope	0.0017	Average	2.74	0.12		0.21	0.00	
					Maximum	4.20	0.12		0.46	0.00	
					Minimum	1.98	0.12		0.09	0.00	
SECONDARY CHANNEL- HADLEY A											
Hadley A	XS 136A	1192	227	4726.16	0.0009	2.23			0.13		
Hadley A	XS 136B	1104	227	4726.04	0.0009	2.26			0.14		
Hadley A	XS 136C	966	227	4725.92	0.0010	2.28			0.14		
Hadley A	XS 136D	846	227	4725.78	0.0013	2.34			0.16		
Hadley A	XS 136E	752	227	4725.69	0.0007	1.97			0.11		
Hadley A	XS 136F	644	227	4725.55	0.0011	2.55			0.18		
Hadley A	XS 136G	488	227	4725.31	0.0021	2.59			0.21		
Hadley A	XS 136H	342	227	4725.27	0.0002	1.33			0.04		
Hadley A	XS 136I	224	227	4725.16	0.0013	2.13			0.14		
Hadley A	XS 136J	135	227	4725.04	0.0010	2.40			0.15		
Hadley A	XS 136K	54	227	4724.93	0.0013	2.63			0.19		
HADLEY A SUMMARY			Slope	0.0012	Average	2.25			0.14		
					Maximum	2.63			0.21		
					Minimum	1.33			0.04		
SECONDARY CHANNEL - HADLEY B											
Hadley B	SXS 165A	1458	198	4719.51	0.0012	2.01			0.12		
Hadley B	SXS 165B	1345	198	4719.34	0.0014	2.67			0.20		
Hadley B	SXS 165C	1219	198	4719.14	0.0015	2.81			0.22		
Hadley B	SXS 165D	1064	198	4718.64	0.0036	3.59			0.39		
Hadley B	SXS 165E	945	198	4718.42	0.0011	2.54			0.17		
Hadley B	SXS 165F	825	198	4718.24	0.0015	2.55			0.19		
Hadley B	SXS 165G	752	198	4718.14	0.0011	2.30			0.15		
Hadley B	SXS 165H	634	198	4718.08	0.0004	1.72			0.08		
Hadley B	SXS 165I	535	198	4718.02	0.0008	1.84			0.10		
Hadley B	SXS 165J	387	198	4717.76	0.0022	2.90			0.25		
Hadley B	SXS 165K	270	198	4717.67	0.0007	1.86			0.10		
Hadley B	SXS 165L	126	198	4717.57	0.0006	1.97			0.10		
Hadley B	SXS 165M	25	198	4717.52	0.0005	1.79			0.08		
HADLEY B SUMMARY			Slope	0.0016	Average	2.35			0.17		
					Maximum	3.59			0.39		
					Minimum	1.72			0.08		

K:\CFR- PHASES 3 AND 4\HecRAS\HecRAS Cross sections_Q2 INUNDATION EC.dwg SAVED: 5/9/2011 PRINTED: 2/11/2016 BY: MAINZHAUSENK



CDM Smith

Figure No. A1

CLARK FORK RIVER -PHASES 3 AND 4

2-YEAR EXISTING CONDITIONS INUNDATION MAP

JAN 2016

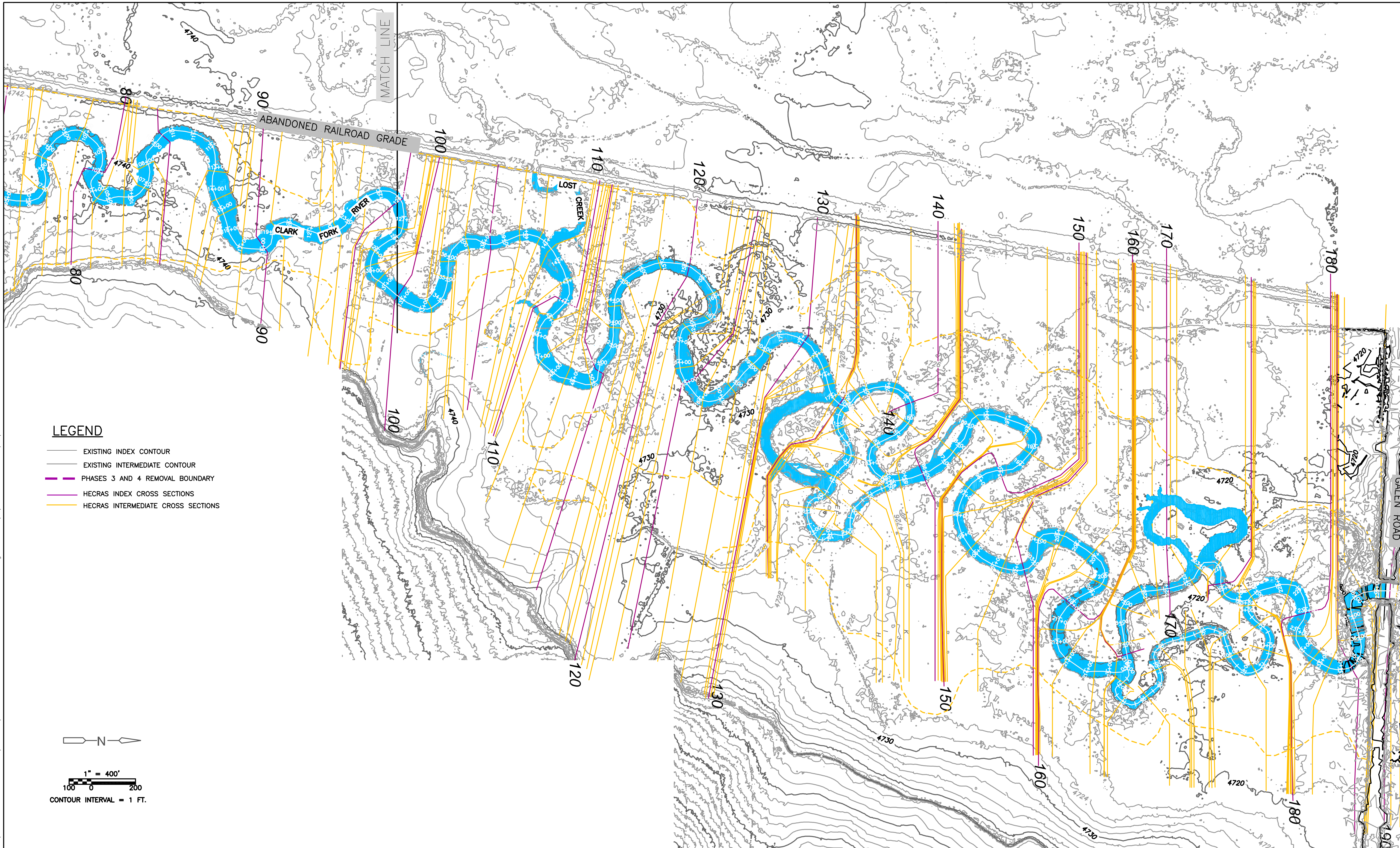


Figure No. A2
CLARK FORK RIVER -PHASES 3 AND 4
2-YEAR EXISTING CONDITIONS INUNDATION MAP
JAN 2016

PHASES 3 AND 4 HYDRAULIC MODEL
EXISTING CONDITIONS, 10-YEAR EVENT
WSE, VELOCITY AND SHEAR STRESS

Reach	Cross Section	River Sta (ft)	Q Total (cfs)	W.S. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Vel Left (ft/s)	Vel Right (ft/s)	Shear Chan (lb/sq ft)	Shear LOB (lb/sq ft)	Shear ROB (lb/sq ft)
REACH 1											
main stem		24762	Bridge								
main stem	XS-1	24735	1169	4758.57	0.0017	4.44			0.45		
main stem	XS-2	24602	1169	4757.85	0.0029	4.57	0.36	0.66	0.53	0.02	0.02
main stem	XS-3	24564	1169	4757.84	0.0014	3.47	0.70	0.59	0.29	0.04	0.01
main stem	XS-4	24490	1169	4757.42	0.0034	5.25	0.39		0.68	0.02	
main stem	XS-5	24380	1169	4757.07	0.0031	5.19	1.57	1.51	0.66	0.16	0.07
main stem	XS-6	24234	1169	4756.65	0.0031	4.10	0.60	0.73	0.46	0.04	0.02
main stem	XS-7	24184	1169	4756.75	0.0003	1.93			0.08		
main stem	XS-8	24053	1169	4756.31	0.0024	4.82			0.55		
main stem	XS-9	23957	1169	4756.07	0.0029	4.76	1.13	0.85	0.56	0.09	0.04
main stem	XS-10	23845	1169	4755.87	0.0018	4.33	0.37	0.71	0.43	0.02	0.03
main stem	XS-11	23766	1169	4755.85	0.0010	3.36	0.66	0.64	0.25	0.03	0.02
main stem	XS-12	23666	1169	4755.76	0.0013	3.22		1.45	0.26		0.07
main stem	XS-13	23557	1169	4755.42	0.0022	4.29	0.59	0.86	0.46	0.05	0.03
main stem	XS-14	23496	1169	4755.39	0.0013	3.67	0.37	0.49	0.31	0.02	0.01
main stem	XS-15	23408	1169	4755.11	0.0033	4.63		0.22	0.56		
main stem	XS-16	23328	1169	4754.79	0.0030	5.18	0.15	1.48	0.65	0.01	0.09
main stem	XS-17	23208	1169	4754.44	0.0027	5.17		0.26	0.63		0.01
main stem	XS-18	23111	1169	4754.55	0.0005	2.51	0.35		0.14	0.01	
main stem	XS-19	23037	1169	4754.16	0.0032	5.07	0.66	0.90	0.64	0.06	0.04
main stem	XS-20	22907	1169	4753.66	0.0037	5.58	0.54	0.88	0.76	0.04	0.04
main stem	XS-21	22830	1169	4753.74	0.0007	3.26	0.30	1.02	0.23	0.01	0.03
main stem	XS-22	22757	1169	4753.72	0.0013	2.96	0.51	1.23	0.23	0.03	0.05
main stem	XS-23	22652	1169	4753.67	0.0006	2.68	0.50	0.85	0.16	0.02	0.02
main stem	XS-24	22513	1169	4753.07	0.0036	5.59		1.75	0.76		0.09
main stem	XS-25	22440	1169	4752.96	0.0024	4.36		1.21	0.47		0.04
main stem	XS-26	22308	1169	4752.68	0.0024	3.97		1.32	0.41		0.05
main stem	XS-27	22146	1169	4752.65	0.0004	2.51	0.18	0.69	0.13	0.00	0.01
main stem	XS-28	22057	1169	4752.38	0.0032	4.61	0.32	2.23	0.55	0.02	0.14
main stem	XS-29	21942	1169	4752.39	0.0004	2.41		0.74	0.13		0.02
main stem	XS-30	21777	1169	4752.12	0.0026	4.06		1.80	0.44		0.09
main stem	XS-31	21729	1169	4752.17	0.0005	2.10	0.34	0.93	0.11	0.01	0.02
main stem	XS-32	21606	1169	4752.06	0.0014	2.68	0.41	1.33	0.20	0.02	0.06
main stem	XS-33	21552	1169	4751.93	0.0024	3.37	0.61	1.84	0.32	0.04	0.10
main stem	XS-34	21501	1169	4751.87	0.0012	2.80	0.16	1.32	0.21	0.00	0.05
main stem	XS-35	21453	1169	4751.82	0.0010	3.12	0.16	1.38	0.23	0.00	0.05
main stem	XS-36	21309	1169	4751.68	0.0013	3.18	0.65	1.54	0.25	0.04	0.07
main stem	XS-37	21171	1169	4751.38	0.0014	3.86	0.33	0.88	0.35	0.01	0.03
main stem	XS-38	21004	1169	4751.02	0.0022	4.45	1.15	0.99	0.48	0.10	0.04
main stem	XS-39	20848	1169	4750.82	0.0014	3.64	0.95	0.67	0.32	0.07	0.02
main stem	XS-40	20694	1169	4750.65	0.0012	3.23	0.96	1.28	0.25	0.07	0.05
main stem	XS-41	20515	1169	4750.46	0.0007	2.88	0.73	1.25	0.19	0.04	0.03
main stem	XS-42	20283	1169	4750.08	0.0015	4.14	0.34	1.20	0.39	0.01	0.04
main stem	XS-43	20008	1169	4749.72	0.0018	3.60	0.99	1.14	0.33	0.03	0.04
main stem	XS-44	19800	1169	4749.31	0.0021	3.89	1.17	1.00	0.39	0.04	0.03
main stem	XS-45	19692	1169	4749.26	0.0006	3.19	1.08	0.51	0.21	0.03	0.01
main stem	XS-46	19492	1169	4748.85	0.0033	4.44	1.07	1.27	0.53	0.04	0.05
main stem	XS-47	19319	1169	4748.36	0.0022	4.58			0.50		
main stem	XS-48	19168	1169	4747.98	0.0025	4.95	0.30	0.74	0.58	0.01	0.03
main stem	XS-49	19098	1169	4748.09	0.0007	2.75	1.41	0.25	0.17	0.04	0.00
main stem		19077	Bridge								

PHASES 3 AND 4 HYDRAULIC MODEL
EXISTING CONDITIONS, 10-YEAR EVENT
WSE, VELOCITY AND SHEAR STRESS

Reach	Cross	River Sta	Q Total	W.S. Elev	E.G. Slope	Vel Chnl	Vel Left	Vel Right	Shear Chan	Shear LOB	Shear ROB
	Section	(ft)	(cfs)	(ft)	(ft/ft)	(ft/s)	(ft/s)	(ft/s)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)
REACH 1 SUMMARY			Slope	0.0019	Average	3.85	0.62	1.04	0.39	0.03	0.04
					Maximum	5.59	1.57	2.23	0.76	0.16	0.14
					Minimum	1.93	0.15	0.22	0.08	0.00	0.00
REACH 2											
main stem	XS-50	19058	1169	4747.90	0.0007	3.02	0.48	0.16	0.20	0.02	0.00
main stem	XS-51	19010	1169	4747.54	0.0047	5.13			0.72		
main stem	XS-52	18974	1169	4747.59	0.0018	3.49	0.07		0.32	0.00	
main stem	XS-53	18878	1169	4747.53	0.0008	2.59	0.64		0.17	0.04	
main stem	XS-54	18709	1169	4747.12	0.0031	3.35	1.52		0.34	0.18	
main stem	XS-55	18570	1169	4746.87	0.0012	2.95	0.88	0.30	0.22	0.06	0.01
main stem	XS-56	18353	1169	4746.55	0.0014	3.71	0.98		0.33	0.07	
main stem	XS-57	18185	1169	4746.38	0.0009	3.18	0.82	0.61	0.23	0.05	0.01
main stem	XS-58	18039	1169	4746.20	0.0015	3.63	0.90	0.31	0.32	0.07	0.01
main stem	XS-59	17904	1169	4745.87	0.0019	4.61	0.83	0.72	0.49	0.05	0.02
main stem	XS-60	17706	1169	4745.64	0.0012	3.61	0.68	0.61	0.30	0.04	0.02
main stem	XS 61	17545	1169	4745.42	0.0011	3.96	0.71	0.63	0.34	0.04	0.02
main stem	XS 62	17398	1169	4745.22	0.0015	4.17	0.61	1.58	0.39	0.04	0.07
main stem	XS-63	17304	1169	4744.92	0.0032	4.95		1.87	0.62		0.10
main stem	XS 64	17170	1169	4744.77	0.0012	3.99	0.43	1.51	0.35	0.02	0.06
main stem	XS-65	17035	1169	4744.30	0.0027	5.34	0.86	0.93	0.66	0.07	0.03
main stem	XS 66	16877	1169	4744.11	0.0015	4.25	0.64	0.58	0.41	0.03	0.01
main stem	XS 67	16755	1169	4744.01	0.0011	3.86	0.70	1.22	0.32	0.03	0.04
main stem	XS 68	16610	1169	4743.96	0.0009	2.91	1.12		0.20	0.06	
main stem	XS-69	16464	1169	4743.72	0.0013	3.81	0.96	0.43	0.34	0.05	0.01
main stem	XS 70	16295	1169	4743.70	0.0006	2.47	0.86		0.14	0.04	
main stem	XS 71	16151	1169	4743.53	0.0011	3.35	0.98	1.00	0.26	0.06	0.03
main stem	XS 72	15978	1169	4743.27	0.0014	3.64	0.90	1.30	0.32	0.04	0.04
main stem	XS-73	15794	1169	4742.98	0.0014	3.95	0.76	0.88	0.36	0.04	0.02
main stem	XS 74	15608	1169	4742.81	0.0008	3.57	0.87	0.79	0.27	0.04	0.02
main stem	XS-75	15438	1169	4742.51	0.0015	4.49	0.92	1.78	0.44	0.06	0.07
main stem	XS 76	15276	1169	4742.16	0.0021	4.93	0.93	1.53	0.55	0.06	0.06
main stem	XS 77	15142	1169	4741.71	0.0027	5.78	1.18		0.74	0.09	
main stem	XS 78	14996	1169	4741.53	0.0023	4.88	0.89	0.93	0.56	0.06	0.03
main stem	XS 79	14757	1169	4741.02	0.0021	4.68	0.75	2.10	0.51	0.04	0.09
main stem	XS80	14538	1169	4740.84	0.0010	3.41		1.93	0.26		0.07
main stem	XS 81	14395	1169	4740.77	0.0008	2.91	1.18	1.67	0.19	0.07	0.05
main stem	XS 82	14268	1169	4740.26	0.0034	5.29	1.07		0.69	0.08	
main stem	XS 83	14164	1169	4740.22	0.0011	4.02	0.97	0.50	0.35	0.06	0.01
main stem	XS 84	14049	1169	4740.12	0.0014	3.59	1.08	1.25	0.31	0.07	0.04
main stem	XS 85	13891	1169	4739.65	0.0024	4.58		1.52	0.51		0.06
main stem	XS 86	13517	1169	4738.56	0.0023	4.33	1.05		0.46	0.06	
main stem	XS 87	13387	1169	4738.23	0.0027	4.20			0.46		
main stem	XS 88	13311	1169	4738.15	0.0013	3.47		0.62	0.29		0.01
main stem	XS 89	13128	1169	4737.88	0.0009	3.25	0.32	0.61	0.24	0.01	0.01
main stem	XS 90	13028	1169	4737.66	0.0020	3.96		1.04	0.39		0.04
main stem	XS 91	12913	1169	4737.52	0.0016	3.43		0.34	0.30		0.01
main stem	XS 92	12683	1169	4737.12	0.0016	3.97	0.57	1.07	0.37	0.02	0.04
main stem	XS 93	12601	1169	4736.96	0.0018	4.18	1.60	1.08	0.41	0.10	0.04
main stem	XS 94	12437	1169	4736.51	0.0022	5.05	0.76	0.53	0.58	0.03	0.01
main stem	XS 95	12225	1169	4736.05	0.0024	5.02	0.13	2.52	0.59		0.14
main stem	XS 96	12093	1169	4735.77	0.0019	4.90	0.35	1.80	0.53	0.01	0.08

PHASES 3 AND 4 HYDRAULIC MODEL
EXISTING CONDITIONS, 10-YEAR EVENT
WSE, VELOCITY AND SHEAR STRESS

Reach	Cross Section	River Sta (ft)	Q Total (cfs)	W.S. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Vel Left (ft/s)	Vel Right (ft/s)	Shear Chan (lb/sq ft)	Shear LOB (lb/sq ft)	Shear ROB (lb/sq ft)
main stem	XS 97	11927	1169	4735.53	0.0018	4.26	1.32	0.67	0.43	0.07	0.02
main stem	XS 98	11859	1169	4735.46	0.0014	4.00	1.42	1.02	0.36	0.08	0.03
main stem	XS 99	11775	1169	4735.22	0.0028	4.60	2.07		0.53	0.17	
main stem	XS 100	11665	1169	4735.03	0.0019	3.98	0.99	0.54	0.39	0.05	0.01
main stem	XS 101	11496	1169	4734.82	0.0011	3.69	1.09	0.76	0.30	0.05	0.02
main stem	XS 102	11332	1169	4734.41	0.0024	4.82	1.62	0.61	0.55	0.11	0.02
main stem	XS 103	11262	1169	4734.45	0.0007	3.15	0.78	0.62	0.21	0.03	0.01
main stem	XS 104	11123	1169	4734.35	0.0007	3.23	0.24	1.26	0.22	0.00	0.04
main stem	XS 105	11007	1169	4734.05	0.0021	4.50	0.71	0.43	0.48	0.03	0.01
main stem	XS 106	10868	1169	4733.79	0.0016	4.57	0.60	0.45	0.46	0.02	0.01
main stem	XS 107	10772	1169	4733.79	0.0007	3.34		1.17	0.23		0.03
main stem	XS 108	10701	1169	4733.81	0.0007	2.33	0.81	0.35	0.13	0.05	0.01
REACH 2 SUMMARY			Slope	0.0017	Average	3.97	0.87	0.98	0.38	0.05	0.03
					Maximum	5.78	2.07	2.52	0.74	0.18	0.14
					Minimum	2.33	0.07	0.16	0.13	0.00	0.00
REACH 3											
main stem	XS 109	10540	1169	4733.56	0.0010	3.64	0.11	1.24	0.29	0.00	0.04
main stem	XS 110	10435	1169	4733.39	0.0012	4.09	0.56	1.00	0.37	0.03	0.03
main stem	XS 111	10321	1169	4733.06	0.0022	5.11	0.28	1.86	0.59	0.01	0.08
main stem	XS 112	10108	1221	4732.87	0.0010	3.46	0.42	1.04	0.27	0.02	0.03
main stem	XS 113	9975	1221	4732.69	0.0013	3.68	0.25	0.07	0.32	0.01	
main stem	XS114	9856	1221	4732.55	0.0012	3.60	0.56		0.30	0.03	
main stem	XS 115	9780	1221	4732.31	0.0018	4.67	0.63	0.74	0.49	0.04	0.02
main stem	XS 116	9563	1221	4731.85	0.0023	4.89	0.77	0.72	0.55	0.06	0.02
main stem	XS 117	9464	1221	4731.60	0.0026	5.01	0.83	1.20	0.60	0.07	0.04
main stem	XS 118	9337	1221	4731.38	0.0018	4.65	0.81	0.45	0.48	0.06	0.01
main stem	XS 119	9157	1221	4730.94	0.0022	5.19	1.28	2.65	0.60	0.14	0.12
main stem	XS 120	9018	1221	4730.68	0.0022	4.80		0.76	0.54		0.02
main stem	XS 121	8852	1221	4730.45	0.0015	4.26	0.16	0.47	0.41	0.01	0.01
main stem	XS 122	8715	1221	4730.02	0.0025	5.38	0.31	1.25	0.65	0.02	0.05
main stem	XS 123	8603	1221	4730.00	0.0011	3.84	0.38	0.76	0.32	0.02	0.02
main stem	XS124	8409	1221	4729.80	0.0014	3.66	0.39		0.32	0.02	
main stem	XS 125	8339	1221	4729.48	0.0026	4.99		0.63	0.59		0.02
main stem	XS 126	8227	1221	4729.36	0.0014	4.10	0.47		0.38	0.03	
main stem	XS 127	8075	1221	4729.18	0.0012	4.06	0.21		0.36	0.01	
main stem	XS 128	7925	1221	4729.26	0.0002	1.56	0.06	0.36	0.05	0.00	0.00
main stem	XS 129	7850	1221	4729.04	0.0011	3.63	0.68		0.30	0.04	
main stem	XS 130	7618	1221	4728.61	0.0017	4.49	0.38		0.45	0.03	
main stem	XS 131	7537	1221	4728.19	0.0038	5.75		1.21	0.81		0.05
main stem	XS132	7468	1221	4728.05	0.0024	5.21		0.92	0.62		0.03
main stem	XS 133	7392	1221	4728.05	0.0012	3.84			0.33		
main stem	XS 134	7319	1221	4727.79	0.0021	4.84			0.53		
main stem	XS 135	7287	1221	4727.79	0.0017	4.21	0.32		0.41	0.02	
REACH 3 SUMMARY			Slope	0.0018	Average	4.32	0.47	0.96	0.44	0.03	0.03
					Maximum	5.75	1.28	2.65	0.81	0.14	0.12
					Minimum	1.56	0.06	0.07	0.05	0.00	0.00
REACH 4											
main stem	XS 136	7239	725	4727.76	0.0013	3.62	0.07		0.31	0.00	
main stem	XS 137	7179	725	4727.56	0.0025	4.35			0.48		
main stem	XS 138	7132	725	4727.61	0.0008	2.85	0.49	0.40	0.19	0.03	0.02

PHASES 3 AND 4 HYDRAULIC MODEL
EXISTING CONDITIONS, 10-YEAR EVENT
WSE, VELOCITY AND SHEAR STRESS

Reach	Cross	River Sta	Q Total	W.S. Elev	E.G. Slope	Vel Chnl	Vel Left	Vel Right	Shear Chan	Shear LOB	Shear ROB
	Section	(ft)	(cfs)	(ft)	(ft/ft)	(ft/s)	(ft/s)	(ft/s)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)
main stem	XS 139	7010	725	4727.29	0.0019	4.25	0.72	0.55	0.43	0.07	0.05
main stem	XS 140	6906	725	4727.13	0.0016	4.03		0.70	0.38		0.06
main stem	XS 141	6807	725	4726.99	0.0015	3.97	0.18	0.60	0.37	0.01	0.05
main stem	XS 142	6627	725	4726.89	0.0006	2.99	0.43	0.43	0.19	0.02	0.02
main stem	XS 143	6446	725	4726.62	0.0015	4.07	0.88	0.52	0.38	0.08	0.04
main stem	XS 144	6363	1221	4726.42	0.0019	4.38	0.08	0.71	0.45		0.02
REACH 4 SUMMARY			Slope	0.0015	Average	3.83	0.41	0.56	0.35	0.04	0.04
					Maximum	4.38	0.88	0.71	0.48	0.08	0.06
					Minimum	2.85	0.07	0.40	0.19	0.00	0.02

REACH 5

main stem	XS 144	6363	1221	4726.42	0.0019	4.38	0.08	0.71	0.45		0.02
main stem	XS 145	6255	1221	4726.28	0.0015	3.97	0.60	1.84	0.37	0.05	0.07
main stem	XS 146	6083	1221	4725.83	0.0027	5.02	1.28	1.24	0.60	0.17	0.05
main stem	XS 147	5888	1221	4725.66	0.0010	3.30	0.26	1.25	0.25	0.01	0.04
main stem	XS 148	5634	1221	4725.42	0.0013	3.69	0.42	1.62	0.31	0.03	0.06
main stem	XS 149	5501	1221	4725.28	0.0014	3.86		1.42	0.35		0.05
main stem	XS 150	5334	1221	4724.99	0.0013	3.84		1.51	0.34		0.05
main stem	XS 151	5170	1221	4724.67	0.0014	4.10		1.15	0.38		0.03
main stem	XS 152	5040	1221	4724.44	0.0014	4.45	0.57	0.73	0.43	0.04	0.03
main stem	XS 153	4869	1221	4724.09	0.0024	4.86	0.67	0.92	0.56	0.05	0.05
main stem	XS 154	4699	1221	4723.82	0.0017	4.30	0.88	0.61	0.42	0.07	0.02
main stem	XS 155	4600	1221	4723.65	0.0015	4.31	0.83		0.41	0.07	
main stem	XS 156	4427	1221	4723.53	0.0013	3.48	0.71	1.90	0.29	0.05	0.12
main stem	XS 157	4310	1221	4723.21	0.0021	4.13	0.03		0.42		
main stem	XS 158	4158	1221	4722.85	0.0022	4.35			0.46		
main stem	XS 159	3996	1221	4722.65	0.0012	3.96	0.63	1.32	0.35	0.04	0.07
main stem	XS 160	3827	1221	4722.35	0.0019	3.95			0.39		
main stem	XS 161	3691	1221	4722.05	0.0017	4.01			0.38		
main stem	XS 162	3544	1221	4721.77	0.0017	3.88			0.36		
main stem	XS 163	3402	1221	4721.39	0.0025	4.40			0.48		
main stem	XS 164	3307	1221	4721.16	0.0020	4.26	1.00	1.29	0.44	0.09	0.08
REACH 5 SUMMARY			Slope	0.0017	Average	4.12	0.61	1.25	0.40	0.06	0.05
					Maximum	5.02	1.28	1.90	0.60	0.17	0.12
					Minimum	3.30	0.03	0.61	0.25	0.01	0.02

REACH 6

main stem	XS 165	3183	796	4720.95	0.0019	4.00	0.87		0.39	0.08	
main stem	XS 166	3129	796	4720.87	0.0014	3.75			0.33		
main stem	XS 167	2971	796	4720.58	0.0017	3.81			0.36		
main stem	XS 168	2849	796	4720.44	0.0011	3.23			0.25		
main stem	XS 169	2779	796	4720.17	0.0018	4.16			0.41		
main stem	XS 170	2725	796	4719.91	0.0027	4.67			0.54		
main stem	XS 171	2618	796	4719.68	0.0024	4.13			0.44		
main stem	XS 172	2554	796	4719.46	0.0021	4.48	2.81	0.97	0.48	0.19	0.05
main stem	XS 174	2451	796	4719.40	0.0011	3.47	0.51	0.88	0.28	0.01	0.04
main stem	XS 175	2361	796	4719.21	0.0021	3.87			0.38		
main stem	XS 176	2308	796	4719.19	0.0011	3.03	1.18	0.53	0.23	0.04	0.02
main stem	XS 177	2236	796	4718.88	0.0034	4.39	1.33	0.96	0.52	0.07	0.06
REACH 6 SUMMARY			Slope	0.0026	Average	3.92	1.34	0.84	0.38	0.08	0.04
					Maximum	4.67	2.81	0.97	0.54	0.19	0.06
					Minimum	3.03	0.51	0.53	0.23	0.01	0.02

PHASES 3 AND 4 HYDRAULIC MODEL
EXISTING CONDITIONS, 10-YEAR EVENT
WSE, VELOCITY AND SHEAR STRESS

Reach	Cross Section	River Sta (ft)	Q Total (cfs)	W.S. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Vel Left (ft/s)	Vel Right (ft/s)	Shear Chan (lb/sq ft)	Shear LOB (lb/sq ft)	Shear ROB (lb/sq ft)
REACH 7											
main stem	XS 178	2173	1221	4718.37	0.0038	6.07	1.88	0.53	0.87	0.12	0.02
main stem	XS 179	1983	1221	4718.20	0.0014	3.92	1.02	0.78	0.35	0.04	0.03
main stem	XS 180	1824	1221	4717.93	0.0021	4.05	1.26	1.26	0.41	0.06	0.07
main stem	XS 181	1710	1221	4717.83	0.0013	3.49	1.33		0.29	0.05	
main stem	XS 182	1576	1221	4717.79	0.0009	2.55	1.19		0.16	0.04	
main stem	XS 184	1494	1221	4717.79	0.0005	2.20	1.01	0.22	0.12	0.03	0.00
main stem	XS 185	1389	1221	4717.73	0.0005	2.51	1.24	0.44	0.14	0.04	0.01
main stem	XS 186	1239	1221	4717.69	0.0005	2.23	1.27	0.54	0.12	0.04	0.01
main stem	XS 187	1102	1221	4717.62	0.0004	2.46	1.20	0.30	0.13	0.04	0.01
main stem	XS 188	998	1221	4717.51	0.0006	3.00	0.72	0.69	0.19	0.02	0.02
main stem	XS 189	919	1221	4717.43	0.0008	3.05			0.21		
REACH 7 SUMMARY		Slope		0.0015	Average	3.23	1.21	0.60	0.27	0.05	0.02
					Maximum	6.07	1.88	1.26	0.87	0.12	0.07
					Minimum	2.20	0.72	0.22	0.12	0.02	0.00

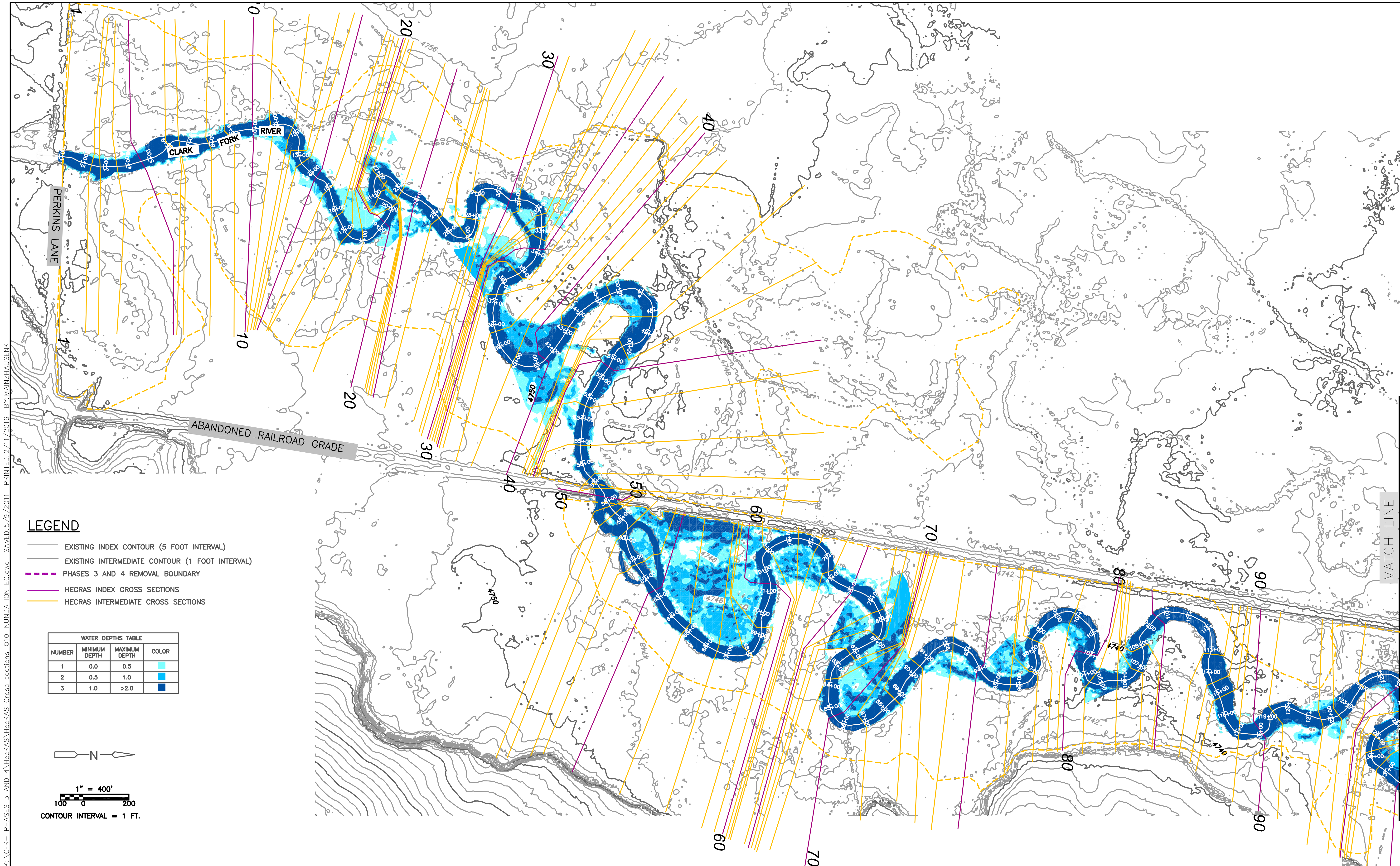
SECONDARY CHANNEL- HADLEY A

Hadley A	XS 136A	1192	496	4727.72	0.0011	3.06			0.23		
Hadley A	XS 136B	1104	496	4727.63	0.0011	2.89			0.21		
Hadley A	XS 136C	966	496	4727.48	0.0011	2.92			0.22		
Hadley A	XS 136D	846	496	4727.37	0.0010	2.49			0.16		
Hadley A	XS 136E	752	496	4727.29	0.0008	2.60			0.16		
Hadley A	XS 136F	644	496	4727.08	0.0013	3.54	0.33	0.23	0.30	0.02	0.00
Hadley A	XS 136G	488	496	4726.97	0.0010	2.65	0.60	0.75	0.18	0.04	0.02
Hadley A	XS 136H	342	496	4726.92	0.0003	1.94	0.13		0.09	0.00	
Hadley A	XS 136I	224	496	4726.84	0.0007	2.33	0.17		0.14	0.01	
Hadley A	XS 136J	135	496	4726.69	0.0014	3.09	0.06	0.80	0.25	0.00	0.02
Hadley A	XS 136K	54	496	4726.59	0.0012	3.12	0.36	1.18	0.24	0.02	0.04
HADLEY A SUMMARY		Slope		0.0012	Average	2.78	0.28	0.74	0.20	0.02	0.02
					Maximum	3.54	0.60	1.18	0.30	0.04	0.04
					Minimum	1.94	0.06	0.23	0.09	0.00	0.00

SECONDARY CHANNEL - HADLEY B

Hadley B	SXS 165A	1458	425	4720.94	0.0008	2.32	0.18	0.40	0.14	0.00	0.01
Hadley B	SXS 165B	1345	425	4720.73	0.0015	3.46	1.05		0.30	0.04	
Hadley B	SXS 165C	1219	425	4720.47	0.0021	3.71	0.53		0.36	0.02	
Hadley B	SXS 165D	1064	425	4720.04	0.0026	4.22	1.16		0.46	0.05	
Hadley B	SXS 165E	945	425	4719.87	0.0016	3.38			0.29		
Hadley B	SXS 165F	825	425	4719.73	0.0012	2.97	0.66	0.93	0.22	0.02	0.04
Hadley B	SXS 165G	752	425	4719.66	0.0012	2.69	0.58	0.25	0.19	0.02	0.01
Hadley B	SXS 165H	634	425	4719.57	0.0007	2.39			0.14		
Hadley B	SXS 165I	535	425	4719.51	0.0008	2.14		0.25	0.12		0.01
Hadley B	SXS 165J	387	425	4719.25	0.0018	3.20	1.19		0.28	0.05	
Hadley B	SXS 165K	270	425	4719.15	0.0007	2.42			0.15		
Hadley B	SXS 165L	126	425	4719.07	0.0005	2.37	0.78	0.68	0.13	0.02	0.02
Hadley B	SXS 165M	25	425	4719.00	0.0007	2.35	0.68	0.62	0.14	0.02	0.02
HADLEY B SUMMARY		Slope		0.0018	Average	2.89	0.76	0.52	0.22	0.03	0.02
					Maximum	4.22	1.19	0.93	0.46	0.05	0.04
					Minimum	2.14	0.18	0.25	0.12	0.00	0.01

Section where channel shear stress is greater than or equal to 0.60 lb/ft^2.



LEGEND

- EXISTING INDEX CONTOUR (5 FOOT INTERVAL)
- EXISTING INTERMEDIATE CONTOUR (1 FOOT INTERVAL)
- PHASES 3 AND 4 REMOVAL BOUNDARY
- HECRAS INDEX CROSS SECTIONS
- HECRAS INTERMEDIATE CROSS SECTIONS

WATER DEPTHS TABLE			
NUMBER	MINIMUM DEPTH	MAXIMUM DEPTH	COLOR
1	0.0	0.5	
2	0.5	1.0	
3	1.0	>2.0	

N

1" = 400'

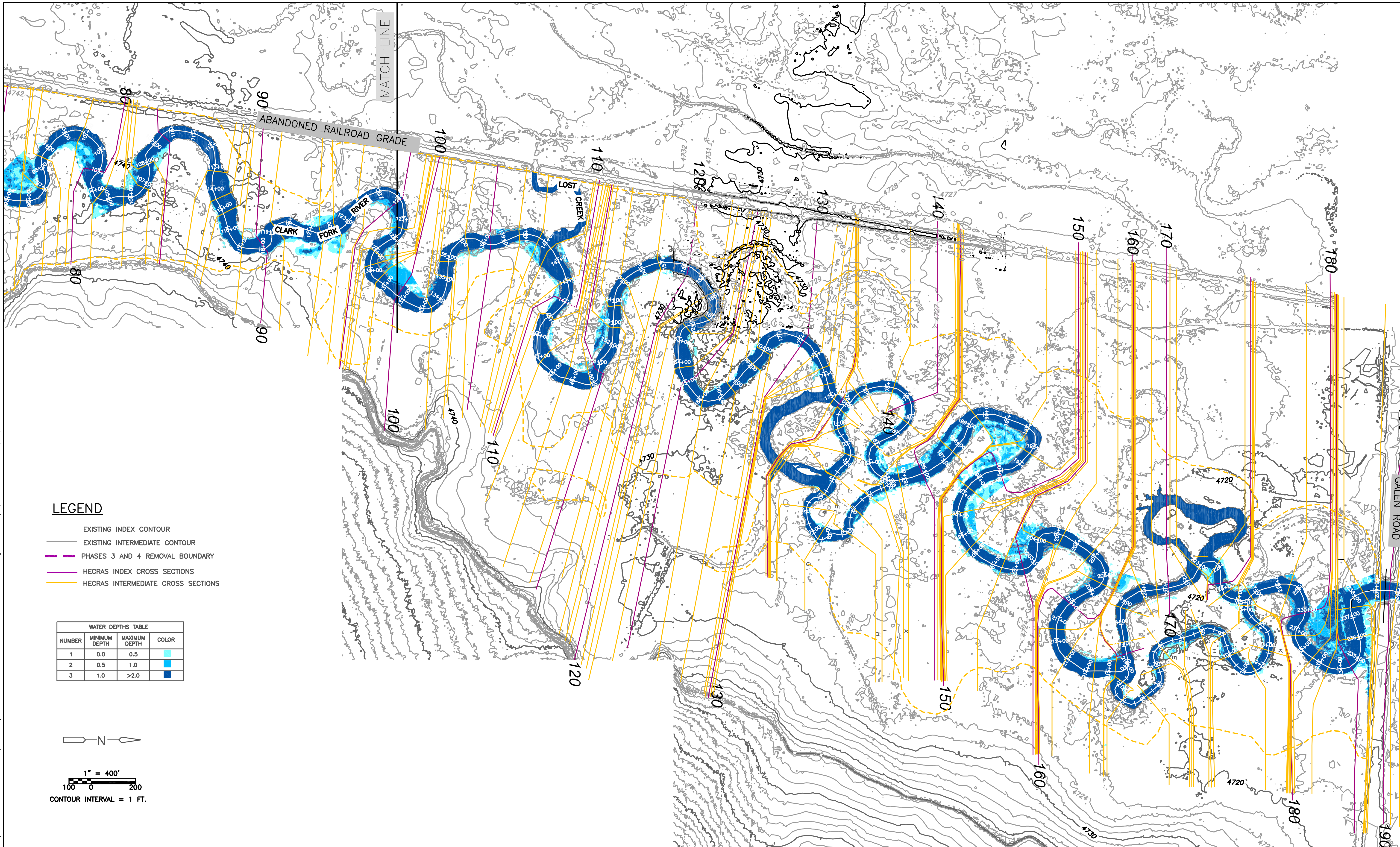
100 0 200

CONTOUR INTERVAL = 1 FT.

K:\CFR– PHASES 3 AND 4\HecRAS\HecRAS Cross sections_Q10 INUNDATION EC.dwg SAVED:5/9/2011 PRINTED:2/11/2016 BY:MAINZHAUSENK

CDM Smith

Figure No. A3
CLARK FORK RIVER-PHASES 3 AND 4
10-YEAR EXISTING CONDITIONS INUNDATION MAP
JAN 2016



WATER DEPTHS TABLE			
NUMBER	MINIMUM DEPTH	MAXIMUM DEPTH	COLOR
1	0.0	0.5	
2	0.5	1.0	
3	1.0	>2.0	

CDM Smith

Figure No. A4

CLARK FORK RIVER-PHASES 3 AND 4

10-YEAR EXISTING CONDITIONS INUNDATION MAP

JAN 2016

PHASES 3 AND 4 HYDRAULIC MODEL
PROPOSED CONDITIONS, 2-YEAR EVENT
WSE, VELOCITY AND SHEAR STRESS

Reach	Cross	River	Q Total	W.S. Elev	E.G. Slope	Vel Chnl	Vel Left	Vel Right	Shear Chan	Shear LOB	Shear ROB
	Section	Station	(cfs)	(ft)	(ft/ft)	(ft/s)	(ft/s)	(ft/s)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)
main stem		24762	Bridge								
main stem	XS-1	24735	569	4756.65	0.0018	3.63			0.34		
main stem	XS-2	24602	569	4756.15	0.0046	4.27			0.54		
main stem	XS-3	24564	569	4756.14	0.0020	3.08			0.27		
main stem	XS-4	24490	569	4755.86	0.0028	4.13			0.45		
main stem	XS-5	24380	569	4755.43	0.0039	4.65			0.59		
main stem	XS-6	24234	569	4755.12	0.0031	3.85	0.11	0.13	0.42	0.01	0.01
main stem	XS-7	24184	569	4755.02	0.0018	3.85			0.37		
main stem	XS-8	24053	569	4754.78	0.0022	3.69			0.36		
main stem	XS-9	23957	569	4754.27	0.0055	5.03			0.72		
main stem	XS-10	23845	569	4754.16	0.0012	3.28			0.26		
main stem	XS-11	23766	569	4754.12	0.0010	2.65			0.18		
main stem	XS-12	23666	569	4753.95	0.0021	3.02			0.26		
main stem	XS-13	23557	569	4753.72	0.0016	3.30			0.28		
main stem	XS-14	23496	569	4753.68	0.0012	3.02			0.23		
main stem	XS-15	23408	569	4753.50	0.0017	3.59			0.32		
main stem	XS-16	23328	569	4753.21	0.0032	4.60			0.55		
main stem	XS-17	23208	569	4753.05	0.0014	3.48			0.29		
main stem	XS-18	23111	569	4753.09	0.0003	1.67			0.07		
main stem	XS-19	23037	569	4752.86	0.0023	3.65			0.36		
main stem	XS-20	22907	569	4752.58	0.0022	3.57			0.34		
main stem	XS-21	22830	569	4752.56	0.0007	2.29			0.13		
main stem	XS-22	22757	569	4752.31	0.0033	3.82		0.08	0.42		0.00
main stem	XS-23	22652	569	4752.26	0.0008	2.13			0.12		
main stem	XS-24	22513	569	4751.85	0.0029	4.19			0.47		
main stem	XS-25	22440	569	4751.78	0.0015	3.20			0.27		
main stem	XS-26	22308	569	4751.55	0.0018	3.38			0.30		
main stem	XS-27	22146	569	4751.56	0.0002	1.40	0.08		0.05	0.00	
main stem	XS-28	22057	569	4751.36	0.0020	3.29	0.09		0.30	0.00	
main stem	XS-29	21942	569	4751.39	0.0002	1.46	0.03	0.03	0.05	0.00	0.00
main stem	XS-30	21777	569	4751.07	0.0024	3.80	0.11	0.11	0.39	0.01	0.01
main stem	XS-31	21729	569	4751.08	0.0010	2.55	0.09	0.07	0.17	0.00	0.00
main stem	XS-32	21606	569	4750.94	0.0008	2.56	0.01	0.04	0.16		0.00
main stem	XS-33	21552	569	4750.50	0.0062	4.83			0.70		
main stem	XS-34	21501	569	4750.29	0.0036	4.06			0.47		
main stem	XS-35	21453	569	4750.20	0.0021	3.52			0.33		
main stem	XS-36	21309	569	4749.83	0.0024	4.05			0.42		
main stem	XS-37	21171	569	4749.73	0.0011	2.70			0.19		
main stem	XS-38	21004	569	4749.50	0.0018	2.73			0.22		
main stem	XS-39	20848	569	4749.31	0.0013	2.04			0.13		
main stem	XS-40	20694	569	4749.09	0.0014	2.14			0.14		
main stem	XS-41	20515	569	4748.77	0.0017	3.48			0.31		
main stem	XS-42	20283	569	4748.51	0.0014	2.92			0.23		
main stem	XS-43	20008	569	4748.12	0.0016	2.93			0.24		
main stem	XS-44	19800	569	4747.69	0.0032	3.67			0.39		
main stem	XS-45	19692	569	4747.68	0.0004	2.20			0.11		
main stem	XS-46	19492	569	4747.28	0.0022	4.11			0.42		
main stem	XS-47	19319	569	4747.11	0.0010	3.01			0.22		
main stem	XS-48	19168	569	4746.92	0.0013	3.34			0.27		
main stem	XS-49	19098	569	4746.94	0.0005	2.14			0.11		
main stem		19077	Bridge								
main stem	XS-50	19058	569	4746.64	0.0004	1.98			0.09		
main stem	XS-51	19010	569	4746.01	0.0177	6.13			1.30		
main stem	XS-52	18974	569	4746.18	0.0018	2.88			0.24		
main stem	XS-53	18878	569	4746.08	0.0009	2.27			0.14		

PHASES 3 AND 4 HYDRAULIC MODEL
PROPOSED CONDITIONS, 2-YEAR EVENT
WSE, VELOCITY AND SHEAR STRESS

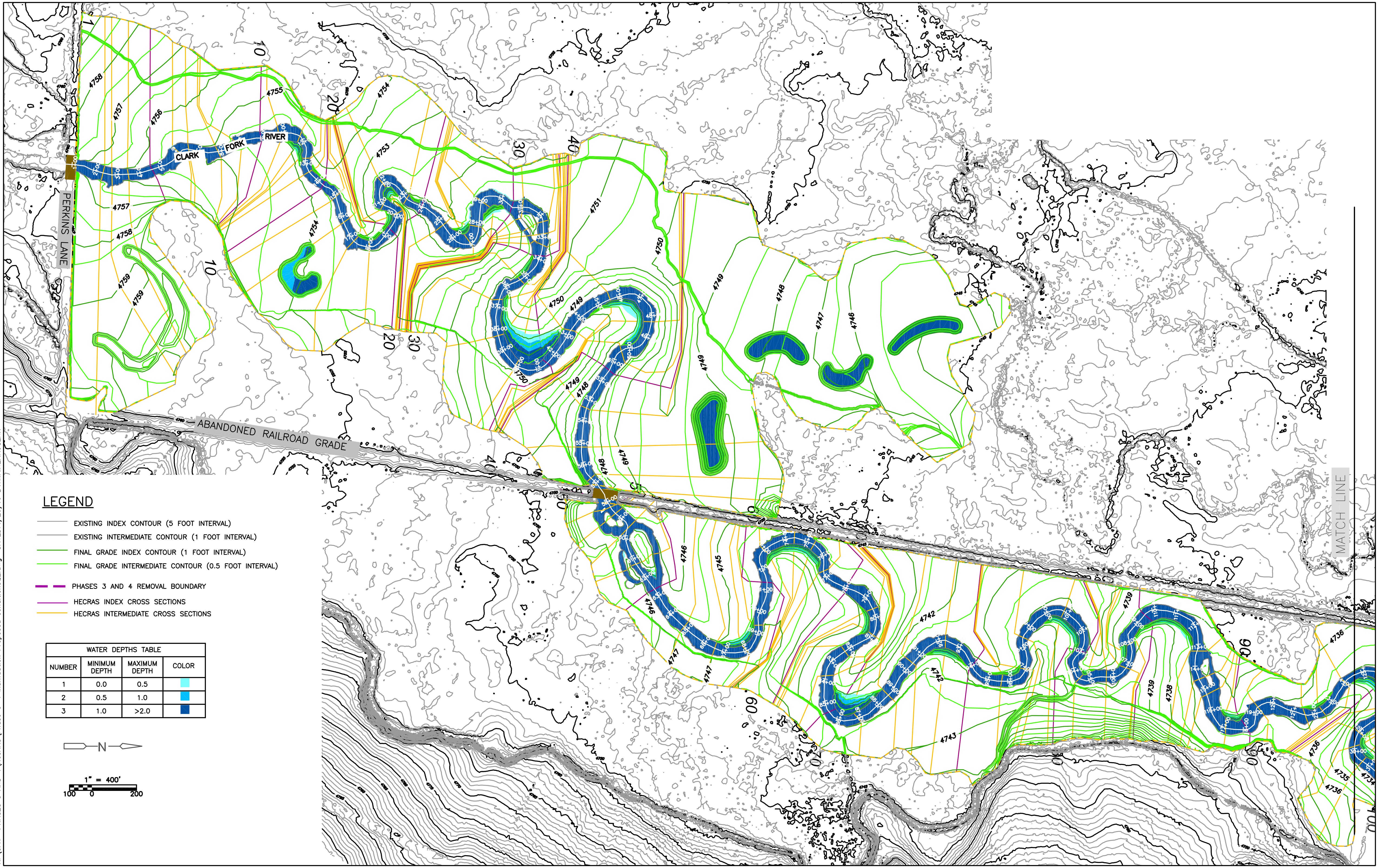
Reach	Cross	River	Q Total	W.S. Elev	E.G. Slope	Vel Chnl	Vel Left	Vel Right	Shear Chan	Shear LOB	Shear ROB
	Section	Station	(cfs)	(ft)	(ft/ft)	(ft/s)	(ft/s)	(ft/s)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)
main stem	XS-54	18709	569	4745.75	0.0016	2.81			0.22		
main stem	XS-55	18570	569	4745.59	0.0011	2.87			0.21		
main stem	XS-56	18353	569	4745.18	0.0021	3.74			0.37		
main stem	XS-57	18185	569	4744.87	0.0018	3.36	0.02		0.30		
main stem	XS-58	18039	569	4744.56	0.0027	3.33			0.33		
main stem	XS-59	17904	569	4744.24	0.0021	3.57			0.34		
main stem	XS-60	17706	569	4743.96	0.0013	3.26			0.26		
main stem	XS 61	17545	569	4743.87	0.0008	2.37			0.14		
main stem	XS 62	17398	569	4743.67	0.0016	2.87			0.23		
main stem	XS-63	17304	569	4743.34	0.0038	3.80			0.43		
main stem	XS 64	17170	569	4743.17	0.0011	3.05			0.23		
main stem	XS-65	17035	569	4742.86	0.0023	3.97			0.41		
main stem	XS 66	16877	569	4742.73	0.0012	2.74			0.20		
main stem	XS 67	16755	569	4742.62	0.0009	2.57			0.17		
main stem	XS 68	16610	569	4742.37	0.0018	3.48			0.31		
main stem	XS-69	16464	569	4742.13	0.0016	3.35			0.29		
main stem	XS 70	16295	569	4742.02	0.0011	2.12	0.03		0.13	0.00	
main stem	XS 71	16151	569	4741.82	0.0014	2.26			0.15		
main stem	XS 72	15978	569	4741.47	0.0021	3.44			0.32		
main stem	XS-73	15794	569	4741.13	0.0017	3.29			0.28		
main stem	XS 74	15608	569	4741.00	0.0007	2.20			0.13		
main stem	XS-75	15438	569	4740.64	0.0020	3.87			0.38		
main stem	XS 76	15276	569	4740.34	0.0025	3.75			0.38		
main stem	XS 77	15142	569	4740.13	0.0015	3.26			0.27		
main stem	XS 78	14996	569	4739.92	0.0015	3.59			0.31		
main stem	XS 79	14757	569	4739.60	0.0020	3.12			0.27		
main stem	XS80	14538	569	4739.24	0.0013	3.02			0.23		
main stem	XS 81	14395	569	4739.13	0.0011	2.63			0.18		
main stem	XS 82	14268	569	4738.61	0.0050	4.87			0.67		
main stem	XS 83	14164	569	4738.59	0.0009	2.84			0.20		
main stem	XS 84	14049	569	4738.42	0.0018	3.20			0.28		
main stem	XS 85	13891	569	4738.07	0.0026	3.28			0.32		
main stem	XS 86	13517	569	4737.26	0.0026	3.50		0.03	0.35		
main stem	XS 87	13387	569	4736.69	0.0035	3.86			0.43		
main stem	XS 88	13311	569	4736.61	0.0016	2.85			0.23		
main stem	XS 89	13128	569	4736.41	0.0007	2.09			0.11		
main stem	XS 90	13028	569	4736.19	0.0025	3.14			0.29		
main stem	XS 91	12913	569	4735.97	0.0019	3.24			0.29		
main stem	XS 92	12683	569	4735.53	0.0016	3.06			0.25		
main stem	XS 93	12601	569	4735.29	0.0027	3.70			0.38		
main stem	XS 94	12437	569	4734.92	0.0021	3.75			0.36		
main stem	XS 95	12225	569	4734.54	0.0025	3.37			0.33		
main stem	XS 96	12093	569	4734.31	0.0013	3.42			0.28		
main stem	XS 97	11927	569	4734.08	0.0017	3.25			0.28		
main stem	XS 98	11859	569	4734.00	0.0013	2.85			0.22		
main stem	XS 99	11775	569	4733.77	0.0029	3.52			0.36		
main stem	XS 100	11665	569	4733.47	0.0031	3.50			0.36		
main stem	XS 101	11496	569	4733.23	0.0010	2.76	0.02	0.02	0.19		
main stem	XS 102	11332	569	4732.72	0.0037	4.41			0.54		
main stem	XS 103	11262	569	4732.75	0.0006	2.41			0.14		
main stem	XS 104	11123	569	4732.67	0.0006	2.38			0.13		
main stem	XS 105	11007	569	4732.33	0.0035	4.11			0.48		
main stem	XS 106	10868	569	4732.08	0.0014	3.29			0.27		
main stem	XS 107	10772	569	4732.05	0.0005	2.30			0.12		
main stem	XS 108	10701	569	4731.95	0.0020	2.68			0.22		

PHASES 3 AND 4 HYDRAULIC MODEL
PROPOSED CONDITIONS, 2-YEAR EVENT
WSE, VELOCITY AND SHEAR STRESS

Reach	Cross Section	River Station	Q Total (cfs)	W.S. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Vel Left (ft/s)	Vel Right (ft/s)	Shear Chan (lb/sq ft)	Shear LOB (lb/sq ft)	Shear ROB (lb/sq ft)
main stem	XS 109	10540	569	4731.78	0.0008	2.45			0.15		
main stem	XS 110	10435	569	4731.66	0.0011	2.71			0.19		
main stem	XS 111	10321	569	4731.39	0.0022	3.85			0.38		
main stem	XS 112	10108	592	4731.11	0.0009	2.28	0.02		0.14		
main stem	XS 113	9975	592	4730.92	0.0016	2.62			0.20		
main stem	XS114	9856	592	4730.77	0.0012	2.38			0.16		
main stem	XS 115	9780	592	4730.64	0.0013	3.01			0.23		
main stem	XS 116	9563	592	4730.21	0.0020	3.78			0.37		
main stem	XS 117	9464	592	4729.93	0.0029	4.15			0.46		
main stem	XS 118	9337	592	4729.66	0.0021	3.83			0.38		
main stem	XS 119	9157	592	4729.25	0.0022	3.96			0.40		
main stem	XS 120	9018	592	4728.98	0.0025	3.51			0.34		
main stem	XS 121	8852	592	4728.73	0.0015	2.78			0.21		
main stem	XS 122	8715	592	4728.50	0.0018	3.02		0.03	0.25		0.00
main stem	XS 123	8603	592	4728.39	0.0009	2.70			0.18		
main stem	XS124	8409	592	4728.14	0.0019	3.04			0.26		
main stem	XS 125	8339	592	4727.87	0.0031	3.99	0.03	0.03	0.44		
main stem	XS 126	8227	592	4727.73	0.0013	2.95	0.06	0.05	0.23	0.00	0.00
main stem	XS 127	8075	592	4727.59	0.0008	2.85	0.05	0.05	0.19	0.00	0.00
main stem	XS 128	7925	592	4727.35	0.0017	3.03			0.25		
main stem	XS 129	7850	592	4727.25	0.0012	2.88			0.21		
main stem	XS 130	7618	592	4726.89	0.0015	3.00			0.24		
main stem	XS 131	7537	592	4726.62	0.0032	3.84	0.05	0.06	0.42	0.00	0.01
main stem	XS132	7468	592	4726.47	0.0021	3.49	0.04	0.05	0.33	0.00	0.00
main stem	XS 133	7392	592	4726.20	0.0026	4.18			0.45		
main stem	XS 134	7319	592	4726.09	0.0018	3.54			0.32		
main stem	XS 135	7287	592	4726.09	0.0010	2.85			0.20		
main stem	XS 136	7239	349	4726.06	0.0012	2.39	0.04		0.16	0.00	
main stem	XS 137	7179	349	4725.84	0.0023	3.64			0.36		
main stem	XS 138	7132	349	4725.80	0.0017	3.09			0.26		
main stem	XS 139	7010	349	4725.48	0.0027	3.68			0.38		
main stem	XS 140	6906	349	4725.36	0.0015	2.54			0.19		
main stem	XS 141	6807	349	4725.19	0.0016	2.93			0.23		
main stem	XS 142	6627	349	4725.06	0.0006	2.24		0.03	0.12		0.00
main stem	XS 143	6446	349	4724.94	0.0012	2.30		0.02	0.15		
main stem	XS 144	6363	592	4724.78	0.0013	2.93			0.22		
main stem	XS 145	6255	592	4724.58	0.0019	3.35			0.30		
main stem	XS 146	6083	592	4724.12	0.0025	4.28			0.47		
main stem	XS 147	5888	592	4723.90	0.0010	2.98			0.22		
main stem	XS 148	5634	592	4723.64	0.0010	2.69			0.19		
main stem	XS 149	5501	592	4723.43	0.0017	3.07			0.26		
main stem	XS 150	5334	592	4723.11	0.0017	3.66			0.34		
main stem	XS 151	5170	592	4722.92	0.0011	3.06			0.23		
main stem	XS 152	5040	592	4722.78	0.0012	3.01			0.23		
main stem	XS 153	4869	592	4722.42	0.0024	3.86			0.39		
main stem	XS 154	4699	592	4722.13	0.0016	3.43			0.30		
main stem	XS 155	4600	592	4722.07	0.0009	2.53			0.17		
main stem	XS 156	4427	592	4721.84	0.0021	3.17			0.28		
main stem	XS 157	4310	592	4721.54	0.0022	3.45		0.02	0.33		
main stem	XS 158	4158	592	4721.18	0.0023	3.61			0.35		
main stem	XS 159	3996	592	4720.92	0.0017	3.09			0.26		
main stem	XS 160	3827	592	4720.59	0.0023	3.58	0.05		0.35		
main stem	XS 161	3691	592	4720.37	0.0016	2.90	0.06		0.23	0.01	
main stem	XS 162	3544	592	4720.05	0.0025	3.40			0.33		
main stem	XS 163	3402	592	4719.75	0.0022	3.21		0.01	0.29		

PHASES 3 AND 4 HYDRAULIC MODEL
PROPOSED CONDITIONS, 2-YEAR EVENT
WSE, VELOCITY AND SHEAR STRESS

Reach	Cross Section	River Station	Q Total (cfs)	W.S. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Vel Left (ft/s)	Vel Right (ft/s)	Shear Chan (lb/sq ft)	Shear LOB (lb/sq ft)	Shear ROB (lb/sq ft)
main stem	XS 164	3307	592	4719.53	0.0021	3.05	0.05		0.27	0.00	
main stem	XS 165	3183	394	4719.38	0.0011	2.45			0.17		
main stem	XS 166	3129	394	4719.15	0.0025	3.70	0.04		0.38	0.00	
main stem	XS 167	2971	394	4718.89	0.0017	2.62	0.01		0.20		
main stem	XS 168	2849	394	4718.69	0.0016	2.80			0.22		
main stem	XS 169	2779	394	4718.52	0.0019	3.37			0.31		
main stem	XS 170	2725	394	4718.34	0.0036	3.86	0.04	0.05	0.44	0.00	0.01
main stem	XS 171	2618	394	4718.04	0.0026	3.25		0.07	0.31		0.01
main stem	XS 172	2554	394	4717.90	0.0021	3.04			0.27		
main stem	XS 174	2451	394	4717.80	0.0013	2.60			0.19		
main stem	XS 175	2361	394	4717.63	0.0015	3.13			0.25		
main stem	XS 176	2308	394	4717.58	0.0016	2.81			0.22		
main stem	XS 177	2236	394	4717.38	0.0027	3.15	0.04		0.30	0.00	
main stem	XS 178	2173	592	4717.16	0.0023	3.75	0.04		0.37	0.00	
main stem	XS 179	1983	592	4717.03	0.0008	2.45			0.15		
main stem	XS 180	1824	592	4716.82	0.0015	2.99		0.02	0.24		0.00
main stem	XS 181	1710	592	4716.71	0.0010	2.98	0.03	0.02	0.22	0.00	0.00
main stem	XS 182	1576	592	4716.49	0.0020	3.44	0.02	0.02	0.32		
main stem	XS 184	1494	592	4716.48	0.0008	2.51	0.02	0.03	0.16	0.00	0.00
main stem	XS 185	1389	592	4716.40	0.0009	2.42	0.04	0.04	0.15	0.00	0.00
main stem	XS 186	1239	592	4716.19	0.0013	2.98	0.03	0.03	0.23	0.00	0.00
main stem	XS 187	1102	592	4716.14	0.0004	2.11	0.02	0.02	0.10	0.00	0.00
main stem	XS 188	998	592	4716.10	0.0003	2.02	0.02	0.02	0.09	0.00	0.00
main stem	XS 189	919	592	4716.05	0.0005	2.11			0.11		
main stem		899	Bridge								
Hadley A	XS 136A	1192	243	4726.05	0.0011	2.47			0.17		
Hadley A	XS 136B	1104	243	4725.96	0.0012	2.50			0.17		
Hadley A	XS 136C	966	243	4725.87	0.0009	1.93			0.11		
Hadley A	XS 136D	846	243	4725.68	0.0017	2.67			0.21		
Hadley A	XS 136E	752	243	4725.58	0.0010	2.20			0.14		
Hadley A	XS 136F	644	243	4725.40	0.0016	2.88			0.23		
Hadley A	XS 136G	488	243	4725.28	0.0008	1.67			0.09		
Hadley A	XS 136H	342	243	4725.22	0.0003	1.24			0.04		
Hadley A	XS 136I	224	243	4725.07	0.0014	2.56	0.07		0.18	0.00	
Hadley A	XS 136J	135	243	4724.94	0.0012	2.67	0.04		0.19	0.00	
Hadley A	XS 136K	54	243	4724.76	0.0019	3.22			0.28		
Hadley B	SXS 165A	1458	198	4719.40	0.0015	2.14			0.14		
Hadley B	SXS 165B	1345	198	4719.31	0.0009	1.95			0.11		
Hadley B	SXS 165C	1219	198	4719.10	0.0016	2.85		0.17	0.23		0.00
Hadley B	SXS 165D	1064	198	4718.66	0.0035	3.52			0.38		
Hadley B	SXS 165E	945	198	4718.48	0.0012	2.36	0.15	0.12	0.16	0.00	0.00
Hadley B	SXS 165F	825	198	4718.33	0.0014	2.43	0.21	0.19	0.17	0.00	0.00
Hadley B	SXS 165G	752	198	4718.21	0.0017	2.59			0.20		
Hadley B	SXS 165H	634	198	4718.15	0.0004	1.56		0.08	0.07		0.00
Hadley B	SXS 165I	535	198	4718.08	0.0006	1.78	0.15	0.13	0.09	0.00	0.00
Hadley B	SXS 165J	387	198	4717.98	0.0007	1.83	0.34	0.27	0.10	0.01	0.01
Hadley B	SXS 165K	270	198	4717.60	0.0051	3.92			0.49		
Hadley B	SXS 165L	126	198	4717.47	0.0006	2.02			0.11		
Hadley B	SXS 165M	25	198	4717.42	0.0006	1.86	0.10		0.09	0.00	



WATER DEPTHS TABLE			
NUMBER	MINIMUM DEPTH	MAXIMUM DEPTH	COLOR
1	0.0	0.5	
2	0.5	1.0	
3	1.0	>2.0	

K:\CFR- PHASES 3 AND 4\HecRAS\Phase 3-4 inundation Proposed conditions02.dwg SAVED:1/26/16 BY:MAINZHAUSENK

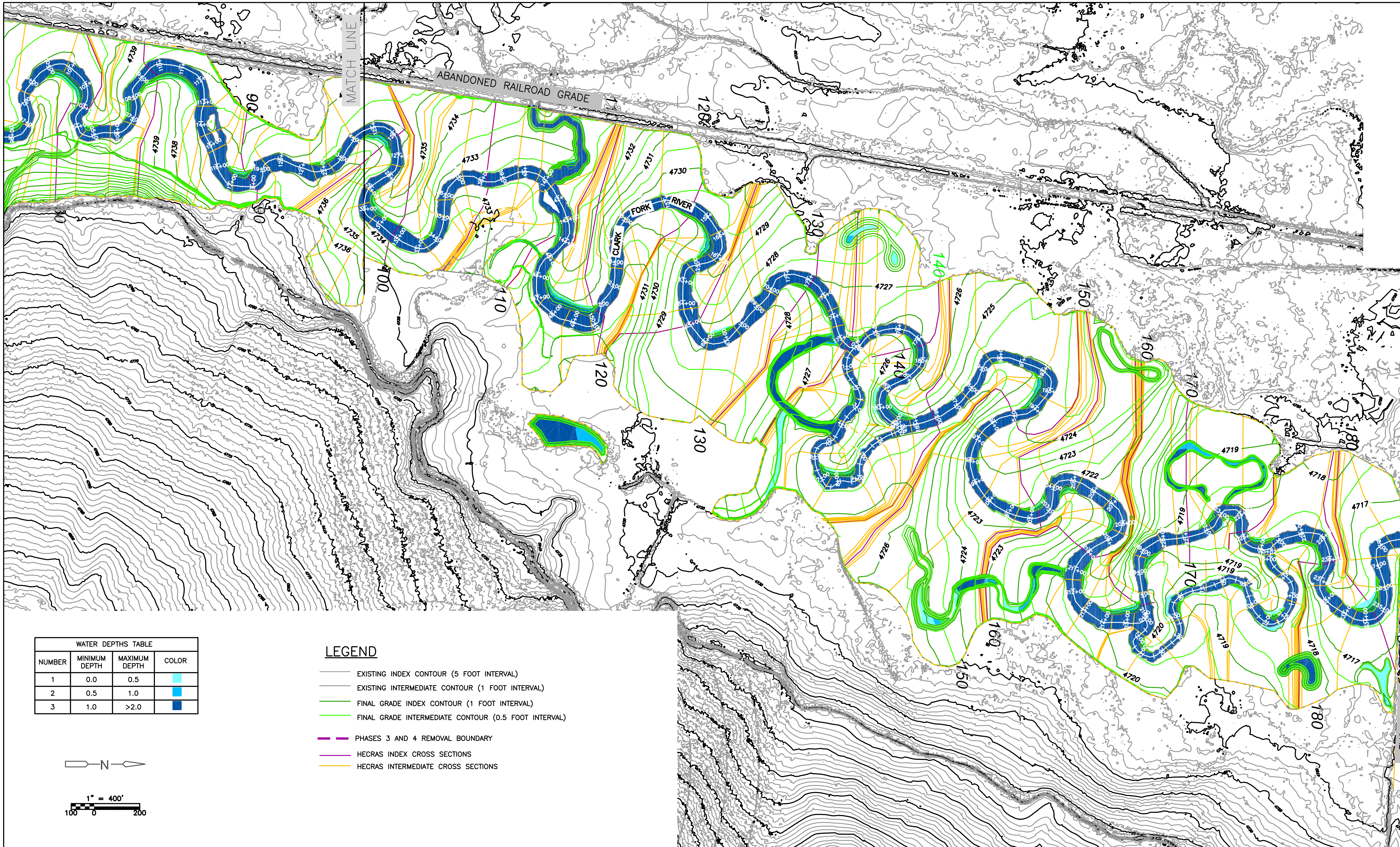
CDM Smith

Figure No. A5

CLARK FORK RIVER - PHASES 3 AND 4

2-YEAR PROPOSED CONDITIONS INUNDATION MAP

JAN 2016



WATER DEPTHS TABLE			
NUMBER	MINIMUM DEPTH	MAXIMUM DEPTH	COLOR
1	0.0	0.5	
2	0.5	1.0	
3	1.0	>2.0	

LEGEND

- EXISTING INDEX CONTOUR (5 FOOT INTERVAL)
- EXISTING INTERMEDIATE CONTOUR (1 FOOT INTERVAL)
- FINAL GRADE INDEX CONTOUR (1 FOOT INTERVAL)
- FINAL GRADE INTERMEDIATE CONTOUR (0.5 FOOT INTERVAL)
- PHASES 3 AND 4 REMOVAL BOUNDARY
- HECRAS INDEX CROSS SECTIONS
- HECRAS INTERMEDIATE CROSS SECTIONS

K:\CFR- PHASES 3 AND 4\HecRAS\Phase 3-4 inumdation Proposed conditions02.dwg SAVED:1/26/16 BY:MAINZHAUSENK

CDM Smith

Figure No. A6
CLARK FORK RIVER - PHASES 3 AND 4
2-YEAR PROPOSED CONDITIONS INUNDATION MAP
JAN 2016

PHASES 3 AND 4 HYDRAULIC MODEL
PROPOSED CONDITIONS, 10-YEAR EVENT
WSE, VELOCITY AND SHEAR STRESS

Reach	Cross Section	River Sta	Q Total (cfs)	W.S. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Vel Left (ft/s)	Vel Right (ft/s)	Shear Chan (lb/sq ft)	Shear LOB (lb/sq ft)	Shear ROB (lb/sq ft)
main stem		24762	Bridge								
main stem	XS-1	24735	1169	4757.80	0.0029	5.36			0.68		
main stem	XS-2	24602	1169	4757.33	0.0036	5.08	0.45	0.75	0.66	0.05	0.10
main stem	XS-3	24564	1169	4757.36	0.0017	3.82	0.35	0.55	0.36	0.04	0.05
main stem	XS-4	24490	1169	4756.96	0.0032	5.52	0.50	0.78	0.73	0.08	0.10
main stem	XS-5	24380	1169	4756.55	0.0039	5.85	0.65	0.85	0.83	0.12	0.12
main stem	XS-6	24234	1169	4756.38	0.0019	4.08	0.51	0.85	0.41	0.07	0.10
main stem	XS-7	24184	1169	4756.11	0.0024	5.26	0.44	0.74	0.63	0.06	0.09
main stem	XS-8	24053	1169	4755.86	0.0023	4.70	0.42	0.73	0.53	0.06	0.09
main stem	XS-9	23957	1169	4755.52	0.0035	5.42	0.68	0.83	0.72	0.13	0.12
main stem	XS-10	23845	1169	4755.36	0.0015	4.37	0.40	0.56	0.42	0.05	0.05
main stem	XS-11	23766	1169	4755.34	0.0010	3.27	0.34	0.49	0.24	0.03	0.04
main stem	XS-12	23666	1169	4755.25	0.0012	3.12	0.53	0.55	0.24	0.07	0.05
main stem	XS-13	23557	1169	4755.03	0.0014	3.98	0.56	0.50	0.36	0.08	0.04
main stem	XS-14	23496	1169	4754.97	0.0012	3.77	0.51	0.44	0.32	0.06	0.03
main stem	XS-15	23408	1169	4754.78	0.0017	4.50	0.54	0.48	0.46	0.07	0.04
main stem	XS-16	23328	1169	4754.21	0.0048	6.63	0.61	0.77	1.06	0.10	0.11
main stem	XS-17	23208	1169	4754.19	0.0013	4.02	0.32	0.75	0.36	0.03	0.08
main stem	XS-18	23111	1169	4754.19	0.0004	2.39	0.21	0.34	0.12	0.01	0.02
main stem	XS-19	23037	1169	4753.97	0.0020	4.27	0.41	0.64	0.44	0.04	0.10
main stem	XS-20	22907	1169	4753.75	0.0017	4.07	0.35	0.56	0.40	0.03	0.08
main stem	XS-21	22830	1169	4753.76	0.0007	2.50	0.26	0.33	0.15	0.02	0.03
main stem	XS-22	22757	1169	4753.59	0.0019	3.85	0.41	0.49	0.37	0.04	0.07
main stem	XS-23	22652	1169	4753.56	0.0006	2.52	0.35	0.28	0.15	0.02	0.02
main stem	XS-24	22513	1169	4753.03	0.0030	5.44	0.60	0.43	0.70	0.08	0.06
main stem	XS-25	22440	1169	4753.02	0.0015	4.01	0.46	0.26	0.37	0.05	0.02
main stem	XS-26	22308	1169	4752.76	0.0018	4.29	0.47	0.43	0.43	0.05	0.05
main stem	XS-27	22146	1169	4752.79	0.0003	2.08	0.21	0.10	0.09	0.01	0.00
main stem	XS-28	22057	1169	4752.52	0.0020	4.23	0.45	0.33	0.43	0.05	0.02
main stem	XS-29	21942	1169	4752.57	0.0003	2.20	0.21	0.18	0.10	0.01	0.01
main stem	XS-30	21777	1169	4752.12	0.0027	5.03	0.80	0.55	0.61	0.13	0.09
main stem	XS-31	21729	1169	4752.21	0.0012	2.97	0.56	0.38	0.22	0.06	0.04
main stem	XS-32	21606	1169	4752.06	0.0012	2.89	0.48	0.39	0.22	0.05	0.04
main stem	XS-33	21552	1169	4751.87	0.0031	3.86	0.71	0.54	0.42	0.11	0.09
main stem	XS-34	21501	1169	4751.69	0.0025	4.10	0.55	0.59	0.44	0.07	0.10
main stem	XS-35	21453	1169	4751.54	0.0019	4.42	0.41	0.51	0.46	0.04	0.07
main stem	XS-36	21309	1169	4750.96	0.0033	5.82	0.41	0.57	0.79	0.05	0.10
main stem	XS-37	21171	1169	4750.90	0.0014	3.85	0.37	0.39	0.34	0.03	0.04
main stem	XS-38	21004	1169	4750.72	0.0014	3.31	0.46	0.43	0.27	0.05	0.05
main stem	XS-39	20848	1169	4750.63	0.0007	2.23	0.32	0.21	0.13	0.02	0.01
main stem	XS-40	20694	1169	4750.52	0.0007	2.24	0.33	0.21	0.13	0.02	0.01
main stem	XS-41	20515	1169	4750.09	0.0020	4.68	0.61	0.23	0.50	0.08	0.02
main stem	XS-42	20283	1169	4749.82	0.0014	3.74	0.52	0.46	0.33	0.06	0.06
main stem	XS-43	20008	1169	4749.50	0.0013	3.53	0.51	0.45	0.29	0.05	0.05
main stem	XS-44	19800	1169	4749.21	0.0017	3.93	0.81	0.56	0.37	0.06	0.09
main stem	XS-45	19692	1169	4749.15	0.0006	3.31	0.48	0.30	0.22	0.02	0.03
main stem	XS-46	19492	1169	4748.55	0.0027	5.70	1.07	0.55	0.73	0.10	0.10
main stem	XS-47	19319	1169	4748.32	0.0015	4.45	0.80	0.42	0.43	0.05	0.06
main stem	XS-48	19168	1169	4747.92	0.0023	5.27	0.96	0.43	0.62	0.08	0.07
main stem	XS-49	19098	1169	4748.04	0.0008	3.06	0.81	0.26	0.21	0.05	0.02
main stem		19077	Bridge								
main stem	XS-50	19058	1169	4747.50	0.0009	3.29	0.17		0.24	0.02	
main stem	XS-51	19010	1169	4747.37	0.0026	3.86	0.22	0.55	0.40	0.03	0.09
main stem	XS-52	18974	1169	4747.32	0.0019	3.35	0.47	0.47	0.30	0.09	0.06
main stem	XS-53	18878	1169	4747.22	0.0011	3.09	0.31	0.40	0.23	0.04	0.04
main stem	XS-54	18709	1169	4747.00	0.0022	2.95	0.48	0.61	0.26	0.09	0.10

PHASES 3 AND 4 HYDRAULIC MODEL
PROPOSED CONDITIONS, 10-YEAR EVENT
WSE, VELOCITY AND SHEAR STRESS

Reach	Cross	River Sta	Q Total	W.S. Elev	E.G. Slope	Vel Chnl	Vel Left	Vel Right	Shear Chan	Shear LOB	Shear ROB
	Section		(cfs)	(ft)	(ft/ft)	(ft/s)	(ft/s)	(ft/s)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)
main stem	XS-55	18570	1169	4746.71	0.0015	4.10	0.31	0.40	0.39	0.04	0.05
main stem	XS-56	18353	1169	4746.21	0.0025	5.00	0.45	0.63	0.59	0.08	0.10
main stem	XS-57	18185	1169	4745.90	0.0019	4.22	0.46	0.48	0.42	0.08	0.07
main stem	XS-58	18039	1169	4745.79	0.0013	3.21	0.50	0.41	0.26	0.08	0.05
main stem	XS-59	17904	1169	4745.56	0.0016	3.96	0.51	0.34	0.37	0.09	0.04
main stem	XS-60	17706	1169	4745.25	0.0014	4.21	0.42	0.45	0.39	0.07	0.05
main stem	XS 61	17545	1169	4745.16	0.0009	3.15	0.36	0.33	0.23	0.05	0.03
main stem	XS 62	17398	1169	4744.93	0.0015	3.69	0.22	0.33	0.33	0.03	0.04
main stem	XS-63	17304	1169	4744.65	0.0026	4.46	0.67	0.35	0.50	0.16	0.04
main stem	XS 64	17170	1169	4744.43	0.0015	4.38	0.46	0.42	0.42	0.08	0.05
main stem	XS-65	17035	1169	4744.12	0.0023	4.96	0.42	0.47	0.57	0.08	0.07
main stem	XS 66	16877	1169	4744.05	0.0010	3.24	0.27	0.39	0.24	0.03	0.04
main stem	XS 67	16755	1169	4743.94	0.0009	3.22	0.14	0.38	0.24	0.01	0.04
main stem	XS 68	16610	1169	4743.60	0.0021	4.70	0.33	0.48	0.51	0.03	0.07
main stem	XS-69	16464	1169	4743.36	0.0018	4.38	0.36	0.66	0.44	0.06	0.10
main stem	XS 70	16295	1169	4743.30	0.0008	2.51	0.28	0.46	0.16	0.03	0.05
main stem	XS 71	16151	1169	4743.17	0.0008	2.54	0.31	0.28	0.16	0.04	0.02
main stem	XS 72	15978	1169	4742.78	0.0020	4.38	0.47	0.66	0.46	0.08	0.10
main stem	XS-73	15794	1169	4742.47	0.0017	4.26	0.38	0.62	0.42	0.06	0.09
main stem	XS 74	15608	1169	4742.37	0.0007	2.81	0.24	0.35	0.18	0.02	0.03
main stem	XS-75	15438	1169	4741.98	0.0020	4.82	0.43	0.71	0.53	0.08	0.12
main stem	XS 76	15276	1169	4741.67	0.0023	4.68	0.32	0.77	0.52	0.05	0.14
main stem	XS 77	15142	1169	4741.54	0.0013	3.92	0.45	0.31	0.35	0.07	0.03
main stem	XS 78	14996	1169	4741.23	0.0019	4.83	0.47	0.36	0.52	0.08	0.04
main stem	XS 79	14757	1169	4740.97	0.0014	3.63	0.46	0.49	0.32	0.08	0.06
main stem	XS80	14538	1169	4740.60	0.0014	4.01	0.14	0.42	0.36	0.02	0.07
main stem	XS 81	14395	1169	4740.49	0.0011	3.53	0.19	0.35	0.29	0.03	0.05
main stem	XS 82	14268	1169	4739.79	0.0049	6.31	0.44	0.65	0.99	0.16	0.18
main stem	XS 83	14164	1169	4739.77	0.0015	4.30	0.26	0.23	0.41	0.05	0.03
main stem	XS 84	14049	1169	4739.58	0.0021	4.32	0.29	0.38	0.45	0.04	0.06
main stem	XS 85	13891	1169	4739.26	0.0022	4.02	0.31	0.30	0.41	0.07	0.05
main stem	XS 86	13517	1169	4738.26	0.0027	4.61	0.38	0.51	0.53	0.11	0.11
main stem	XS 87	13387	1169	4737.94	0.0027	4.12	0.38	0.51	0.45	0.11	0.10
main stem	XS 88	13311	1169	4737.82	0.0015	3.63	0.27	0.36	0.32	0.06	0.05
main stem	XS 89	13128	1169	4737.64	0.0008	2.86	0.19	0.35	0.19	0.03	0.04
main stem	XS 90	13028	1169	4737.43	0.0018	3.76	0.21	0.53	0.36	0.04	0.10
main stem	XS 91	12913	1169	4737.21	0.0018	4.15	0.31	0.46	0.41	0.07	0.08
main stem	XS 92	12683	1169	4736.84	0.0015	3.84	0.33	0.41	0.35	0.07	0.06
main stem	XS 93	12601	1169	4736.64	0.0021	4.39	0.57	0.24	0.47	0.12	0.04
main stem	XS 94	12437	1169	4736.17	0.0024	5.12	0.40	0.38	0.61	0.07	0.08
main stem	XS 95	12225	1169	4735.93	0.0017	3.82	0.44	0.35	0.35	0.08	0.06
main stem	XS 96	12093	1169	4735.53	0.0021	5.09	0.21	0.42	0.58	0.03	0.08
main stem	XS 97	11927	1169	4735.20	0.0024	4.75	0.34	0.40	0.54	0.05	0.08
main stem	XS 98	11859	1169	4735.14	0.0016	3.98	0.30	0.28	0.38	0.04	0.04
main stem	XS 99	11775	1169	4734.90	0.0027	4.51	0.42	0.42	0.51	0.08	0.09
main stem	XS 100	11665	1169	4734.66	0.0024	4.27	0.42	0.43	0.46	0.07	0.09
main stem	XS 101	11496	1169	4734.45	0.0012	3.67	0.34	0.33	0.31	0.05	0.05
main stem	XS 102	11332	1169	4734.00	0.0028	5.12	0.47	0.47	0.63	0.09	0.10
main stem	XS 103	11262	1169	4734.02	0.0008	3.37	0.27	0.26	0.25	0.03	0.03
main stem	XS 104	11123	1169	4733.92	0.0008	3.30	0.25	0.24	0.24	0.03	0.03
main stem	XS 105	11007	1169	4733.58	0.0027	4.86	0.48	0.32	0.58	0.09	0.06
main stem	XS 106	10868	1169	4733.41	0.0012	3.93	0.34	0.39	0.34	0.05	0.06
main stem	XS 107	10772	1169	4733.38	0.0006	3.02	0.30	0.27	0.19	0.03	0.03
main stem	XS 108	10701	1221	4733.36	0.0008	2.52	0.35	0.33	0.16	0.04	0.05
main stem	XS 109	10540	1221	4733.21	0.0007	2.96	0.24	0.35	0.20	0.03	0.05
main stem	XS 110	10435	1221	4733.09	0.0010	3.29	0.25	0.46	0.25	0.03	0.08

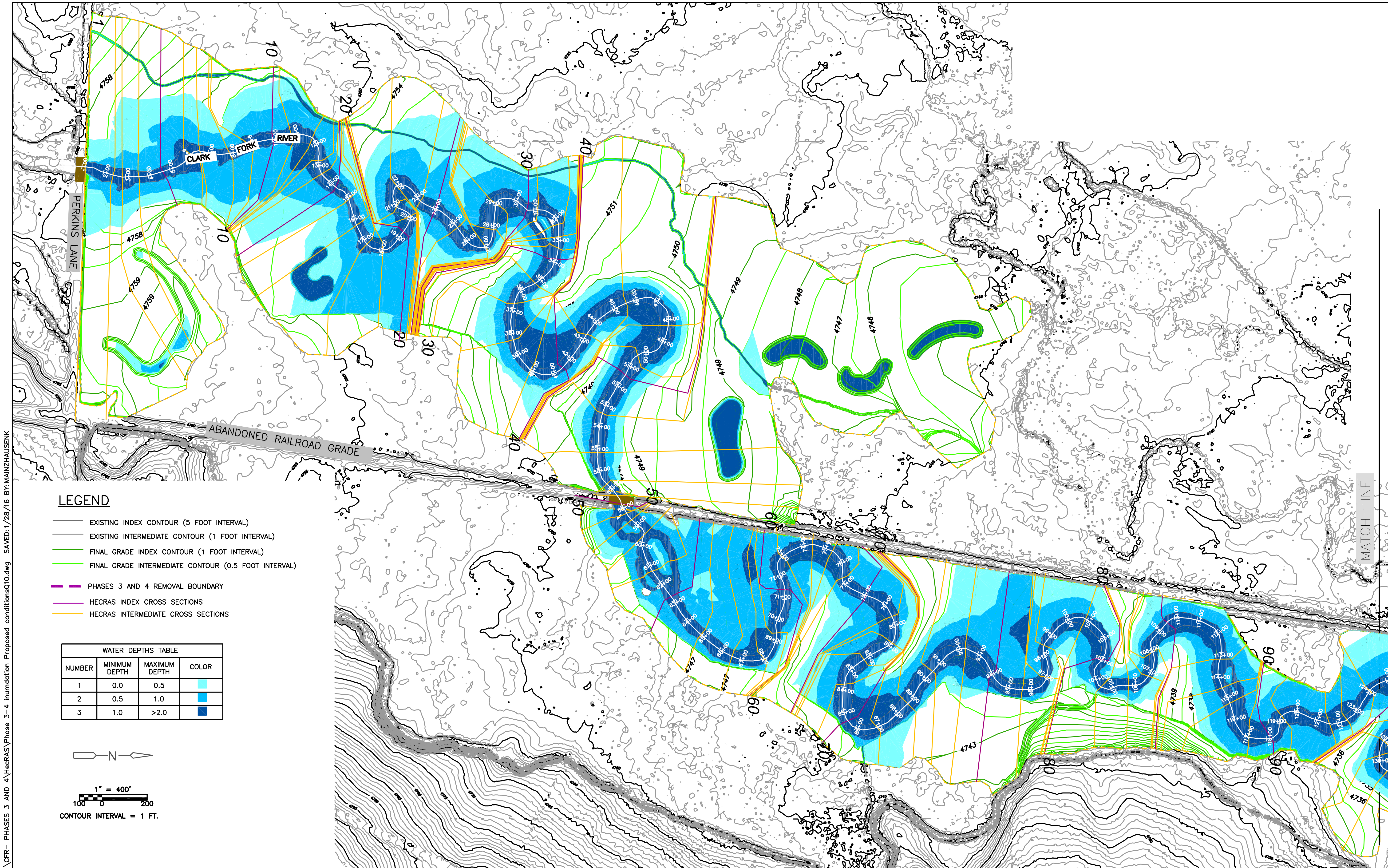
PHASES 3 AND 4 HYDRAULIC MODEL
PROPOSED CONDITIONS, 10-YEAR EVENT
WSE, VELOCITY AND SHEAR STRESS

Reach	Cross Section	River Sta	Q Total (cfs)	W.S. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Vel Left (ft/s)	Vel Right (ft/s)	Shear Chan (lb/sq ft)	Shear LOB (lb/sq ft)	Shear ROB (lb/sq ft)
main stem	XS 111	10321	1221	4732.70	0.0025	5.19	0.33	0.64	0.62	0.04	0.16
main stem	XS 112	10108	1221	4732.49	0.0009	2.96	0.24	0.35	0.20	0.03	0.05
main stem	XS 113	9975	1221	4732.38	0.0010	2.84	0.25	0.25	0.20	0.03	0.03
main stem	XS114	9856	1221	4732.29	0.0008	2.78	0.27	0.21	0.18	0.03	0.02
main stem	XS 115	9780	1221	4732.12	0.0013	3.82	0.39	0.25	0.33	0.06	0.03
main stem	XS 116	9563	1221	4731.54	0.0025	5.24	0.49	0.21	0.63	0.10	0.03
main stem	XS 117	9464	1221	4731.26	0.0029	5.46	0.52	0.33	0.70	0.11	0.06
main stem	XS 118	9337	1221	4730.92	0.0026	5.31	0.47	0.37	0.65	0.09	0.07
main stem	XS 119	9157	1221	4730.40	0.0029	5.57	0.45	0.40	0.72	0.09	0.08
main stem	XS 120	9018	1221	4730.18	0.0023	4.45	0.52	0.36	0.48	0.10	0.07
main stem	XS 121	8852	1221	4729.97	0.0014	3.58	0.25	0.36	0.31	0.03	0.06
main stem	XS 122	8715	1221	4729.77	0.0016	3.77	0.29	0.38	0.34	0.04	0.07
main stem	XS 123	8603	1221	4729.62	0.0013	3.93	0.27	0.32	0.35	0.03	0.05
main stem	XS124	8409	1221	4729.38	0.0017	3.84	0.33	0.42	0.36	0.05	0.08
main stem	XS 125	8339	1221	4729.06	0.0029	5.07	0.42	0.50	0.62	0.08	0.12
main stem	XS 126	8227	1221	4728.95	0.0014	3.94	0.33	0.33	0.36	0.05	0.05
main stem	XS 127	8075	1221	4728.66	0.0015	4.49	0.30	0.18	0.44	0.04	0.02
main stem	XS 128	7925	1221	4728.35	0.0023	4.35	0.32	0.20	0.47	0.05	0.03
main stem	XS 129	7850	1221	4728.16	0.0022	4.55	0.32	0.14	0.49	0.05	0.02
main stem	XS 130	7618	1221	4727.55	0.0032	5.02	0.27	0.29	0.63	0.04	0.05
main stem	XS 131	7537	1221	4727.64	0.0012	3.01	0.27	0.48	0.23	0.03	0.09
main stem	XS132	7468	1221	4727.56	0.0011	3.11	0.28	0.46	0.23	0.03	0.08
main stem	XS 133	7392	1221	4727.49	0.0011	3.07	0.30	0.50	0.23	0.04	0.09
main stem	XS 134	7319	1221	4727.40	0.0010	3.31	0.27	0.45	0.25	0.03	0.08
main stem	XS 135	7287	1221	4727.37	0.0008	3.14	0.18	0.34	0.22	0.03	0.07
main stem	XS 136	7239	1221	4727.38	0.0006	1.81	0.15	0.30	0.08	0.02	0.05
main stem	XS 137	7179	1221	4727.31	0.0007	1.64	0.15	0.38	0.06	0.02	0.06
main stem	XS 138	7132	1221	4727.25	0.0007	1.39	0.18	0.32	0.05	0.02	0.06
main stem	XS 139	7010	1221	4727.13	0.0094	1.02	0.86	1.13	0.58	0.45	0.75
main stem	XS 140	6906	1221	4727.03	0.0006	1.25	0.18	0.29	0.04	0.02	0.05
main stem	XS 141	6807	1221	4726.94	0.0004	1.23	0.14	0.19	0.03	0.01	0.02
main stem	XS 142	6627	1221	4726.84	0.0005	1.85	0.17	0.21	0.04	0.02	0.03
main stem	XS 143	6446	1221	4726.58	0.0008	2.53	0.16	0.20	0.15	0.02	0.03
main stem	XS 144	6363	1221	4726.38	0.0011	3.56	0.16	0.18	0.29	0.02	0.03
main stem	XS 145	6255	1221	4726.19	0.0015	4.08	0.17	0.22	0.38	0.03	0.04
main stem	XS 146	6083	1221	4725.54	0.0031	5.99	0.39	0.21	0.82	0.12	0.05
main stem	XS 147	5888	1221	4725.31	0.0014	4.28	0.19	0.20	0.40	0.03	0.04
main stem	XS 148	5634	1221	4725.07	0.0010	3.46	0.25	0.25	0.27	0.04	0.05
main stem	XS 149	5501	1221	4724.90	0.0014	3.70	0.18	0.27	0.32	0.03	0.05
main stem	XS 150	5334	1221	4724.52	0.0019	4.81	0.26	0.33	0.52	0.06	0.08
main stem	XS 151	5170	1221	4724.32	0.0014	4.27	0.25	0.31	0.40	0.05	0.07
main stem	XS 152	5040	1221	4724.16	0.0014	4.19	0.24	0.28	0.39	0.05	0.06
main stem	XS 153	4869	1221	4723.74	0.0025	5.08	0.33	0.35	0.60	0.08	0.09
main stem	XS 154	4699	1221	4723.40	0.0020	4.79	0.32	0.25	0.52	0.08	0.05
main stem	XS 155	4600	1221	4723.38	0.0011	3.47	0.24	0.16	0.27	0.04	0.02
main stem	XS 156	4427	1221	4723.13	0.0018	3.96	0.31	0.17	0.38	0.07	0.03
main stem	XS 157	4310	1221	4722.81	0.0022	4.56	0.29	0.24	0.50	0.07	0.05
main stem	XS 158	4158	1221	4722.43	0.0024	4.77	0.31	0.23	0.54	0.08	0.05
main stem	XS 159	3996	1221	4722.20	0.0017	4.03	0.19	0.24	0.39	0.03	0.05
main stem	XS 160	3827	1221	4721.74	0.0028	5.03	0.29	0.34	0.61	0.07	0.09
main stem	XS 161	3691	1221	4721.56	0.0016	3.82	0.25	0.32	0.35	0.05	0.07
main stem	XS 162	3544	1221	4721.25	0.0023	4.32	0.28	0.37	0.46	0.06	0.10
main stem	XS 163	3402	1221	4721.01	0.0018	3.93	0.27	0.37	0.38	0.06	0.09
main stem	XS 164	3307	1221	4720.89	0.0014	3.53	0.29	0.31	0.30	0.06	0.07
main stem	XS 165	3183	1221	4720.75	0.0009	1.95	0.22	0.24	0.10	0.04	0.04
main stem	XS 166	3129	1221	4720.59	0.0015	2.72	0.31	0.32	0.11	0.07	0.07

PHASES 3 AND 4 HYDRAULIC MODEL
PROPOSED CONDITIONS, 10-YEAR EVENT
WSE, VELOCITY AND SHEAR STRESS

Reach	Cross Section	River Sta	Q Total (cfs)	W.S. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Vel Left (ft/s)	Vel Right (ft/s)	Shear Chan (lb/sq ft)	Shear LOB (lb/sq ft)	Shear ROB (lb/sq ft)
main stem	XS 167	2971	1221	4720.28	0.0012	2.58	0.32	0.28	0.11	0.07	0.06
main stem	XS 168	2849	1221	4720.10	0.0012	2.43	0.27	0.28	0.11	0.05	0.05
main stem	XS 169	2779	1221	4720.05	0.0008	1.79	0.30	0.22	0.10	0.06	0.04
main stem	XS 170	2725	1221	4719.84	0.0061	1.47	0.76	0.49	0.71	0.37	0.19
main stem	XS 171	2618	1221	4719.29	0.0020	2.40	0.32	0.29	0.19	0.08	0.06
main stem	XS 172	2554	1221	4719.21	0.0007	1.80	0.20	0.18	0.07	0.03	0.02
main stem	XS 174	2451	1221	4719.13	0.0008	1.72	0.21	0.18	0.06	0.03	0.02
main stem	XS 175	2361	1221	4719.05	0.0008	1.72	0.30	0.28	0.06	0.06	0.05
main stem	XS 176	2308	1221	4718.98	0.0010	1.84	1.20	0.26	0.19	0.07	0.05
main stem	XS 177	2236	1221	4718.87	0.0018	1.88	0.41	0.31	0.19	0.11	0.07
main stem	XS 178	2173	1221	4718.48	0.0021	4.61	0.34	0.26	0.50	0.09	0.05
main stem	XS 179	1983	1221	4718.36	0.0009	3.31	0.19	0.19	0.25	0.03	0.03
main stem	XS 180	1824	1221	4718.10	0.0016	4.05	0.17	0.24	0.39	0.03	0.04
main stem	XS 181	1710	1221	4717.88	0.0016	4.56	0.19	0.32	0.46	0.03	0.07
main stem	XS 182	1576	1221	4717.61	0.0025	4.86	0.35	0.38	0.56	0.09	0.10
main stem	XS 184	1494	1221	4717.65	0.0011	3.57	0.25	0.23	0.29	0.04	0.04
main stem	XS 185	1389	1221	4717.56	0.0011	3.33	0.26	0.25	0.26	0.05	0.04
main stem	XS 186	1239	1221	4717.21	0.0020	4.45	0.28	0.36	0.47	0.06	0.09
main stem	XS 187	1102	1221	4717.12	0.0009	3.47	0.20	0.23	0.26	0.03	0.04
main stem	XS 188	998	1221	4717.05	0.0008	3.40	0.15	0.21	0.24	0.02	0.03
main stem	XS 189	919	1221	4716.95	0.0011	3.43			0.27		
main stem		899	Bridge								

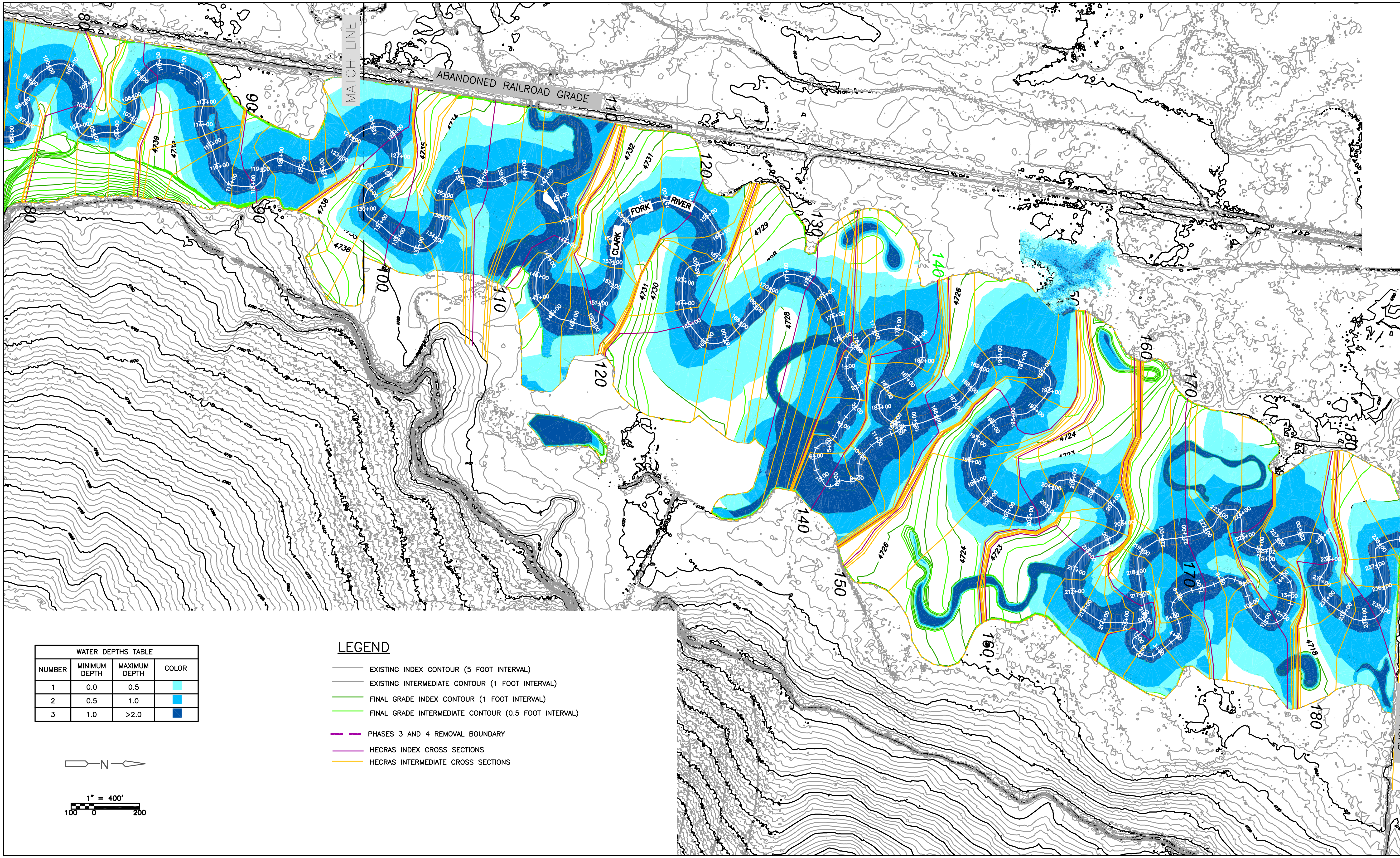
Section where channel shear stress is greater than or equal to 0.60 lb/ft^2.



WATER DEPTHS TABLE

NUMBER	MINIMUM DEPTH	MAXIMUM DEPTH	COLOR
1	0.0	0.5	
2	0.5	1.0	
3	1.0	>2.0	

Figure No. A7
CLARK FORK RIVER - PHASES 3 AND 4
10-YEAR PROPOSED CONDITIONS INUNDATION MAP
JAN 2016



WATER DEPTHS TABLE

NUMBER	MINIMUM DEPTH	MAXIMUM DEPTH	COLOR
1	0.0	0.5	
2	0.5	1.0	
3	1.0	>2.0	

LEGEND

- EXISTING INDEX CONTOUR (5 FOOT INTERVAL)
- EXISTING INTERMEDIATE CONTOUR (1 FOOT INTERVAL)
- FINAL GRADE INDEX CONTOUR (1 FOOT INTERVAL)
- FINAL GRADE INTERMEDIATE CONTOUR (0.5 FOOT INTERVAL)
- PHASES 3 AND 4 REMOVAL BOUNDARY
- HECRAS INDEX CROSS SECTIONS
- HECRAS INTERMEDIATE CROSS SECTIONS

K:\CFR- PHASES 3 AND 4\HecRAS\Phase 3-4 inundation Proposed conditionsQ10.dwg SAVED:1/28/16 BY:MAINZHAUSENK

CDM Smith

Figure No. A8
CLARK FORK RIVER - PHASES 3 AND 4
10-YEAR PROPOSED CONDITIONS INUNDATION MAP
JAN 2016

Appendix B

Revegetation Treatments

Appendix B

Revegetation Treatments

Table 1 summarizes revegetation treatments proposed for the Phases 3 and 4 project area and the general locations where each treatment is proposed for application. Each treatment is described in more detail in the following sections. Figure 1 shows the floodplain cover types for Phases 3 and 4.

Table 1. Summary of Revegetation Treatments and General Locations for Phases 3 and 4

Revegetation Treatment	Treatment Location
Floodplain Grading	
Geomorphic Features	All areas within grading limits except Grassland Pasture and Hayfield
Substrate	All areas within grading limits
Floodplain swales	Within the Floodplain Riparian Shrub and Riparian Pasture cover types
Microtopography	All areas within grading limits except the Exposed Depositional, Grassland Pasture, Riparian Pasture and Hayfield cover types
Bank Treatment Revegetation (dormant willow cuttings)	All constructed streambanks
Planting	
Containerized Planting: Shrubs and Trees	All cover types except Exposed Depositional, Grassland Pasture and Hayfield. Planting will occur in swales, select streambanks and high risk avulsion paths within Floodplain Riparian Shrub cover type; approximately half the area of Colonizing Depositional cover type; and in corridors through the Riparian Pasture cover type
Containerized Planting: Herbaceous Plugs	Approximately half the area within Colonizing Depositional cover type and all areas of Emergent Wetland cover type according to hydrologic zones
Mature Shrub Salvage	Within select areas of the Conservation land use type
Browse Protection	All areas where containerized trees and shrubs are installed
Seeding	
Seed Mix – Drill Seeding	All areas within grading limits where equipment access is feasible except the Exposed Depositional cover type
Seed Mix – Broadcast	All areas within grading limits where equipment access is not feasible except the Exposed Depositional cover type

Floodplain Grading

Geomorphic Features

The grading plan includes details for removing contaminated sediments from the floodplain and creating a new floodplain surface. Section 4.2 and 4.6 describe the geomorphic features integrated into the grading plan and how floodplain cover types are tied to these geomorphic features. Floodplain cover types are the basis for applying revegetation treatments in the project area. Table 2 summarizes the grading criteria applied for each floodplain cover type and summarizes the total area of each floodplain cover type in the grading limits.

Table 2. Relationship of Floodplain Cover Type to Geomorphic Features, Elevation Relative to the 2-Year WSE, and Total Area Based on the Preliminary Design Grading Surface

Floodplain Cover Type	Geomorphic Floodplain Feature	Elevation Relative to 2-Year WSE (feet)	Area (acres)
Exposed Depositional (Non-vegetated)	Non-vegetated portion of point bars	-2.5 to -1.0	2.6
Colonizing Depositional (Vegetated)	Vegetated portion of point bars	-1.0 to 0	2.4
Emergent Wetland	Passive margins along channel, wetlands, oxbows, and backwater areas	-2.5 to -1.0	2.2
Riparian Wetland	Bankfull floodplain in backwater areas; edge of emergent wetlands and oxbows	-1.0 to 0	5.2
Floodplain Riparian Shrub	Bankfull floodplain; low terrace	-0.5 to 2.5	134.8
Outer Bank Riparian Shrub	Streambanks along outer meanders	0 to 2.0	16.6
Hayfield	None	Same as pre-removal	21.3
Grassland Pasture	Areas within the constructed floodplain that will be maintained as grass dominated pasture	0.0 to 2.0+	26.7
Riparian Pasture	Areas within the constructed floodplain that are will be maintained as pastures with areas of riparian shrub	-2.0 to 2.0+	51.6

Substrate Variation

Plant community development within floodplain cover types requires varied substrate and soil textures. Substrates range from bare alluvium in Exposed Depositional and Colonizing Depositional cover types to vegetative backfill (silt loam to sandy loam) in other cover types. Table 3 summarizes the desired substrate for each floodplain cover type; it also distinguishes among cover types where alluvium will underlie vegetative backfill and cover types where vegetative backfill can be placed on a wider range of material, depending on the available subgrade material.

Table 3. Vegetative Backfill Criteria and Volumes for Floodplain Cover Types

Floodplain Cover Type	Soil/Substrate Texture	Vegetative Backfill Depth (inches)	Approximate Volume of Vegetative Backfill Phase 3 (cubic yards)	Approximate Volume of Vegetative Backfill Phase 4 (cubic yards)
Exposed Depositional (Non-vegetated)	Sand, fine to coarse gravel or cobble (alluvium)	0	0	0
Colonizing Depositional (Vegetated)	Sand, fine to coarse gravel or cobble (alluvium)	0	0	0
Riparian Wetland	Silt to sandy loam (vegetative backfill)	12	1,936	6,453
Floodplain Riparian Shrub[1]	Silt loam to sandy loam (vegetative backfill)	6	32,010	64,162
Outer Bank Riparian Shrub	Silt loam to sandy loam (vegetative backfill)	6	3,122	6,705
Emergent Wetland	Silt to sandy loam (vegetative backfill)	12	1,775	1,775
Hayfield	Silt loam to sandy loam (vegetative backfill)	18	46,222	5,324
Grassland Pasture	Silt loam to sandy loam (vegetative backfill)	6	21,538	0
Riparian Pasture	Silt loam to sandy loam (vegetative backfill)	6	32,589	9,035
		Total	**139,192**	**93,454**

[1] Approximately 15 acres of Floodplain Riparian Shrub and 4 acres of Outer Bank Riparian Shrub receive Type A material rather than vegetative backfill in the top 6 inches.

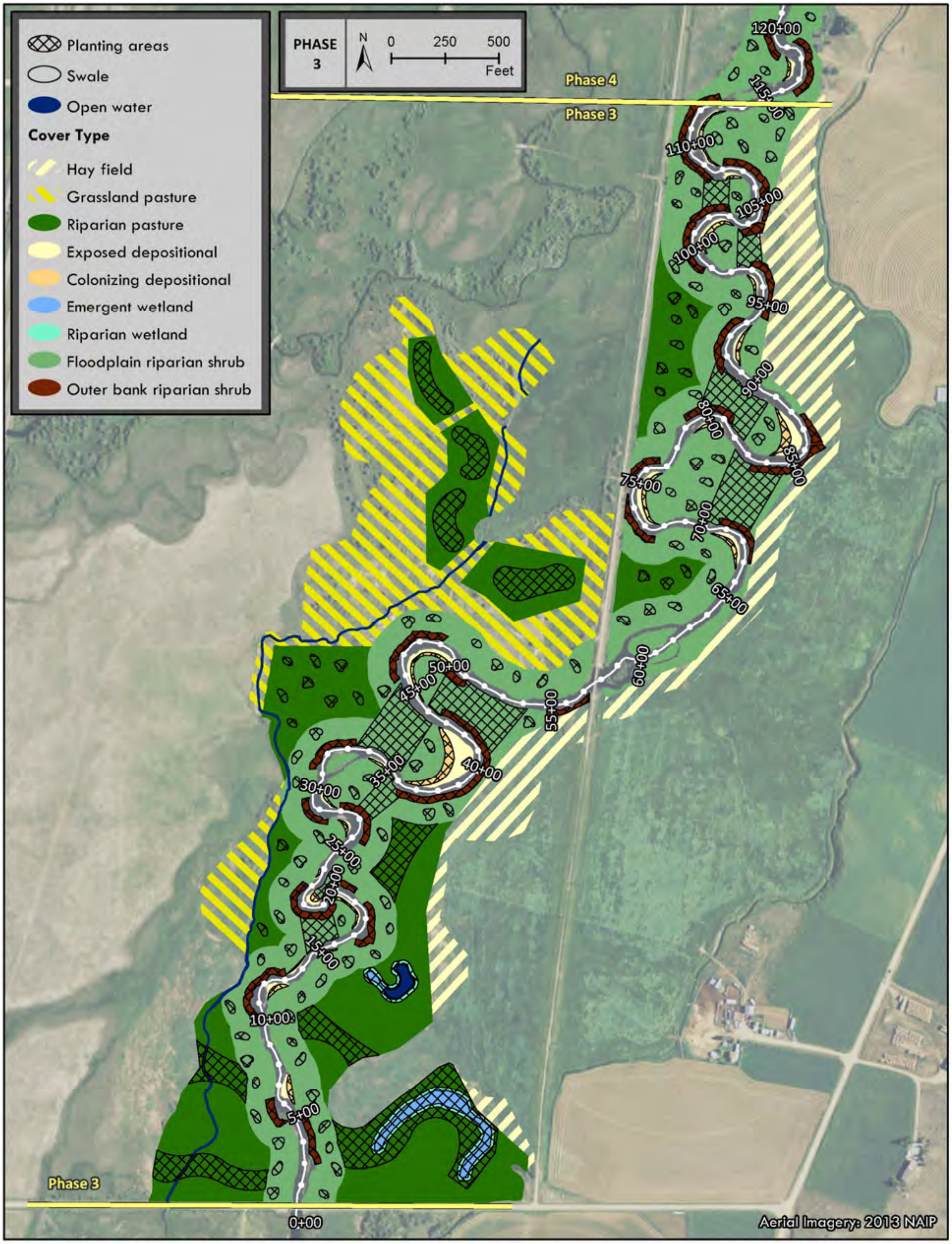


Figure 1. Cover Type and Planting Locations in Phase 3 Project Area

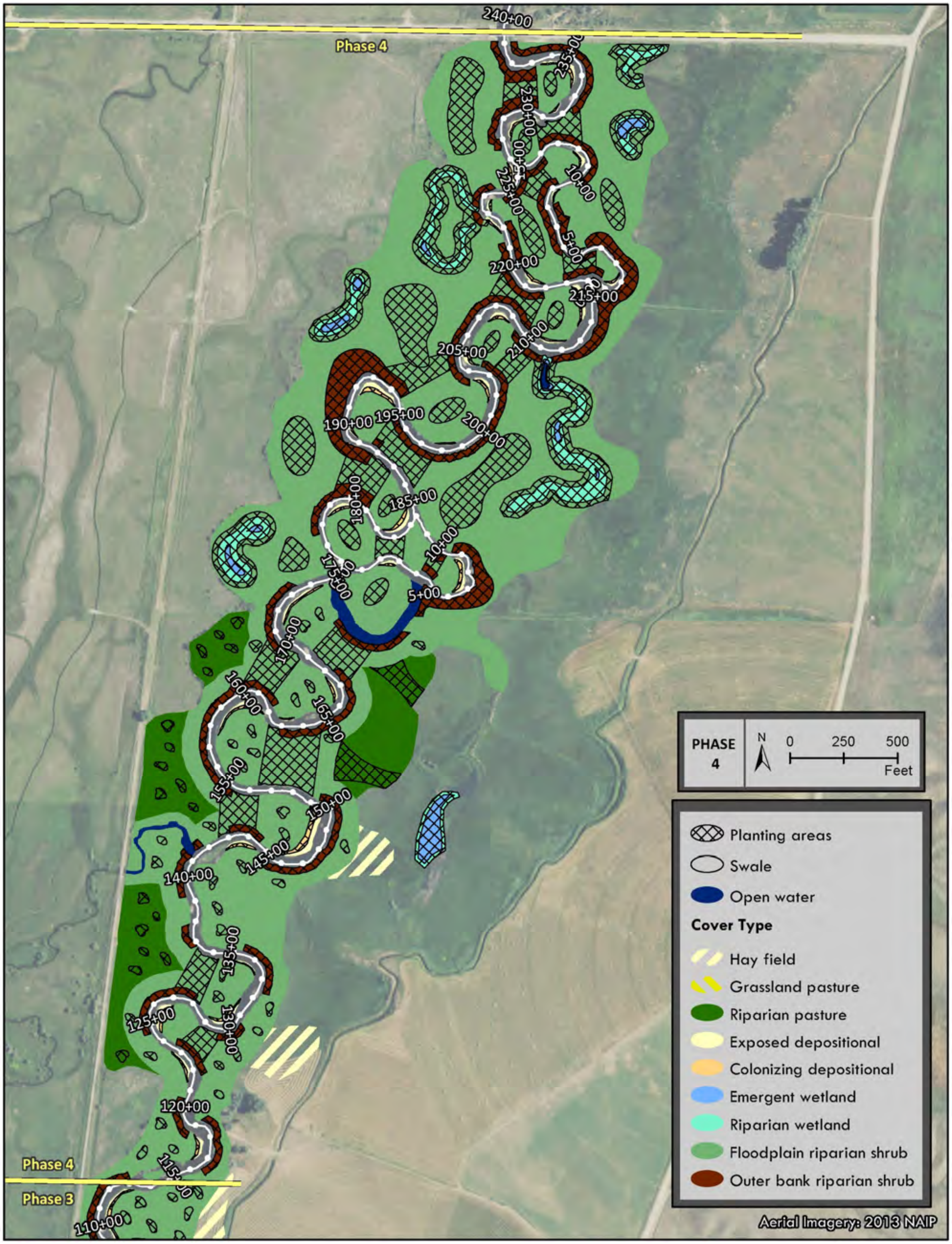


Figure 2. Cover Type and Planting Locations in Phase 4 Project Area

Floodplain Swales

Floodplain swales are small depression features incorporated into the Floodplain Riparian Shrub and Riparian Pasture cover type that provide microsites where floodplain vegetation can establish at slightly lower elevations—closer to the water table—than adjacent floodplain surfaces. Floodplain swales also provide flood water and sediment storage at variable flows, in addition to broadening the range of habitats available on the floodplain surface to support different life stages (and behaviors) of plant, bird, amphibian, and terrestrial wildlife species.

To maximize diversity, floodplain swales should vary in size and depth. Dimensions will vary and range from 30 to 60 feet long and 15 to 50 feet wide. Swale depth will be up to 2.5 feet below the two year water surface elevation (WSE) and at least 1.5 feet below the adjacent surface. The side slopes of swales will be no steeper than 4:1. Swales will be located a minimum of 30 feet from the streambank. Swales will not be located in moderate to high risk avulsion paths. Figure 3 shows an example of a constructed floodplain swale.

Figure 3. Constructed Floodplain Swale Features

Microtopography

This treatment creates complexity and microsites on newly constructed floodplain surfaces to trap and protect seed and other plant propagules, and to provide resistance to erosion by limiting rill formation. Microtopography is created using equipment to roughen the floodplain surface and partially bury woody debris in the soil (Figure 4). Roughness or microtopography creates variation in the constructed floodplain surface ranging from 0.5 feet above to 0.5 feet below the design floodplain surface. The woody debris increases soil moisture retention, creates protective microsites for establishing seed and plants, and promotes soil development by introducing organic material. Microtopography will be placed in all floodplain cover types except Exposed Depositional, Colonizing Depositional Grassland Pasture, and Hayfield.

Two types of woody debris, large and coarse, are included as part of the microtopography treatment. Large woody debris consists of 8-inch diameter pieces of wood that are at least 10 feet in length, and these pieces will be placed at a rate of approximately 50 pieces per acre. Large woody debris will be partially buried within the floodplain surface, leaving no more than half of the log exposed. Smaller, coarse woody debris can be highly variable in size (salvaged material from floodplain clearing within the removal boundary is suitable) and will be placed at a rate of approximately 100 to 150 pieces per acre. Coarse woody debris does not need to be buried but should be scattered within swales or piled around planted shrubs and trees.

Figure 4. Microtopography Treatment on a Constructed Floodplain Surface

Bank Treatment Revegetation

Dormant cuttings from native shrub and tree species are the primary plant material incorporated into streambank treatments. Cuttings are collected from plants that root easily, such as willows (*Salix* species) and cottonwoods (*Populus* species). The best species to use for willow cuttings for the Phase 2 project area, in order of preference, are as follows: sandbar willow (*Salix exigua*), Geyer willow (*Salix geyeriana*), Booth's willow (*Salix boothii*), Bebb willow (*Salix bebbiana*), yellow willow (*Salix lutea*), and Pacific willow (*Salix lasiandra*). All species should be used as part of a multi-species collection. In addition, black cottonwood (*Populus balsamifera ssp. trichocarpa*) cuttings can be used in some areas. Red-osier dogwood (*Cornus sericea*) and gray alder (*Alnus incana*) may also be used as cuttings, but should only be used as part of a mix consisting primarily of willow species. All streambank treatments require dormant cuttings incorporated into some portion of the reconstructed streambank; the dimensions and quantities of cuttings needed for each treatment will be included in the final design.

Table 4. Willow Cuttings by Bank Treatment

Bank Treatment Type[1]	Length Phase 3 (feet)	Length Phase 4 (feet)	Willow cuttings/ linear foot	Total # willow cuttings Phase 3	Total # willow cuttings Phase 4
Group 1 (Brush Trench)	4,176	4,788	3	12,526	14,362
Group 2 (Brush matrix, Preserve Vegetation/Brush Trench)	7,422.48	12,422	3	22,268	37,266
Group 3 (Double Vegetated Soil Lift)	10,524	10,515	6	63,141	63,090
Bifurcation	48	50	3	145	151
TOTAL TREATMENT LENGTH	**22,170**	**27,775**		**98,080**	**114,869**
TOTAL	**49,944**			**212,949**	

[1] This table only includes lengths for bank treatments where willow cuttings are used

Planting

Containerized plants will be installed within the following floodplain cover types: Colonizing Depositional, Emergent Wetland, Riparian Wetland, Outer Bank Riparian Shrub, in swales within Floodplain Riparian Shrub, and swales and planting units in Riparian Pasture (Figures 1 and 2) (Table 5). In general, plant mixes include early-successional species such as cottonwoods, aspen, willows, currant (*Ribes* species), birch (*Betula* species), and alder (*Alnus* species) that may be better suited for the minimal shade conditions and lack of developed soils that will be present on the newly constructed floodplain surface. Plant mixes also include productive native shrub species such as serviceberry (*Amelanchier alnifolia*), chokecherry (*Prunus virginiana*), currant (*Ribes* species), and red raspberry (*Rubus idaeus*).

In the Floodplain Riparian Shrub and Riparian Pasture cover types, planting will be concentrated within excavated swale features or in linear corridor features. Additional streambank areas within the Floodplain Riparian Shrub cover type will also be planted. Shrubs will be installed throughout the Colonizing Depositional, Outer Bank Riparian Shrub, and Riparian Wetland cover types. Herbaceous plugs, consisting of sedges (*Carex* species) and rushes (*Juncus* species), will be installed within the Emergent Wetland and Colonizing Depositional cover types. Table 5 provides a summary of approximate plant material sizes, spacing and quantities for each cover type. Tables 6 through Table 11 provide the species included in each plant mix.

Table 5. Floodplain Cover Type Planting Locations, Plant Mixes, and Number of Plants

Floodplain Cover Type	Planting Locations	Area to be Planted Phase 3 (acres)	Area to be Planted Phase 4 (acres)	Type of Plant Material	Approx. Spacing (feet on center)	Approx. Number of Plants Phase 3	Approx. Number of Plants Phase 4
Exposed Depositional	None	N/A	N/A	N/A	N/A	N/A	N/A
Colonizing Depositional	All Areas	1.3	1.1	10 in^3 herbaceous	3	3,150	2,600
		1.3	1.1	10 in^3 shrub	3	3,150	2,600
Emergent Wetland	All Areas	1.1	1.1	10 in^3 herbaceous	2	12,000	12,000
Riparian Wetland	All Areas	1.2	4.0	1 gallon shrubs	8	800	2,800
Floodplain Riparian Shrub	Swales, Streambanks, & Avulsion Paths	10.5	22.2	1 gallon trees shrubs	8 15	7,150	15,100
Outer Bank Riparian Shrub	All Areas	5.0	11.6	1 gallon trees and shrubs	8	3,500	8,000
Hayfield	None	N/A	N/A	N/A	N/A	N/A	N/A
Grassland Pasture	None	N/A	N/A	N/A	N/A	N/A	N/A
Riparian Pasture	Swales & Corridors	10.1	1.9	1 gallon trees and shrubs	8	7,000	1,300
Total					10 in^3 herbaceous	15,150	14,600
					10 in^3 shrub	3,150	2,600
					1 gallon trees and shrubs	18,450	27,200

The following tables list the approximate species and quantities for plant mixes to be used for the Phases 3 and 4 Project area.

Table 6. Colonizing Depositional – Herbaceous Plant Mix.

Scientific Name	Common Name	Approx. Percent of Mix
Carex aquatilis	water sedge	20
Carex nebrascensis	Nebraska sedge	10
Carex pellita (syn. C. lanuginosa)	woolly sedge	10
Carex utriculata	Northwest Territory sedge	20
Eleocharis palustris	common spikerush	10
Juncus arcticus	arctic rush	10
Scirpus microcarpus	panicled bulrush	20
	Total	**100**

Table 7. Colonizing Depositional – Shrub Plant Mix.

Scientific Name	Common Name	Approx. Percent of Mix
Alnus incana	gray alder	5
Betula occidentalis	water birch	20
Salix bebbiana	Bebb willow	5
Salix boothii	Booth's willow	20
Salix exigua	sandbar willow	45
Salix geyeriana	Geyer willow	5
	Total	**100**

Table 8. Emergent Wetland – Herbaceous Plant Mix.

Scientific Name	Common Name	Approx. Percent of Mix
Carex aquatilis	water sedge	15
Carex microptera	small winged sedge	5
Carex nebrascensis	Nebraska sedge	10
Carex pellita (syn. C. lanuginosa)	woolly sedge	5
Carex utriculata	Northwest Territory sedge	10
Carex vesicaria	inflated sedge	20
Eleocharis palustris	common spikerush	5
Juncus arcticus	arctic rush	10
Schoenoplectus acutus	hardstem bulrush	10
Scirpus microcarpus	panicled bulrush	10
	Total	**100**

Table 9. Riparian Wetland – Shrub Plant Mix

Scientific Name	Common Name	Approx. Percent of Mix
Alnus incana	gray alder	10
Betula occidentalis	water birch	15
Cornus sericea	red-osier dogwood	10
Ribes setosum	inland gooseberry	5
Salix bebbiana	Bebb willow	10
Salix boothii	Booth's willow	20
Salix exigua	sandbar willow	25
Salix geyeriana	Geyer willow	5
	Total	**100**

Table 10. Floodplain Riparian Shrub – Tree and Shrub Plant Mix

Scientific Name	Common Name	Approx. Percent of Mix
Trees		
Populus balsamifera ssp. trichocarpa	black cottonwood	8
Populus tremuloides	quaking aspen	2
Shrubs		
Alnus incana	gray alder	7
Amelanchier alnifolia	Serviceberry	2
Betula occidentalis	water birch	10
Cornus sericea	red osier dogwood	10
Prunus virginiana	common chokecherry	2
Ribes setosum	inland gooseberry	2
Rubus idaeus	red raspberry	1
Salix bebbiana	Bebb willow	9
Salix boothii	Booth's willow	10
Salix exigua	sandbar willow	20
Salix geyeriana	Geyer willow	5
Salix lasiandra	Pacific willow	3
Salix lutea	yellow willow	3
Shepherdia argentea	silver buffaloberry	3
Symphoricarpos occidentalis	western snowberry	3
	Total	**100**

Table 11. Outer Bank Riparian Shrub – Tree and Shrub Plant Mix

Scientific Name	Common Name	Approx. Percent of Mix
Trees		
Populus balsamifera ssp. trichocarpa	black cottonwood	10
Populus tremuloides	quaking aspen	5
Shrubs		
Alnus incana	gray alder	10
Amelanchier alnifolia	serviceberry	2
Betula occidentalis	water birch	10
Cornus sericea	red-osier dogwood	5
Dasiphora floribunda	shrubby cinquefoil	2
Prunus virginiana	common chokecherry	5
Ribes aureum	golden currant	1
Ribes setosum	inland gooseberry	1
Rosa woodsii	Woods' rose	1
Rubus idaeus	red raspberry	1
Salix bebbiana	Bebb willow	10
Salix boothii	Booth's willow	20
Salix exigua	sandbar willow	15
Shepherdia argentea	silver buffaloberry	1
Symphoricarpos occidentalis	western snowberry	1
	Total	**100**

Table 12. Riparian Pasture – Tree and Shrub Plant Mix

Scientific Name	Common Name	Approx. Percent of Mix
Trees		
Populus balsamifera ssp. trichocarpa	black cottonwood	10
Populus tremuloides	quaking aspen	5
Shrubs		
Alnus incana	gray alder	15
Amelanchier alnifolia	serviceberry	2
Betula occidentalis	water birch	10
Cornus sericea	red-osier dogwood	5
Dasiphora floribunda	shrubby cinquefoil	2
Prunus virginiana	common chokecherry	5
Ribes aureum	golden currant	1
Ribes setosum	inland gooseberry	1
Rosa woodsii	Woods' rose	1
Rubus idaeus	red raspberry	1
Salix bebbiana	Bebb willow	10
Salix boothii	Booth's willow	15
Salix exigua	sandbar willow	15
Shepherdia argentea	silver buffaloberry	1
Symphoricarpos occidentalis	western snowberry	1
	Total	**100**

Table 13. Summary of Phases 3 and 4 Plants

Scientific Name	Common Name	Approximate Number of Plants
Graminoids – 10 cubic inch container size		
Carex aquatilis	water sedge	4,750
Carex microptera	small winged sedge	1,200
Carex nebrascensis	Nebraska sedge	2,975
Carex pellita (syn. C. lanuginosa)	woolly sedge	1,775
Carex utriculata	Northwest Territory sedge	3,550
Carex vesicaria	inflated sedge	4,800
Eleocharis palustris	common spikerush	1,775
Juncus arcticus	arctic rush	2,975
Schoenoplectus acutus	hardstem bulrush	2,400
Scirpus microcarpus	panicled bulrush	3,550
	Total 10 cubic inch graminoids	**29,750**
Shrubs – 10 cubic inch container size		
Alnus incana	gray alder	288
Betula occidentalis	water birch	1,150
Salix bebbiana	Bebb willow	288
Salix boothii	Booth's willow	1,150
Salix exigua	sandbar willow	2,588
Salix geyeriana	Geyer willow	288
	Total 10 cubic inch shrubs	**5,750**
Shrubs – one gallon container size		
Alnus incana	gray alder	4,313
Amelanchier alnifolia	serviceberry	841
Betula occidentalis	water birch	4,745
Cornus sericea	red-osier dogwood	3,575
Dasiphora floribunda	shrubby cinquefoil	396
Prunus virginiana	common chokecherry	1,435
Ribes aureum	golden currant	198
Ribes setosum	inland gooseberry	823
Rosa woodsii	Woods' rose	198
Rubus idaeus	red raspberry	421
Salix bebbiana	Bebb willow	4,343
Salix boothii	Booth's willow	6,490
Salix exigua	sandbar willow	8,320
Salix geyeriana	Geyer willow	1,293
Salix lasiandra	Pacific willow	668
Salix lutea	yellow willow	668
Shepherdia argentea	silver buffaloberry	866
Symphoricarpos occidentalis	western snowberry	866
	Total One Gallon Shrubs	**40,455**
Trees – one gallon container size		
Populus tremuloides	quaking aspen	3,760
Populus balsamifera	black cottonwood	1,435
	Total One Gallon Trees	**5,195**

Browse Protection

Browse protection measures are intended to protect planted shrubs and trees from browse and other damage caused by wildlife and livestock. Two types of browse protection may be used for the Phases 3 and 4 project area: riparian protection fence and individual plant protectors. Fence is the preferred method of protection because it requires less maintenance than individual protectors and can protect plantings over a longer period of time. Fences will be installed to protect the riparian corridor from livestock and also installed around target groups of plants installed in constructed floodplain swale and wetland features. Individual protectors will be needed in areas where fencing cannot be installed or where additional protection to prevent beaver browse is required.

The preferred fence option for floodplain swales includes a sturdy wire mesh fence material secured to 12-foot long, 4-inch diameter untreated wooden posts installed vertically at least 3 feet deep (Figure 5, left). When possible this fence follows the perimeter of the removal or planted area. However, to allow for wildlife passage, smaller exclosures surrounding groups of planting areas may also be used. Individual browse protectors consist of a 4-foot wide by 4-foot tall piece of high density black polyethylene (UV-stabilized) mesh or 2-inch by 2-inch wire mesh rounded into a 16-inch diameter cylinder (Figure 5, right). The individual browse protector encloses a plant and is secured to two 2-inch-square wooden stakes with releasable cable ties. The browse protector will be installed so its base is in contact with the ground surface to discourage rodents from girdling plants. Details for browse protection will be included in the final design for Phases 3 and 4.

Figure 5. Browse Protection Measures: Individual Browse Protector (left) and Riparian Protection Fence (right).

Seeding

Establishing native vegetative cover on the newly created floodplain is essential for maintaining soil stability and preventing weed infestations. Planting will establish native vegetation in portions of the floodplain, but seeding is the primary mechanism for stabilizing soil within the new floodplain. To ensure quick, long-lasting vegetation establishment a two-stage seed mix will be used. The two-stage seed mix includes two components: a mix of quick germinating species (nurse crop or cover crop) that will provide immediate cover to limit colonization by invasive species and a mix of long-term desired species that may not germinate immediately after construction because they may require a stratification period. Seed mixes consist of a range of herbaceous species including grasses, forbs, sedges, and/or rushes. Woody species may also be seeded in select areas of most of the floodplain cover types.

Several seed mixes will be used throughout the floodplain to support establishment of desired plant communities. Seed mixes will be linked to specific floodplain and land use cover types. Exact species and seeding rates will be developed in cooperation with landowners.

Various methods for seeding may be required due to ground conditions or because the variety of seeds within the seed mixes need to be planted at different depths and/or during different seasons. Drill seeding will be the preferred seed application method where feasible. Hand broadcast seeding will be required in most areas where the microtopography treatment is installed. The roughness created by the microtopography treatment makes equipment access difficult or impossible. Where possible, broadcast seed should be either hand raked or harrowed into the soil after application, depending on the size and sensitivity of the seeded areas.

Mature Shrub Transplant

Mature shrubs growing near the project area may be transplanted to areas within the newly constructed floodplain. Transplanting mature shrubs provides local adapted plant material that can help increase plant diversity; provide habitat for wildlife; and reproduce and expand more rapidly than nursery grown plants. Soil transplanted with mature shrubs can also provide soil microorganisms that can help improve nutrient cycling in the new floodplain. Only shrubs growing in areas with no contamination will be considered for transplant. The exact number of shrubs to transplant, donor sites and transplant locations are yet to be determined for Phases 3 and 4. Transplant locations will likely be primarily in Phase 4 within the Conservation land use type. Donor shrubs will be transplanted in clusters in selected locations. This can increase survivorship and help re-establish nutrient cycling between shrubs.