Draft Final
Geomorphic, Hydrologic, and Hydraulic Investigation
Clark Fork River Operable Unit
Phases 5 and 6

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Acronyms and Abbreviations

ARCO	Atlantic Richfield Company
BEHI	Bank Erosion Hazard Index
CFR	Clark Fork River
CFROU	Clark Fork River Operable Unit of the Milltown Reservoir/Clark Fork River Superfund Site
cfs	cubic feet per second
Clark Fork Site	Milltown Reservoir/Clark Fork River Superfund Site
D_{bf}	bankfull flow depth
D_{cf}	channel-forming flow depth
DEQ	Montana Department of Environmental Quality
LiDAR	Light Detection and Ranging
NPL	National Priorities List
NPS	National Park Service
NRDP	Natural Resource Damage Program
OU	Operable Unit
Q_{bf}	Bankfull flow
Q_{cf}	Channel-forming flow
Rc	Radius of Curvature
RipES	Riparian Evaluation System
ROD	Record of Decision
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
W_{bf}	bankfull width
W_{cf}	channel-forming width

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Section 1.0 Introduction

The Clark Fork River Operable Unit (CFROU) is part of the Milltown Reservoir/Clark Fork River Superfund Site and includes the uppermost 120 miles of the Clark Fork River (CFR) between Warm Springs Ponds and Missoula, Montana. The Operable Unit was divided into three reaches (A, B, and C) as shown on Figure 1. This project site is designated as Phases 5 and 6 (Figure 2), covering 4.5 river miles of Reach A from river mile 7.8 to river mile 12.3. Phases 5 and 6 encompass the reach of river through the Dry Cottonwood Creek Ranch from Galen Road to the Powell/Deer Lodge county line about 300 feet north of Gemback Road. The documentation of the investigation and characterization for this project is included in two reports: Floodplain Investigation Data Summary Report (TerraGraphics, 2012), encompasses the floodplain sampling to determine the extent of the floodplain deposited tailings; and this report: Geomorphic, Hydrologic, and Hydraulic Investigation to provide supporting analyses for the remediation design.

1.1 Site Background

Heavy metals originating from historic mining activities, milling, and smelting processes associated to the Anaconda Company operations in Butte and Anaconda have accumulated in the Clark Fork River stream banks and floodplain over a period of at least 100 years. The primary sources of contamination are tailings and contaminated sediments mixed with soils in the stream banks and floodplains, 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 directly into the groundwater and eventually to surface water. These contaminant transport pathways result in impacts to terrestrial and aquatic life along the Clark Fork River as described in the Record of Decision (ROD) for the site (USEPA/MDEQ, 2004).

The Montana Department of Environmental Quality (DEQ), as lead agency for remediation of the CFROU, with additional oversight from the U.S. Environmental Protection Agency (USEPA) (and the National Park Service (NPS) for remedial activities on the Grant-Kohrs Ranch), will oversee, manage, coordinate, and implement the Remedial Design, Remedial Action(s), and Operation and Maintenance for the CFROU. DEQ will coordinate with the Natural Resource Damage Program (NRDP) at the Montana
Department of Justice in the implementation of the Clark Fork Aquatic and Riparian Resources Restoration Plan and in the integration of the Clark Fork Aquatic and Riparian Restoration Plan components into the Work. DEQ will coordinate with NPS to implement the Federal Restoration Plan at the Grant-Kohrs Ranch and, where appropriate, integrate the Federal Restoration Plan components into the work. NRDP and NPS are included in the Sampling and Analysis Planning Team to understand and receive the information to be collected, understand how that information is to be analyzed, provide review and comment, and better coordinate aspects of state and federal restoration with the remedy for the Clark Fork Site.

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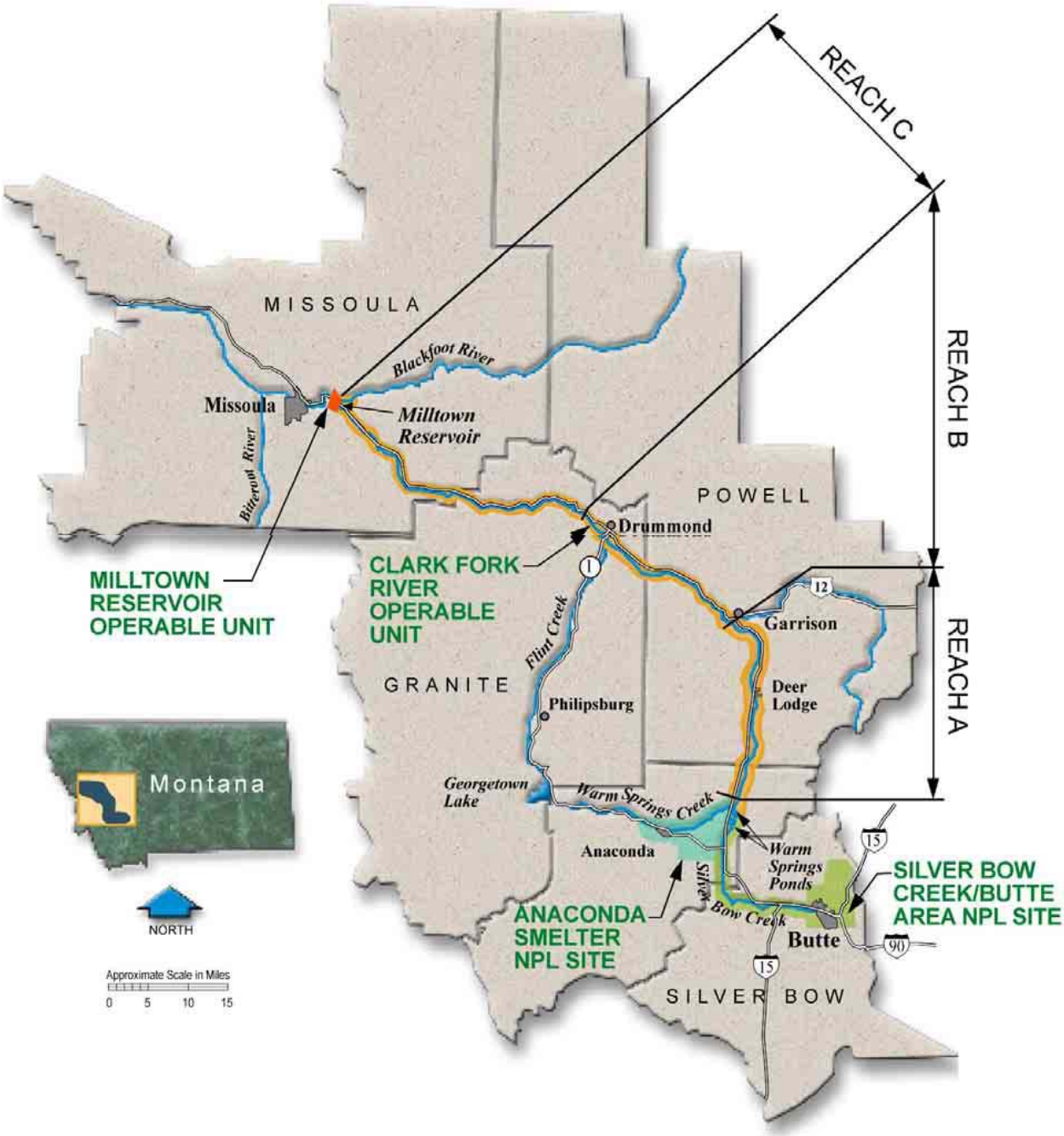

Figure 1. Clark Fork River Operable Unit (USEPA/DEQ, 2004)

1.2 Purpose and Objectives

The purpose of this project is to evaluate the geomorphic, hydrologic, and hydraulic characteristics of the river within this designated portion of the CFROU. The overall objective of the investigations described herein is to guide and support the remediation design for Phases 5 and 6. Specific objectives of the investigations include the following:

- Assess existing bank erosion condition.
- Identify location and extent of contamination and bank conditions.
- Assess existing instream pool habitat.
- Identify current geomorphic characteristics.
- Review and verify prior analyses of peak flow hydrology.
- Prepare hydraulic analysis for 2-year, 10-year, and 100-year peak flow conditions.
- Evaluate bank toe gravels and identify depth to floodplain gravel.
- Identify floodplain conditions related to human impacts.
- Identify appropriately functioning river system features.

1.3 Site Location and Description

The CFROU is located within Deer Lodge, Powell, and Missoula Counties. The upstream boundary at the Operable Unit is located at the confluence of Silver Bow Creek and the original Clark Fork River channel just downstream of Warm Springs Ponds. The original channel of the river upstream of this point was obliterated when the Warm Springs Ponds were built. The downstream boundary is the Milltown Reservoir Sediments Operable Unit, just east of Missoula, Montana. The CFROU was divided into three main reaches, Reach A, B, and C as shown in Figure 1. This site, designated as Phases 5 and 6, is located along the CFR in Deer Lodge County, Montana. Phases 5 and 6 encompass the reach of river through Dry Cottonwood Creek Ranch, from Galen Road at the southern, upstream end to the Powell County line about 300 feet north of Gemback Road (Figure 2). The site contains 4.5 river miles of sinuous flow, extending from river mile 7.8 to river mile 12.3. Bridges cross the CFR at both Galen Road and Gemback Road. Irrigation water is diverted along this reach for the Whalen, West Side, and Alvi Beck ditches. The site is currently operated as part of a 2,300-acre working cattle ranch partially owned by the Clark Fork Coalition. About 200 acres of crop lands along the CFR within the project area are irrigated with water from Dry Cottonwood Creek and Lost Creek.

1.4 Previous Studies

Several studies have been conducted on the CFROU and other OUs in the Anaconda/Butte Area since their addition to the National Priorities List (NPL). Related studies from the other OUs include those for the Warm Springs Ponds OU of the Silver Bow Creek/Butte Area Site, located at the headwaters of the CFR.

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In the late 1980s and early 1990s, several studies were conducted on Warm Springs Ponds to evaluate the hydrology of Silver Bow Creek for the purpose of improving its water quality treatment capacity to meet the USEPA requirements in the Warm Springs Ponds Operable Unit 4 ROD (USEPA, 1990). Two such studies were the Supplemental Work Plan for Warm Springs Ponds Phase III Construction (ESA, 1991), and Silver Bow Creek Flood Modeling Study (CH2M Hill, 1989). These studies included hydrologic, hydraulic, and sediment transport modeling for Silver Bow Creek and portions of the upper CFR from the outlet of Warm Springs Ponds to Deer Lodge.

In the late 1990s and early 2000s, the U.S. Geological Survey (USGS) and others prepared several studies on the CFR regarding assessments of the geomorphic conditions, vegetation stabilization influences on the floodplain and banks, and metals transport (Smith et al., 1998; Griffin and Smith, 2001; Smith and Griffin, 2002). The study reported by Smith et al. (1998) was conducted to assess floodplain tailings and metals transport and included an assessment of geomorphology and hydrology in the upper CFR valley. The 2001 and 2002 reports focused on the effects of vegetation on floodplain stability and streambank erosion. Smith and Griffin (2001; 2002) concluded in both of these studies that streambank erosion rates and floodplain shear stresses decrease with increasing density of woody riparian vegetation.

The CFROU ROD (USEPA/DEQ, 2004) presented the site's characteristics, risks, remedial action objectives, and a selected remedy. *Part 2, Decision Summary*, of the ROD included *Appendix B, Clark Fork River OU Streambank Stabilization Design Considerations and Examples*. This Appendix presented hydrology estimates for Deer Lodge and included four conceptual stream bank treatment designs.

In 2010, DEQ developed a two-part investigation of the upper part of Reach A of the CFROU, designated as Phase 1, which included an area approximately coinciding with the Governor's Demonstration Project from the outlet of Warm Springs Ponds to Perkins Lane (Figure 2). *Part 1: Floodplain Investigation Data Summary Report* identified the extent of soil contamination and *Part 2: Geomorphic, Hydrologic, and Hydraulic Investigation* evaluated the existing characteristics and developed design data on floodplain materials and streambank conditions (CDM and AGI, 2010).

In 2011, the Clark Fork Coalition and Montana NRDP investigated groundwater-surface water interaction, water management, and instream flow potential on the Dry Cottonwood Creek Ranch (Clark Fork Coalition and Montana NRDP, 2011). The investigation: 1) characterized the hydrologic losses and gains along the CFR through the ranch, 2) determined the irrigation water demands of the ranch, 3) investigated groundwater storage and return flow, and 4) assessed the potential for increasing the ranch's efficiency and converting excess/salvaged water to instream flow.

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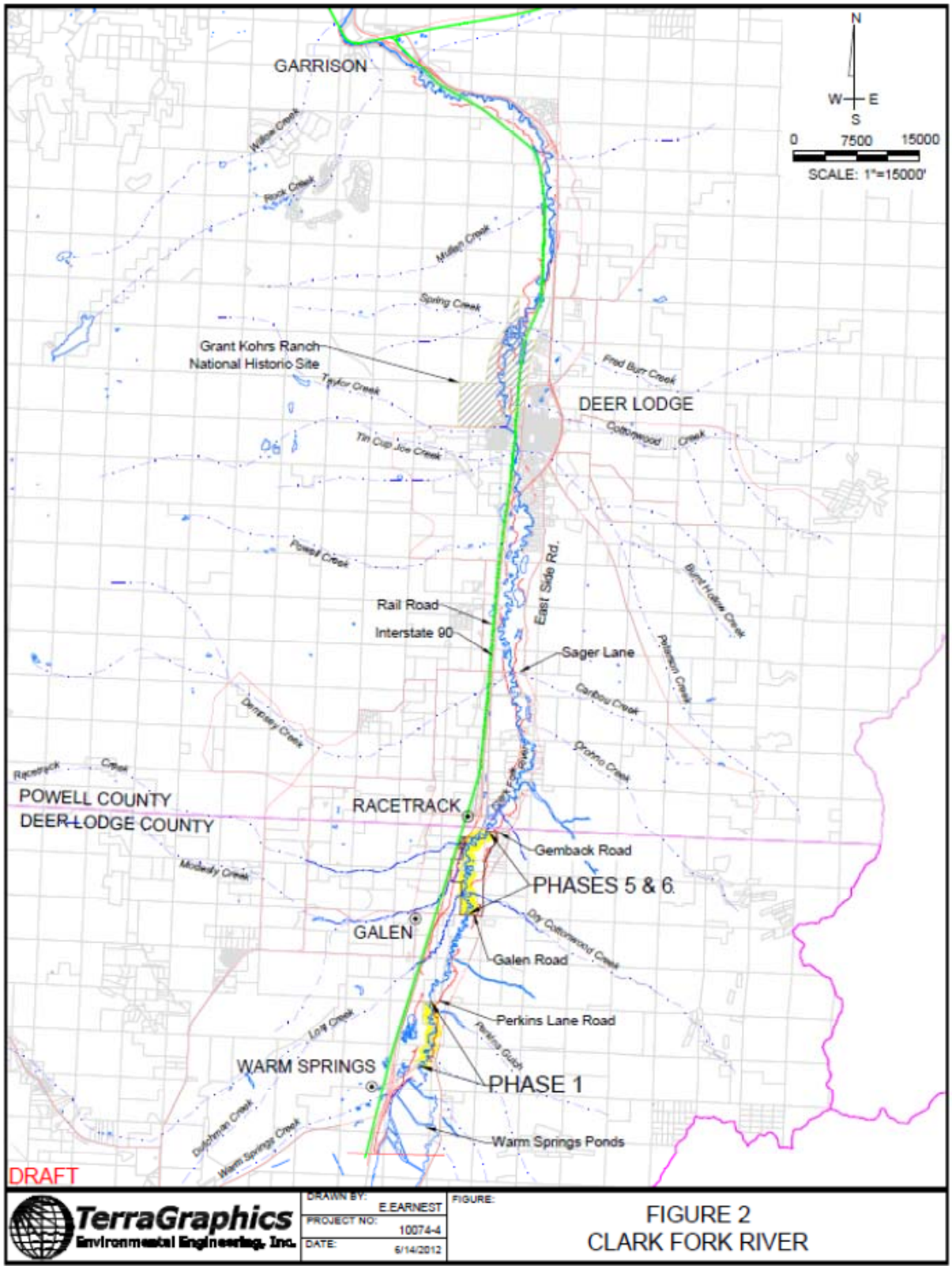

Figure 2. Phase 5 and 6 location (modified from CDM and AGI, 2010)

Section 2.0 Regional and Project Setting

2.1 Geologic Setting

The Deer Lodge Valley is bounded to the west by the eastern front of the Flint Creek Range. The Flint Creek Range is at the leading edge of a large block of the earth's crust that moved east out of Idaho about 70 million years ago and contains rocks that have been deformed into tight folds and broken by faults as this Sapphire block collided with the rocks ahead of it (Wallace et al., 1989). Large masses of magma spread east from the Idaho batholith along thrust faults to invade the folds and further complicate the geologic structure of the range. Granite that was intruded along the thrust faults now forms the high peaks of the Flint Creek Range (Emmons and Calkins, 1913). Ore deposits that developed around the margins of the granite intrusions have been a source of mining activity in the area since gold was first discovered north of Deer Lodge at Gold Creek in 1852.

Ice age glaciers that gouged the high valleys of the Flint Creek Range descended to the elevation of the Deer Lodge Valley floor. Evidence of this glaciation can be seen in the deeply carved high peaks, sharp ridges, and valleys shaped like deep troughs. Hummocky moraines littered with erratic boulders spread around the mouths of the canyons near the eastern flank of the Flint Creek Range (Sears et al., 2000).

The rounded hills to the east of the Deer Lodge Valley are eroded into granite of the Boulder batholith and its cover of darker volcanic andesite that was erupted from the same mass of magma. The hills in the northern part of the Deer Lodge Valley expose sedimentary formations, mostly Cretaceous sandstone, which was tilted as it was pushed ahead of the eastward moving Sapphire block (Hyndman, 1975).

High benches visible on the western side of the southern part of the Deer Lodge Valley are primarily Tertiary basin fill deposits of the Renova formation and the eastern side are Quaternary basin fill deposits. These sediments were deposited under desert conditions over millions of years during Oligocene and early Miocene times and consist of gravels, sands, muds, volcanic ashes, limestones, and coal. Broad, gravel-veneered pediments have developed as prominent landforms over both the Tertiary sediments and older monzonite. These pediment deposits are 1–20 feet thick and contain subrounded cobbles and pebbles in a sandy matrix with some caliche development (Berg and Hargrove, 2004). Modern streams began to erode their valleys into the basin fill deposits of the CFR and its tributaries sometime between 2 and 3 million years ago (Sears et al., 2000).

Figure 3 presents the geology of the region; the following excerpt from Berg and Hargrove (2004) summarizes the geological units shown in the figure.

QUATERNARY

Holocene Epoch

Qal **Alluvium –** Gravel, sand, silt, and clay along active channels of modern rivers, creeks, and intermittent streams.

Qat1 **Alluvial terrace deposit, youngest –** Deposits on irregularly shaped, unpaired terraces 3 to 6 feet above the modern floodplain that consist of 3 to 6 feet of well to poorly sorted rock clasts derived from Tertiary and older strata.

Qat2 **Alluvial terrace deposit, second youngest** – Deposits on irregularly shaped, unpaired terraces 6 to16 feet above the modern floodplain that consist of 3 to 6 feet of poorly sorted clasts similar to those in the youngest alluvial terrace deposits.

Qat 3 **Alluvial terrace deposit, third youngest** - Deposits on irregularly shaped unpaired terraces 20 to30 feet above the modern floodplain that consist of 3 to 6 feet of poorly sorted clasts similar to those in the younger alluvial terrace deposits (Derkey et al., 2004).

Qac **Alluvium and colluvium -** Alluvium and colluvium are combined where it is not practical to distinguish between them.

Pleistocene Epoch

Qgo **Glacial outwash deposit** – Poorly sorted deposits of well-rounded material that ranges in size from boulder to sand. There are extensive outwash deposits on both the east and west sides of the Deer Lodge Valley. Outwash deposits on the east side of the valley consist mainly of basalt and porphyritic volcanic rock boulders, cobbles, and pebbles. On the west side of the valley outwash deposits consist of 80 to 95 percent granite clasts with the remainder quartzite. On the west side of the Deer Lodge Valley the percent of quartzite increases with distance from the mountain front. Near the Clark Fork River outwash contains an estimated 50 percent quartzite and 50 percent granite.

Qpg **Pediment gravel deposit** – Poorly sorted and poorly stratified gravels that range in thickness from 1 to 20 feet. Subrounded cobbles and pebbles in a sandy matrix with local development of caliche. Pediment gravels on the east side of the Deer Lodge Valley consist mainly of basalt and porphyritic volcanic rock fragments with rare granite and quartzite. Pediment gravels on the west side of the Deer Lodge Valley, where examined on the surface, consist of an estimated 90 percent metasedimentary rocks derived from the Belt Supergroup (mainly quartzite) with the remainder granite. In those rare instances where a complete section of the pediment gravel is exposed, crumbly, strongly weathered granite cobbles and boulders are present in the lower part of the gravel deposit.

TERTIARY

Ts Sedimentary rocks, undivided

Southern Deer Lodge Valley

Highly variable, silty to sandy mudstone to conglomeratic deposits; some sediment is of volcanic origin and some derives from the Butte Quartz Monzonite. Beds appear to be flat-lying, with low-angle dips measured in gullies; many apparent dips measured may be simply expressions of fluvial structures. Volcanic fragments increase in abundance to the north while clasts related to the Butte Quartz Monzonite (mostly aplite and vein quartz) dominate to the south. Chalcedonic quartz, white vein quartz, and Butte Quartz Monzonite clasts are common south of Interstates 90 and 15 transitioning to black tourmaline and aplite cobbles and porphyritic volcanic clasts to the north and slightly south of Interstate 90 and Rocker. Conglomerates and cobble layers in finer grained rocks

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are heterolithologic. As exposed in excavations for borrow material for reclamation in 2003, typical fine-grained mudstone and siltstone sediments contain large (3- to 5-foot) boulders of Butte Quartz Monzonite and Lowland Creek Volcanics near the contact with bedrock.

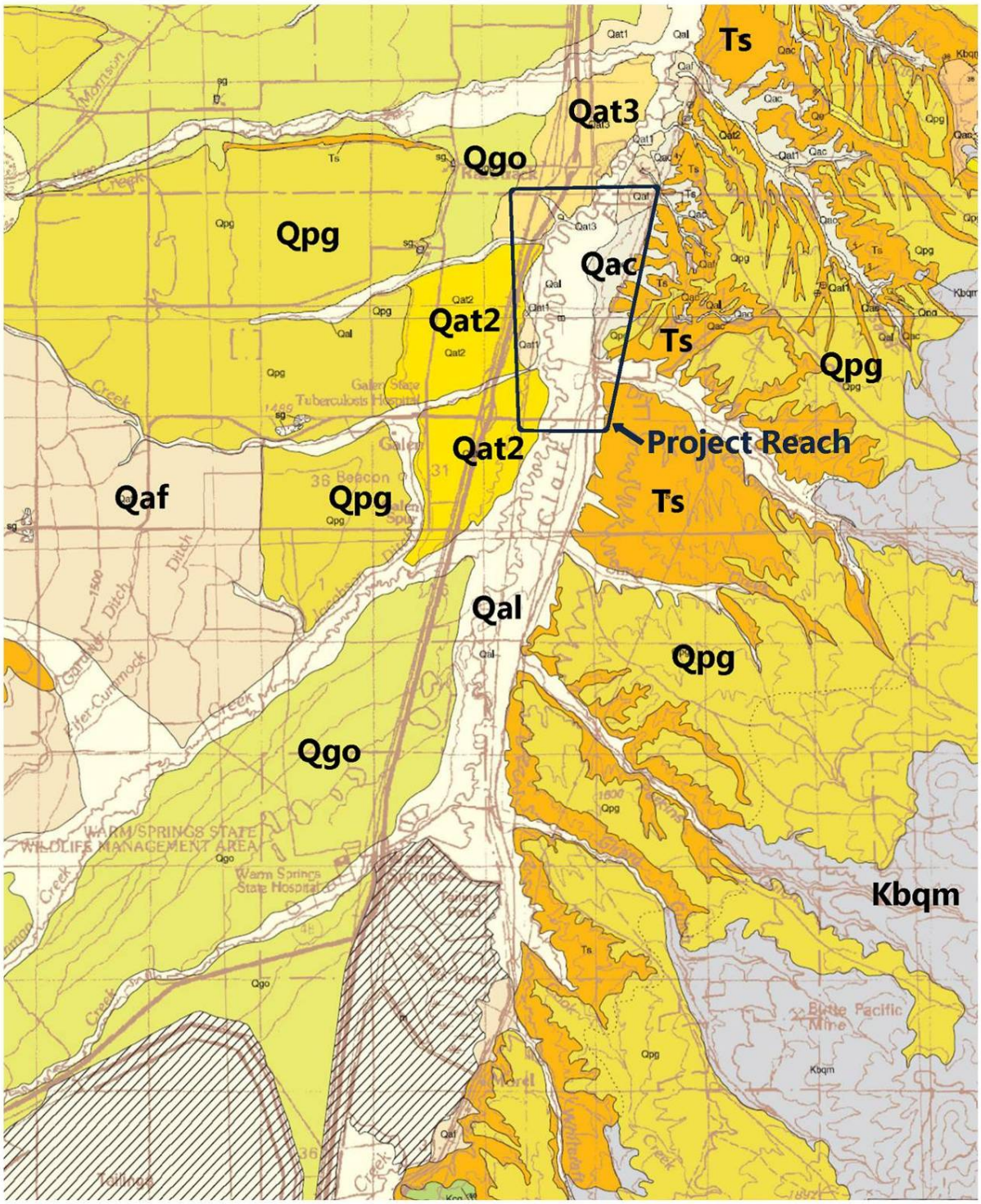

Figure 3. Geology map for the Upper Clark Fork River region (from Berg and Hargrove, 2004)

2.2 Geomorphic History

2.2.1 Pre Beaver Trapping and Mining Era

Historical and current geomorphic observations indicate that the upper CFR and its tributaries supported dense populations of water birch, willow, and other shrubs prior to inhabitation by miners and ranchers; the tributaries also supported cottonwood and aspen groves. Beaver populations likely played an important role in shaping the river and its floodplain, with numerous dams causing localized ponding and overland flow on the floodplain which spread over a wide expanse of the valley broader than the river and its floodplain currently occupy. Supporting evidence includes accounts by fur trappers in the early 1800s of aspen groves, willow thickets, and clusters of currant and gooseberry bushes with clear, deep, rapid water in the river. Current physical evidence includes perched gravel layers and buried peat throughout the floodplain. These observations indicate a historically wet floodplain consistent with a single thread, low banked river with a floodplain that was at least occasionally ponded during flood events (Smith et al., 1998).

2.2.2 Early Mining Era

Beaver were presumably eradicated from the area by the early 1800s, and soon after extensive mining began in the early 1860s the dense riparian vegetation on the floodplain and streambanks that stabilized the system and buffered hydrologic events was severely impacted by tailings deposition (Weed, 1912). Several floods in the late 1800s and early 1900s, with the largest in 1908, along with more frequent out-of-bank flood events, resulted in more than a century of suspension and deposition of tailings on the CFR floodplain. The extent of tailings deposition and impacts to vegetation are evident in the earliest available aerial imagery from 1947 for the project reach. Smith et al. (1998) suggest the pre-mining geomorphology, dense vegetation, and likely existence of a beaver-pond setting as the explanation for why these floods were able to deposit fine-grained tailings on the floodplain. These conditions included low main-channel banks, perched side channels, irregular floodplain topography, and dense floodplain vegetation, which, in part, offer an explanation for the variations in thickness of tailings deposits.

2.2.3 Post Late 1800s and early 1900s Floods

In the Upper Deer Lodge Valley, the CFR remains a single thread, sinuous river with alternating cut banks and point bars, riffle-pool sequence, and a gravel bed. Beaver populations have not recovered to the pre-mining era numbers; the riparian vegetation has been highly impacted by tailings deposits; the floodplain has become variably aggraded from the extremely high mining-related sediment load; and the floodplain has been strongly influenced by human activities including grazing, farming, an abandoned railroad embankment, road crossings, and the construction and operation of Warm Springs Ponds. Today, streambanks are probably more susceptible to erosion where impacted by tailings, agricultural practices, and manmade structures where vegetation density is reduced or non-existent. Although the concentrated tailings deposits have proved toxic to willows and other riparian vegetation as evident from the bare tailings and dead willow stands visible today, some willows have grown where floodplain tailings are diffuse or have been overlain by finer sediments, such as on recently-formed inset floodplains and point bars (Smith et al., 1998).

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The Anaconda Company constructed two of the manmade Warm Springs Ponds in two phases between 1911 and 1959. Initially, the ponds were constructed in part to address agricultural impacts related to water use by farmers and ranchers The primary function of Warm Springs Ponds was to trap tailings before they entered the CFR. As environmental policies changed, concerns over human health and the environment increased, in particular with the passage of the Clean Water Act in 1972. Work on the ponds continued through the 1990s with dry closure of Pond 1, wet closure of Pond 2, and significant expansion of Pond 3 to treat up to 600 cubic feet per second (cfs) of water for dissolved metals and detain the 100-year flow for sediment removal. The three ponds cover an area of 2,400 acres and contain an estimated 19 million cubic yards of tailings and sediment. Although the quality of water discharged from Warm Springs Ponds has improved significantly, the reduction to the sediment supply and attenuation of peak flood events has impacted the natural development of the river system along the upper reach. Some of these effects include dampening of the development of point bars and evolution of an inset floodplain along the aggraded banks of the channel (CDM and AGI 2010).

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Section 3.0 Geomorphic Investigation

Phases 5 and 6 begin about nine miles downstream from Warm Springs Ponds on the CFR. The current geomorphology of this reach can be described as a single thread, slightly entrenched, sinuous river with alternating cut banks and point bars, riffle-pool sequence, and a gravel bed. The upstream half of Phase 5 is distinguished by a wider floodplain with numerous meander scars and evidence of frequent overbank flooding. This flows into a narrower reach as the Dry Cottonwood Creek alluvial fan encroaches on the east side, limiting migration and partially confining flows between it and low floodplain deposits on the west. The Phase 6 floodplain remains narrower with flows confined to the active channel and floodplain tabs between the western floodplain terrace and remnants of the same terrace now on the east side. In recent history the river shifted alignment to the west leaving an abandoned alignment in Phase 6, which becomes at least partially inundated during less frequent (2- to 10-year) events but conveys little flow discharged from the main channel. The location of tailings deposits in this reach is consistent with its geomorphology and depositional processes postulated by Smith et al. (1998). These processes included prolonged overbank flooding during large flood events and continual advection of silt-laden water onto an irregular floodplain with thick riparian vegetation and substantial barriers to return flows (See 1947 and 2011 Aerial Test Pit Depth of Contamination Results Maps, HTP-1 to HTP-5 and TP1-TP-5). The elevated streambanks have reduced the frequency of floodplain access during seasonal high flows and storm events, and have increased shear stresses on the bed and bank material. Currently, the bed of the Clark Fork River consists of coarse pebbles and cobbles. Smith et al. (1998) concluded that this bed material represents a largely immobile armor layer that formed as the floodplain aggraded in response to beaver dam removal, human activity, and flood events, and that this armor layer is at the same elevation as the pre-mining channel bed. Excavations on the channel margins during the current investigation consistently encountered a coarse pebble-fine cobble horizon at the same general elevations as the channel bed. Based on a comparison of the historical and current bank locations, lateral migration of the river is occurring and continually exposes coarse floodplain alluvium. Lateral migration may be constrained in some areas by the accumulation of sediment on the floodplain where vegetation has been reestablished and by confining features that have been built in and adjacent to the river.

Sections 3.0 and 4.0 describe the work and results of a geomorphic investigation conducted in 2010 on Phases 5 and 6. Stationing referenced herein starts at Station 0+00 just north of the Powell/Deer Lodge county line and increases upstream along the approximate river centerline to Station 232+00 just upstream of Galen Road. Referenced drawings are located after the report text, before the appendices.

3.1 Channel Geomorphology

In late September 2010, TerraGraphics personnel surveyed Phases 5 and 6 to investigate existing geomorphic and hydrologic conditions and to collect topographic data for hydraulic modeling and in support of design. Data were collected to assess the locations and characteristics of pools and other bed features; to measure river plan form, cross-sections, and bed material; and to characterize bank erosion. Geomorphic indicators of the channel-forming flow were noted and measured, and the relationship between streambank features and deposited floodplain

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contaminants was investigated. This survey, in conjunction with LiDAR (Light Detection and Ranging) data and aerial imagery, was used to develop plan form, longitudinal, and cross-sectional metrics. This report section describes both the data collected in the field and results of calculations that help describe the existing geomorphic characteristics of these two reaches.

Phases 5 and 6 include a number of inflows and irrigation diversions: Dry Cottonwood Creek enters from river right near station 173+00; the Alvi Beck Ditch diverts water from river right near station 172+00; Lost Creek enters from river left near Station 163+00; the Whalen Diversion weir is at Station 77+00 and diverts flow to river left; the West Side Ditch diversion is near Station 62+00 and diverts flow to river left; and Modesty Creek crosses over the Whalen ditch and flows into the West Side Ditch, no longer reaching the CFR directly.

3.1.1 Longitudinal Profile

Changes in elevation and the existence of bed features and hydraulic controls were measured from the upstream to downstream ends of Phases 5 and 6.

3.1.1.1 Channel Gradient and Water Surface Profile

Surveyed thalweg and water surface longitudinal profiles are shown in Figure 4 and Figure 5. The overall bedslope is 0.14% in Phase 5, 0.17% in Phase 6, and 0.16% overall. The water surface slope is 0.16% for both reaches. The bedslope is flatter in the wider floodplain in Phase 5 and steeper in the more constricted floodplain in Phase 6.

3.1.1.2 Pools

Pools were surveyed throughout the Phase 5 and 6 portions of the CFR. Each pool was surveyed at the point of maximum depth and at the first downstream hydraulic control point. All pools in this reach were identified as lateral scour. A few pools are associated with fallen trees or other small obstructions near the bank. There are no bedrock features in Phases 5 or 6. Pools are slightly more frequent in Phase 5, and significantly more widely spaced in Phase 6. A synopsis of pool parameters is shown in Table 1 and surveyed pool locations are shown on EBPL-1 through EBPL-5. Pool depths were measured from the water surface. Residual pool depth is the difference between the elevation at maximum pool depth and the surveyed elevation of the hydraulic control.

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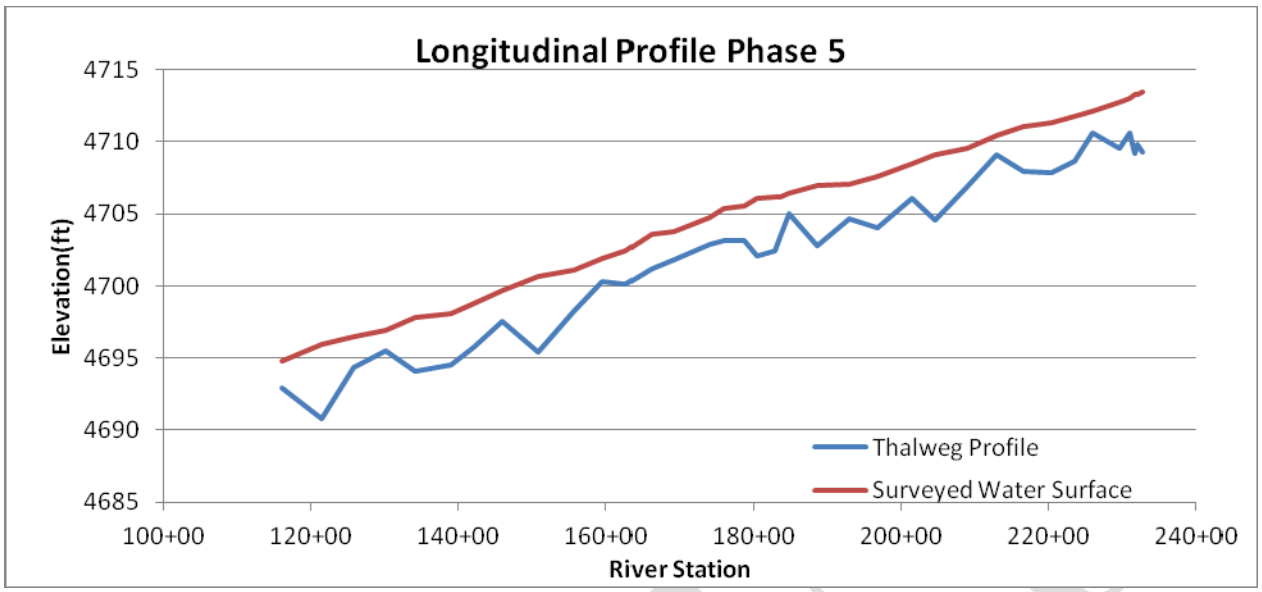

Figure 4. Longitudinal profile, Phase 5

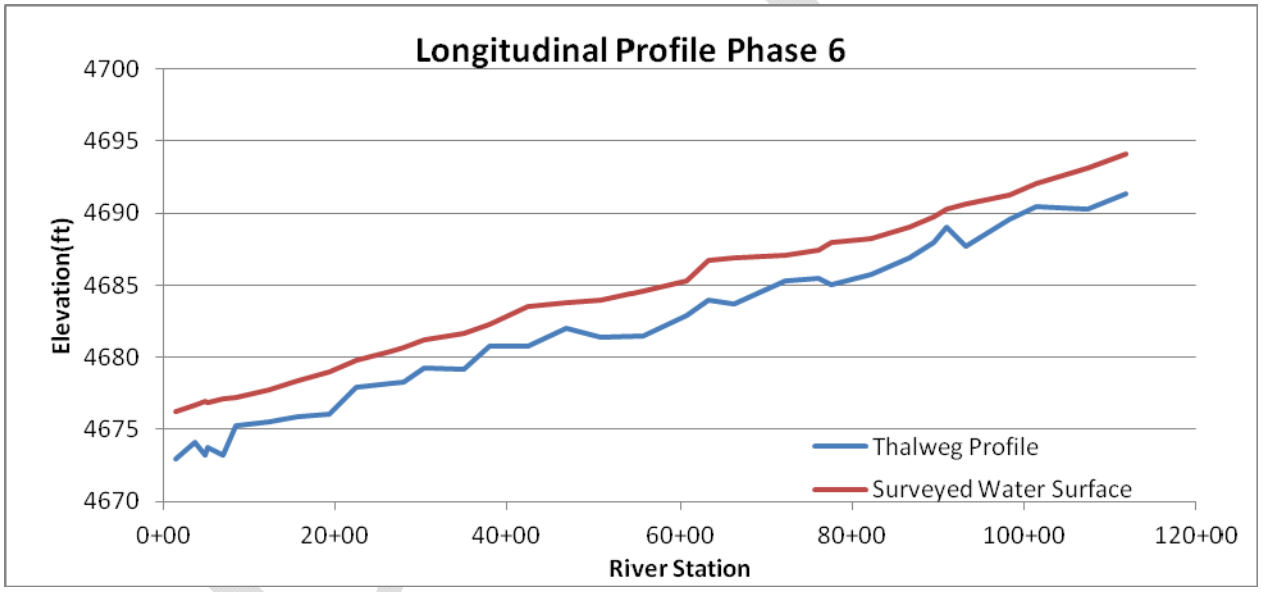

Figure 5. Longitudinal profile, Phase 6

Table 1. Pool Parameters

Parameter	Whole Reach	Phase 5	Phase 6
Number of Pools	51	28	23
Pools per Mile	11.6	12.2	11.0
Average Bankfull Widths Between Pools	6.8	5.5	8.6
Max Pool Depth (ft)	6.0	5.7	6.0
Average Pool Depth (ft)	4.3	4.4	4.3
Max Residual Depth (ft)	3.9	3.6	3.9
Average Residual Depth (ft)	2.2	2.1	2.3

3.1.1.3 Hydraulic Controls

Four manmade hydraulic controls were encountered at the project reach: two bridges and two in-stream irrigation diversions. The bridges are at Galen Road at the upstream end of Phase 5 and at Gemback Road near the downstream end of Phase 6. The diversions are the Whalen Ditch diversion at river station 77+00 and the West Side Ditch diversion at river station 61+65. The Whalen diversion spans about ¾ of the river width and the West Side diversion spans the river completely. Both bridges are relatively new concrete truss type construction with a center pier at Galen Road and clear span at Gemback Road. The bridge at Galen Road has ample capacity to pass the 100-year flood below the low chord of the bridge. The Gemback Road bridge barely has the capacity to pass the 100-yer flow. The road embankments constrict out-of-bank flows to the bridge openings. The constriction of flow to the main channel reduces the hydraulic energy upstream of the bridges and increases the hydraulic energy as the flow passes through the bridge openings. The changes in energy of the system cause increased deposition upstream of the bridges and increased scour and straightening downstream.

3.1.2 Cross-sections

Seventy-one cross-sections were surveyed through the river and over the near banks: 37 in Phase 5 and 34 in Phase 6. Their locations were selected randomly, but spacing between them was selected to average about 0.5 feet in water surface elevation change between cross-sections. Cross-section parameters associated with bankfull flow and channel forming flow are shown in Table 2 and are discussed further in this section. Estimation of the bankfull and channel forming flows are discussed in the River Hydraulics section (Section 5.0). Surveyed cross-section locations are shown on Geomorphic and Floodplain Features Maps, GFF-1 and GFF-2.

Six cross-sections showing the existing ground, depth of tailings contaminated soil and depth to river gravels are shown in Floodplain Cross-Section Drawings CS-1 and CS-2. These cross-sections were plotted from the survey and LiDAR data and from the results of the floodplain tailings investigation. The locations of these cross-sections are shown on Test Pit Depth of Contamination, TP-1 through TP-5.

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Table 2. Cross-section Depths and Widths

		Bankfull Flow (Approx 5 yr Event at 1197 cfs)			Channel-forming Flow(Approx. 2yr Event at 754 cfs)		
		Max Channel Depth (ft)	Channel Width (W_{bf}) (ft)	Width/ Depth	Max Channel Depth (ft)	Channel Width (W_{cf}) (ft)	Width/ Depth
Phases 5 & 6	**Average**	4.1	72.3	18.9	3.4	67.2	21.3
Phase 5	**Minimum**	2.6	47.1	9.0	2.7	45.7	10.7
	Maximum	5.8	175.0	67.3	5.1	110.1	37.3
	Average	4.2	67.4	16.8	3.6	61.9	18.0
Phase 6	**Minimum**	2.7	55.5	11.0	1.9	55.5	14.7
	Maximum	5.1	193.6	72.8	3.9	175.4	91.8
	Average	3.9	77.6	21.1	3.1	73.1	25.0

3.1.2.1 Depths

Field indicators of the channel-forming flow depth (D_{cf}) were noted and surveyed at some cross-sections. These include low banks and point bars and the limits of persistent wood y vegetation. An example feature is shown in Figure 6. The channel-forming flow depth is best represented by the peak flow of the 2-year recurrence interval. Bankfull elevation, measured from the bank point where water will leave the active channel, was surveyed at each cross-section. Bankfull depth (D_{bf}) was measured from the lowest top-of-bank point to the deepest part of the cross-section. The modeled flow associated with D_{bf} varies, but is approximately 1000 cfs to 1200 cfs or approximately the 5-year recurrence interval.

D_{bf} is not considered a good indicator of D_{cf} for this reach. The introduction of mine waste upstream provided years of excess sediment transport into and through this reach, resulting in deposition of contaminated sediments and aggradation on the banks and adjacent floodplain of Phases 5 and 6. In addition, previous remedial actions included the construction of berms along the banks in some places; therefore, banks and portions of the floodplain in this reach tend to be unnaturally high. During hydraulic modeling, the 2 year flow showed the best correlation with field indicators of the channel forming flow and was used for D_{cf}. Channel-forming flow (Q_{cf}) is estimated to be 754 cfs for this reach. Most banks in Phases 5 and 6 are taller than $D_{cf.}$

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Figure 6. Point bar – channel-forming flow elevation indicator

3.1.2.2 Widths

Widths were measured in the field between bankfull points. The average bankfull width (W_{bf}) for Phases 5 and 6 is 72.3 feet. Using the hydraulic model, the width at each cross-section at D_{cf} was recorded. The average channel-forming width (W_{cf}) is 67.2 feet. Additional width information is shown in Table 2.

Width-to-depth ratios were computed based on both the W_{bf} and W_{cf} and the associated maximum depth at each cross-section. Average values are shown in Table 2, and all measured cross-section values are tabulated in Appendix A.

There is significant evidence that the river is slightly entrenched and the banks are taller than they were historically due to the deposition of contaminated sediments along the banks (see Table 2). On Drawings CS-1 and CS-2 cross-sections through the river and floodplain show that a low floodplain was much more common before the deposition of contaminated sediment and that berms, both deposited and constructed, are currently seen along the banks immediately adjacent to the river.

3.1.3 Point Bars and Inset Floodplains

Numerous point bars and inset floodplains are found in Phases 5 and 6 (Figure 6 and Figure 7). These features are geomorphically indicative of the existing channel forming hydrologic regime in this reach. Contamination has been documented on most of the point bars, in some cases to

the depth of river gravels. Despite this, most are vegetated with herbaceous plants and willows and are actively aggrading. By comparing the point bars between the 1947 and 2011 aerial images, it appears that the open point bars have migrated slightly and some have become vegetated. The creation of these features and migration of the river by outside bend erosion and avulsion are the current processes that most closely mimic the likely pre-mining river migration regime. Based on the results of test pit sampling and identification of point bars developed within the last 50-60 years, it is apparent that eroding banks upstream of Phase 5 are still contributing contaminated sediments to the formation of these bars.

Point bars and low floodplains range from sandy with some cobbles, such as the one shown in Figure 7, to densely vegetated with either wetland herbaceous communities or willow, alder, and birch shrubs.

Figure 7. Typical point bar with sand deposit

3.1.4 Bed Material

Seven Wolman pebble count (Wolman, 1954) procedures were performed at surveyed cross-sections on riffle crests for Phases 5 and 6. The Wolman pebble count is a sampling method that produces a statistically reliable measure of the coarse fraction of river bed material. The pebble count results at each site are included in Appendix B. The particle sizes at 16, 50, and 84 percent finer for each sample are shown from the upstream to downstream locations in Table 3. River bed particle sizes remain fairly uniform from upstream to downstream.

Table 3. Bed material particle sizes

Cross-Section	HEC-RAS Station (ft)	Pebble Diameter (inches)		
		D_{16}	D_{50}	D_{84}
XS07	226+06	0.63	1.58	2.64
XS11	212+88	0.87	1.65	2.76
XS18	184+68	0.71	1.46	2.40
XS27	162+64	0.83	1.65	2.88
XS37	121+45	0.99	1.85	2.92
XS49	76+14	0.99	1.69	2.84
XS62	26+45	0.25	0.99	1.73

3.1.5 Plan Features and Migration Rates

Features of the river plan form were measured and are tabulated in Table 4. These data, as well as aerial photographs, indicate that Phase 6 is less sinuous and has fewer, larger meanders than Phase 5. Phase 6 is more confined by roads, irrigation and railroad embankments, other irrigation structures, and also by the elevated floodplain. Belt widths are greater in Phase 6, and there appears to be a greater current tendency toward avulsion and meander bend cut-offs. An abandoned channel in Phase 6 as shown on Geomorphic Floodplain Features Phase 6, GFF-2, has a sinuosity of 2.7, considerably higher than either of the active reaches in Phase 5 or Phase 6 (see Table 4, GFF-1, and GFF-2). The relationships measured on the active reaches between meander geometry, dominant discharge, and bed slope are consistent with those noted in Leopold, Wolman, and Miller (1964) for meandering rivers.

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Table 4. River Plan Features

Feature	Phase 5	Phase 6	Phases 5 and 6
River Length (ft)	11,850	11,282	23,132
Straight Length (ft)	5,235	5,854	10,786
Number of Meanders	20	13	33
Average Wavelength (ft)	524	901	654
Average Radius of Curvature (Rc) (ft)	151	248	189
Average Belt Width (ft)	326	530	406
Sinuosity	2.3	1.9	2.1
Average Rc/W_{cf}	2.7	3.4	3.0

In an attempt to quantify recent migration rates of the river in Phases 5 and 6, the banks and point bars were traced on aerial photographs from 1947 and 2011 (See Drawings EBPL-1 through EBPL-5). The maximum migration distance noted is at the upstream end of Phase 6 at station 108+82 where the channel avulsed across a tight bend, leaving a large oxbow. More typical outward migration distances of the banks range from 5 to 50 feet over the 64 years between photographs, with an average erosion rate of 0.4 feet per year. The depositional migration rates ranged from 0.2 to 0.9 feet per year with an average depositional migration rate is 0.5 feet per year. The relationship between migration rates and eroding banks will be discussed further in Section 3.2.

3.2 Stream Bank Investigation

During the geomorphic survey in 2010, the types and conditions of banks throughout the reach were observed and tabulated. Bank erosion was measured using the Bank Erosion Hazard Index (BEHI) method from Rosgen (2001). The objectives of this exercise were to determine whether observed bank erosion is accelerated from historical conditions and to evaluate the severity of bank erosion in this reach.

3.2.1 Bank Erosion Hazard Index

For the BEHI calculation, the following metrics and observations were recorded at each bank segment that showed signs of active erosion:

1. Bank angle
2. Bank height
3. Rooting depth relative to bank height
4. Root density
5. Surface protection
6. Bank height relative to bankfull height
7. Bank toe gravels
8. Upper bank materials

These data were then used to calculate the following BEHI parameters:

1. Bank height divided by bankfull height

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2. Root depth divided by bank height
3. Root density percent
4. Bank angle
5. Surface protection percent

The BEHI parameters were assigned an index value and an adjustment was included based on bank material type. Finally, a Severity Rating was calculated according to the BEHI methodology shown in Table 5. The locations of eroding banks are shown in Drawings EBPL-1 through EBPL-5. A qualitative assessment of eroding banks in the project reach indicates that they fall into several distinct categories, discussed below, which are not necessarily reflected by the BEHI ratings. The results of the BEHI assessment and associated observations are shown in Table 6. The total length of eroding banks in Phase 5 and Phase 6 that fell into each of the BEHI Severity categories is shown in Figure 8.

Additional BEHI results are also displayed by severity rating in Table 7. These ratings are not indicative of the rate of migration between 1947 and 2011. Some correlation can be seen in Table 7 between the BEHI rating and average eroding bank indicators. Average depth of tailings increases, average channel shear stress increases, and average radius of curvature decreases as BEHI Severity goes from Moderate to Extreme; however, no such correlation is seen when banks are tabulated individually (Table 6).

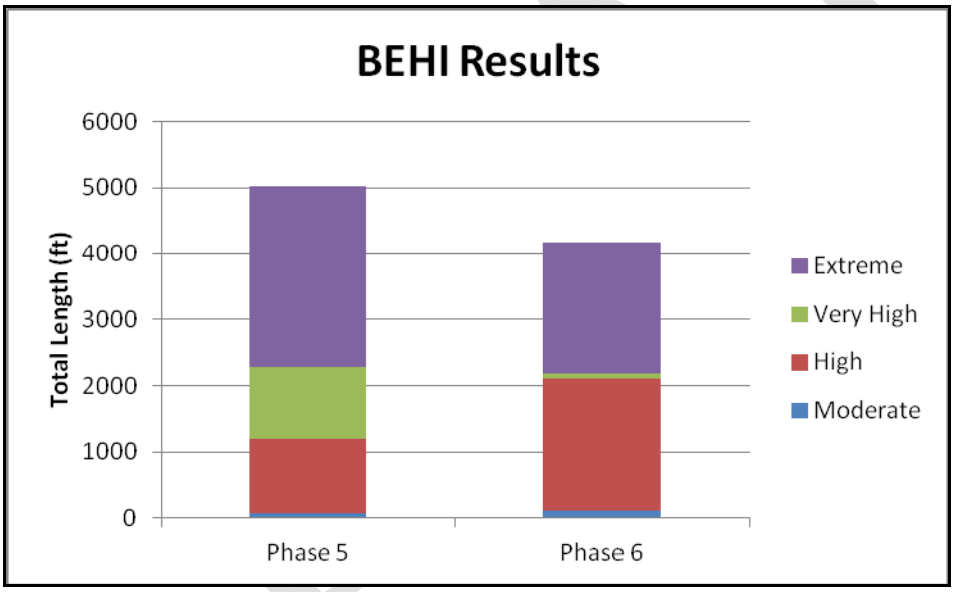

Figure 8. Eroding bank lengths by BEHI severity

3.2.2 Migration of Eroding Banks

Aerial photos from 1947 and 2011 were compared to assess the recent migration of the river in the project reach. Little relationship is noted between the bank erosion severity, as measured during the bank erosion assessment, and migration rates (See Table 6 and Drawings EBPL-1 through EBPL-5). Banks that have moved due to outward migration (bank erosion) have done so

at an average rate of about 0.4 feet per year. Banks that have migrated water-ward due to aggradation have moved at an average rate of 1.4 feet per year. The bank with the highest BEHI rating is migrating at a rate of 0.6 feet per year.

3.2.3 RipES Classification and BEHI

There is no apparent correlation between the BEHI results and the RipES classification system (Table 6). Banks of every RipES classification were rated in each BEHI category, with the surprising exception that no RipES Class 3[1] segments received the lowest BEHI rating of Moderate. This result is not highly significant because the two classification systems rely on different measurement techniques.

3.2.4 Eroding Bank Characteristics

Most of the severely eroding banks in Phases 5 and 6 are characterized by sparse or weedy top-of-bank vegetation (Figure 9); tall, steep, and bare banks (Figure 10); or evidence of active slumping and erosion (Figure 11). In several cases, as in Figure 9, there is no evidence of tailings in the bank or contamination in the floodplain behind the bank, yet lengthy outer-bank erosion is noted. Except for one cut bank, these instances occur throughout Phase 6 downstream of Station 105+00 where the river is eroding into floodplain terraces and in various locations in Phase 5 including at floodplain terraces and at the Dry Cottonwood Creek alluvial fan. Tailings were observed in 29 of the 44 eroded banks surveyed and typically extend from the ground surface to varying depths. In some cases they form a thin veneer on the top of tall banks and in other cases they are more than 2 feet thick and extend down to the capillary fringe of the water surface during a typical base flow regime. In a few cases significant contamination was detected in test pits behind eroding banks, but tailings were not apparent in the bank (e.g. EB_8-2_L).

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[1] RipES Streambank Class Descriptions:

Class 1 streambanks – Phytotoxic conditions exist as demonstrated by an inability of the active channel areas to support and sustain significant amounts of woody and herbaceous vegetation. Streambanks are actively eroding and are significant contributors of contaminant release to the river.

Class 2 streambanks – These streambanks demonstrate some current woody and herbaceous vegetation, but are contaminated, unstable, and eroding.

Class 3 streambanks – These streambanks are contaminated but they may have varying amounts of deep, binding, woody vegetation holding the streambank in place.

Figure 9. Very high erosion severity at EB_9-6_L, but no contamination noted

Eroding banks are most often found on outside bends, sometimes on straight reaches, and only one is on an inside bend (EB_9-7_L). Many banks around outside bends are very long and tailings are usually present in the top soil strata of the bank (Figure 10). Dense clay sills were noted at or near the toe of many eroding banks in Phases 5 and 6, often riverward of the bank toes (Figure 12). No apparent correlation exists between the presence or absence of clay sills and the BEHI rating or migration rate. Cobble, pebble, and sand toe materials are also common throughout the reach.

In very few cases eroding banks in Phases 5 and 6 have dense top-of-bank vegetation but still show signs of active sloughing (Figure 13). These banks are 2 to 4 feet high, and tailings are usually present.

Scalloped banks are common in Reach 5 (Figure 14). These banks have short eroded sections ranging in length from just a few feet to about 30 feet. Often woody vegetation is stabilizing between the scallops and appears to provide additional resistance to bank erosion when it is rooted below the top of bank. Not all these banks have tailings present, and there is often vegetation at the top of the bank. It is also common to find live root material sprouting within eroding banks. In some cases there is significant evidence that viable plant material exists under deposited contaminated sediments (Figure 15).

Bank-dwelling beavers have had some impact on streambanks in Phases 5 and 6. Slides, such as the one shown in Figure 16, and den tunnels are common.

Upper bank materials in addition to tailings are most commonly sand and silty sand. In some areas there is a distinctive gray clay material in the top bank layer (Figure 17).

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Figure 10. Long eroding bank near EB_10-6_L

Figure 11. Active slumping at EB_9-1_R

3.2.5 Non-eroding Banks

Much of the highest floodplain contamination concentrations on Phases 5 and 6 occur on inside bends, and in many of these areas the banks are in good condition. For example, the meander bend at station 57+00 has contamination depths potentially exceeding 30 inches; however, the point bar and bank are well vegetated and free of erosion problems (Figure 18).

Undercut banks are common on Phases 5 and 6, but many are very well vegetated (Figure 19). Although RiPES classified many of these banks as Class 2 ("…some current woody and herbaceous vegetation, but are contaminated, unstable, and eroding), they do not appear to be actively eroding and are not problematic unless test pitting shows contamination.

Most non-eroding banks in Phases 5 and 6 are well vegetated with either shrubs and trees, or in the case of point bars and inset floodplain features, herbaceous plants.

Figure 12. Clay sill under water at toe of eroding bank EB_9-3_L

Figure 13. Eroding bank with dense woody vegetation at EB_10-1_R

Figure 14. Scalloped bank near Station 230+00

Figure 15. Sprouting plant material below tailings in eroding bank EB_8-3_L

Figure 16. Beaver slide

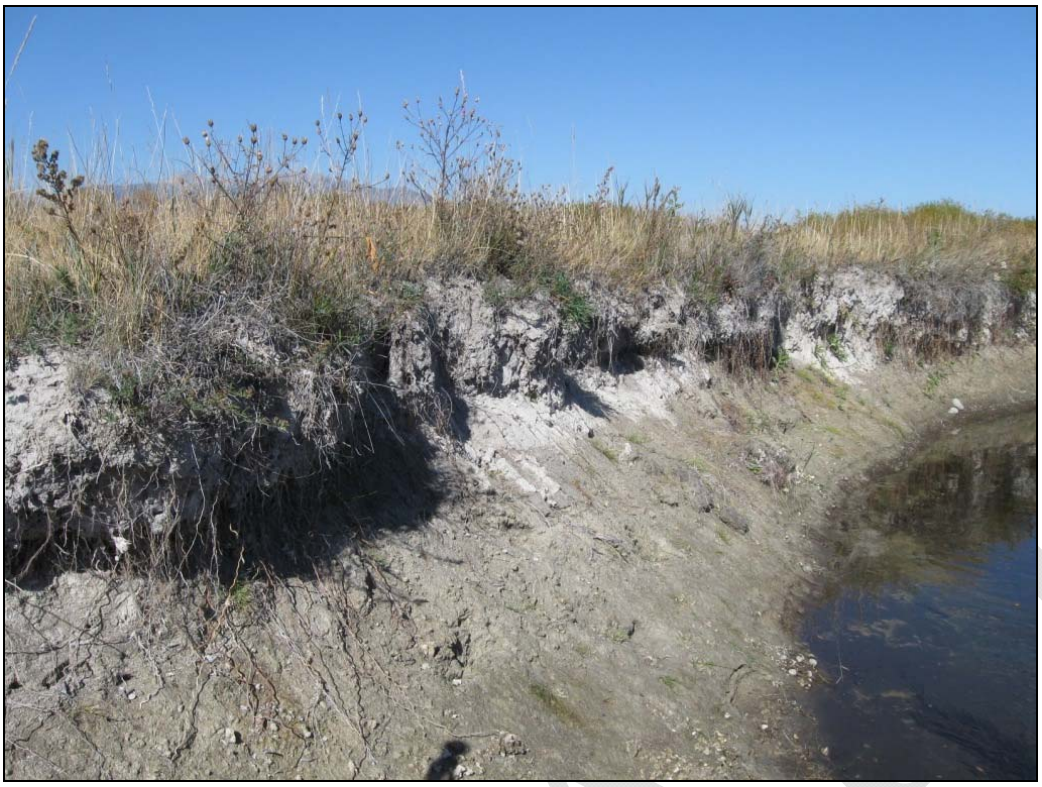

Figure 17. Gray clay layer in top of bank at EB_9-6_L

Figure 18. Point bar in front of contamination near Station 57+00

Figure 19. Undercut bank

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Table 5. BEHI Calculation Guide (from Rosgen, 2001).

Bank Erosion Hazard Rating Guide

Stream | Reach | Date | Crew

Bank Erosion Potential		Bank Height/ Bankfull Ht	Root Depth/ Bank Height	Root Density %	Bank Angle (Degrees)	Surface Protection%
Bank Height (ft): Bankfull Height (ft):						
VERY LOW	Value	1.0-1.1	1.0-0.9	100-80	0-20	100-80
	Index	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
LOW	Value	1.11-1.19	0.89-0.5	79-55	21-60	79-55
	Index	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
MODERATE	Value	1.2-1.5	0.49-0.3	54-30	61-80	54-30
	Index	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
HIGH	Value	1.6-2.0	0.29-0.15	29-15	81-90	29-15
	Index	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
VERY HIGH	Value	2.1-2.8	0.14-0.05	14-5.0	91-119	14-10
	Index	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
EXTREME	Value	>2.8	<0.05	<5	>119	<10
	Index	10	10	10	10	10
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
V = value, I = index					SUB-TOTAL (Sum one index from each column)	

Bank Material Description:

Bank Materials

Bedrock (Bedrock banks have very low bank erosion potential)
Boulders (Banks composed of boulders have low bank erosion potential)
Cobble (Subtract 10 points. If sand/gravel matrix greater than 50% of bank material, then do not adjust)
Gravel (Add 5-10 points depending percentage of bank material that is composed of sand)
Sand (Add 10 points)
Silt Clay (+ 0: no adjustment)

BANK MATERIAL ADJUSTMENT

Stratification Comments:

Stratification

Add 5-10 points depending on position of unstable layers in relation to bankfull stage

STRATIFICATION ADJUSTMENT

VERY LOW	LOW	MODERATE	HIGH	VERY HIGH	EXTREME
5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

Bank location description (circle one)
Straight Reach Outside of Bend

GRAND TOTAL
BEHI RATING

Table 6. BEHI Results from Upstream to Downstream (3 pages)

Phase (Reach)	Bank Code	Eroded Length (ft)	BEHI Severity	Channel Shear Stress (lb/ft^2)	Bankfull Width (W_{BF}) (ft)	Average Tailings Depth Observed (ft)	*Max Depth of Contam (inch)	Approx Migration Since 1947 (ft)	RiPES Class	Radius of Curvature (ft)	Top of Bank Vegetation
5	8-1_R	65	Very High			0.4	48	25	1	S	Grass
5	8-1_L	183	High	0.3	52.4	1.5	6	20	1	S	Grass
5	8-2_R	13	Moderate			0.6	18	10	1	S	Grass, willow
5	8-2_L	93	Very High			0	36	0	2	134	Grass, willow
5	8-3_R	82	Very High	0.3	63.6	0	48	10	1	162	Grass
5	8-4_R	68	Extreme			1.0	18	20	1	162	Grass
5	8-5_R	70	Extreme	0.3	50.9	0	48	0	2	I	Grass, willow
5	8-3_L	84	High			1.1	30	20	3	134	Grass
5	8-6_R	36	High			0.5	30	30	2	191	Grass, weeds
5	9-1_R	516	Extreme	0.5	64.1	0.8	24	40	2	191	Grass
5	9-1_L	202	Very High	0.3	62.3	0.5	36	10	1	217	Betula
5	9-2_R	69	Extreme			0.9	36	0	1	I	Grass
5	9-2_L	87	High			0.8	42	15	1	217	Grass
5	9-3_R	88	High	0.3	56.2	2.0	42	35	2	74	Grass, willow
5	9-3_L	27	Very High			0.9	24	30	1	104	Grass, willow
5	9-4_L	68	Extreme	0.4	52.6	2.0	18	30	1	104	Grass, wildrye
5	9-5_L	33	Very High			2.0	24	25	2	178	Grass, willow
5	9-6_L	170	Very High			0	Clean	10	2	133	Grass, weeds
5	9-4_R	330	Extreme	0.2	75.1	1.3	48	40	1	124	Grass, woodies between scallops
5	9-5_R	60	Moderate			0.3	30	5	1	S	Grass, woodies

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Table 6. BEHI Results from Upstream to Downstream (3 pages)

Phase (Reach)	Bank Code	Eroded Length (ft)	BEHI Severity	Channel Shear Stress (lb/ft^2)	Bankfull Width (W_{BF}) (ft)	Average Tailings Depth Observed (ft)	*Max Depth of Contam (inch)	Approx Migration Since 1947 (ft)	RiPES Class	Radius of Curvature (ft)	Top of Bank Vegetation
5	9-6_R	20	High	0.3	56.1	0	30+	5	2	S	Grass, woodies (rosa), weeds
5	9-7_R	250	Extreme	0.3	80.3	0	Clean	20	1	226	Wildrye, weeds
5	9-7_L	50	Very High			0	36	25	2	I	Willow
5	9-8_L	40	Extreme			0.7	18	25	3	193	Grass, wildrye
5	10-1_L	20	Extreme			1.0	18	0	2	116	Grass, weeds, woodies between scallops
5	10-2_L	50	Very High			1.0	18	10	2	S	Grass, willow, betula
5	10-1_R	220	Extreme	0.5	49.5	1.5	24	20	2	73	Dense willow
5	10-3_L	140	Very High			1.4	18	25	1	126	Wildrye, grass, weeds
5	10-4_L	70	Very High			1.2	Clean	15	2	206	Grass, betula
5	10-5_L	430	Extreme	0.5	63.2	2.3	24	40	2	206	Grass
5	10-2_R	90	Very High			1.5	12	25	3	155	Grass, snowberry
5	10-6_L	630	High	0.3	79.4	1.1	18	20	1	258	Grass, wildrye, wild licorice
5	10-3_R	670	Extreme	0.2	75.8	1.5	18	40	1	188	Grass
6	10-7_L	620	Extreme	0.5	90.3	1.1	30	25	1	210	Grass, wildrye, dead/live woodies
6	11-1_L	920	Very High	0.4	72.5	0	Clean	25	1	349	Weeds, grass, rosa
6	11-1_R	450	High	0.4	76.6	0	Clean	25	2	325	Grass, weeds, woodies

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Table 6. BEHI Results from Upstream to Downstream (3 pages)

Phase (Reach)	Bank Code	Eroded Length (ft)	BEHI Severity	Channel Shear Stress (lb/ft^2)	Bankfull Width (W_{BF}) (ft)	Average Tailings Depth Observed (ft)	*Max Depth of Contam (inch)	Approx Migration Since 1947 (ft)	RiPES Class	Radius of Curvature (ft)	Top of Bank Vegetation
6	11-2_L	100	High			0	Clean	0	1	S	Grass, weeds, willow
6	11-2_R	500	High	0.1	73.8	0	Clean	30	1	277	Weeds, grass
6	11-3_L	420	Extreme	0.3	75.6	0	Clean	35	1	230	Weeds, pasture grass
6	12-1_R	350	Extreme			0	42**	30	1	195	Weeds, woodies
6	12-1_L	60	High			0	Clean	15	1	274	Weeds
6	12-2_R	550	High	0.3	71.3	0.6	18	30	1	244	Grass
6	12-3_R	120	High			0.9	12	35	1	244	Grass, willow, betula
6	13-1_L	85	Moderate			0	NS	5	2	359	Grass, snowberry, wild licorice

R = Right Bank; L = Left Bank
I = Inside Bend; S = Straight
NS = Not Sampled
*Max Depth of Contamination per Test Pit Data
**Long bank with all clean test pits except at end of bank

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Table 7. BEHI Severity metrics

	BEHI Severity			
	Moderate	**High**	**Very High**	**Extreme**
Eroding Banks on Phase 5	2	7	12	12
Eroding Banks on Phase 6	1	6	1	3
Average Length (ft)	53	224	153	276
Average Length on Phase 5 (ft)	37	161	89	229
Average Length on Phase 6 (ft)	120	330	85	663
Average Depth of Tailings (ft)	0.3	0.7	0.8	0.9
Average Radius of Curvature (ft)	359	224	176	171
Average Shear Stress (lb/ft^2)	N/A	0.28	0.35	0.37
Total Length (ft)	158	2908	1992	4141
Total Length on Phase 5 (ft)	73	1128	1072	2751
Total Length on Phase 6 (ft)	120	1980	85	1990
Average Migration Distance (ft)	6.7	0.7	18.1	24.3
Average Migration Rate (ft/year)	0.11	0.01	0.29	0.39

3.3 Floodplain Investigation

The floodplain was investigated to determine the extent of tailings contamination, locations of manmade structures, land use practices, geomorphic features, and depth to and characteristics of floodplain gravels.

3.3.1 Tailings Contamination

The extent of contaminated tailings deposited on the floodplain was investigated, characterized, and documented in the Floodplain Investigation Data Summary Report (TerraGraphics, 2012). Tailings spread over a wide portion of the floodplain from Galen Road to about Station 170+00 and are deposited in meander scars and the adjacent depressions. As the migration corridor narrows downstream, tailings deposits are found along the active meander bend, point bars, and a narrow overbank area. The extent and depth of tailings deposits as determined from the floodplain investigation (TerraGraphics, 2012) are overlain on historical aerial images and shown on 1947 Aerial Test Pit Depth of Contamination Results Maps HTP-1 to HTP-5. The tailings contamination is also shown on the 2011 Aerial Test Pit Depth of Contamination Maps, TP-1 to TP-5. The depths shown on the maps are the maximum depth of tailings contamination in inches from the existing ground surface. [2]For the purposes of this report, soil is considered tailings or contaminated by tailings when the sum of the contaminants of concern is greater than 800 mg/kg. The contaminants of concern are cadmium, copper, lead, zinc, and arsenic. Refer to

[2] DEQ is currently evaluating criteria for determining contaminated materials versus non-contaminated materials.

the Floodplain Investigation Data Summary Report (TerraGraphics, 2012) for more information related to the extent of the floodplain tailings and investigation methods.

3.3.2 Manmade Structures

Manmade structures at the site include Galen Road and Gemback Road, bridges over the CFR at these two roads, an abandoned railroad embankment, irrigation diversions and embankments, and a dredge channel and small berms that Atlantic Richfield Company (ARCO) constructed to reduce erosion of tailings onto the floodplain. Locations of these structures are shown on the Geomorphic Floodplain Features Maps, GFF-1 and GFF-2.

An abandoned railroad embankment traverses the site in a north/south direction along the west side of the floodplain from Galen Road to an underpass at Interstate 90 south of Gemback Road. The embankment has significant impact on the river system between Stations 65+00 and 85+00 where continued westward river migration and out-of-bank flows are blocked. This embankment encroachment on the meander belt partially diverts flow from upland areas west of the river, causes downstream migration, and likely causes the development of the downstream meander cutoff to accelerate.

Irrigation diversion structures are located near Stations 77+00 and 62+00 for Whalen Ditch and West Side Ditch, respectively. These diversion structures are shown in Section 5.0. The diversions operate under low head and do not have a significant impact on the river hydraulics; however, stabilization practices to maintain the headgate and ditch locations have impeded migration. The irrigation ditch embankments begin at the diversions, run along the migration corridor, and meet the outside edge of three meander bends from Station 77+00 to Station 24+00 near Gemback Road, where they begin to move out of the migration corridor. Lateral movement at the cut banks and left overbank flow are limited along this reach due to the location and configuration of the irrigation ditch embankments.

One dredge channel is located in the wet meadow on the east side of the river in Phase 5. This was probably originally installed to drain the meadow to improve grazing access. It is unknown if this dredge channel is maintained or needed for current ranch operations. A beaver dam has been observed at the outlet of the dredge channel to the river.

Prior contamination control efforts by ARCO included the construction of 1- to 3-foot high berms around the more prominent tailings-impacted areas. Portions of many of the berms are still visible today; however, they do not appear to have been maintained, portions have eroded, and their ability to control tailings migration appears ineffective.

3.3.3 Land Use Practices

The site is currently operated as part of a 2,300-acre working cattle ranch partially owned by the Clark Fork Coalition. About 200 acres of crop lands along the CFR within the project area are irrigated from Dry Cottonwood Creek and Lost Creek. Crop lands are generally located outside the riparian corridor. Grazing appears to be permitted in most areas of the ranch including within portions of the riparian area and up to the river banks in several areas; however, riparian fencing was installed in 2011to reduce grazing access to the riparian areas.

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3.3.4 Floodplain Geomorphic Features

During the floodplain investigation and subsequent review of the current and historical aerial mapping and topography, several large-scale geomorphic features were observed along this reach. These include changes in the meander belt width, an alluvial fan from Dry Cottonwood Creek, recent avulsions, and an abandoned river migration corridor (see GFF-1 and GFF-2).

In the upstream portion of the project reach from Galen Road to approximately station 165+00, the river has a wider meander belt than downstream. The upstream reach is characterized more by out-of-bank flow during runoff events, numerous meander bend scars, and a few oxbows. Downstream of this wider meander belt, the river becomes more confined as it passes the alluvial fan from Dry Cottonwood Creek and the Alvi Beck Ditch and flows through a relatively newer channel alignment.

Dry Cottonwood Creek currently enters the main stem of the CFR at 173+00. Historically, Dry Cottonwood Creek likely changed its flow path, trending to the north, and braiding as it exited the canyon from the east and made its way over the alluvial fan to the river. Some evidence of its prior alignment exists in the aerial mapping, and the current alignment is assumed to be manmade in association with agricultural needs. The alluvial fan from Dry Cottonwood Creek extends into the migration corridor from approximately Station 175+00 to Station 155+00. The Alvi Beck Ditch intercepts runoff and irrigation return flows from the alluvial fan. Agricultural practices, the ditch, and the alluvial fan itself limit eastward migration and create some tall eroding banks. Figure 20 shows the cut bank on a meander bend at approximately Station 174+00.

Figure 20. Cut bank into Dry Cottonwood alluvial fan near Station 174+00

The wider portion of the meander belt downstream of Galen Road to about Station 165+00 is characterized by evidence of numerous avulsions, all of which predate the 1947 aerial photos. The only recent avulsion documentable from the aerial topography is located downstream in the narrower meander corridor at approximately Station 107+00. The resulting oxbow was an active part of the main stem as late as 1960, but was cut off from the main channel prior to 1979. A well-developed meander bend cutoff is located further downstream, between Stations 50+00 and 32+00. The outlet portion of the cutoff is shown in Figure 21.

An abandoned river migration corridor exists downstream of station 94+00 along the east side of the meander belt. The active alignment likely began as an anabranch of the abandoned channel going around a floodplain bench generally located between stations 94+00 and 18+00 along what is now the east side of the floodplain. The active channel is confined to a narrower meander belt through this reach due to the higher ground associated with the floodplain bench to the east and the railroad and irrigation ditch embankments to the west.

Figure 21. Advanced cutoff channel outlet at Station 33+00

3.3.5 Point Bar Development

Point bars have developed by aggradation at an average lateral rate of approximately 1.4 feet per year based on the movement of the bank lines as measured from the 1947 and 2011 aerial photos. This more recent development of the point bars can also seen on the floodplain by the location of the ARCO berms; changes in vegetation from older willows and water birch to recently sprouted willows, grasses, rushes, and sedges; and a lower floodplain elevation (Figure 22). Although these portions of the point bars developed after the 1908 flood and construction of portions of

Warm Springs Ponds, they are contaminated and continue to develop with contaminated sediments (Figure 23).

Figure 22. Low floodplain looking downstream from Test Pit 746, Station 124+00

Figure 23. Sediments on floodplain looking downstream, Test Pit 625, Station 219+00

3.3.6 Floodplain Material Investigation

The floodplain material investigation was conducted to study the existing gravels in the floodplain and near the bank toe. This section discusses the collection of these data and their correlation to each other, to bank toe elevations, to groundwater elevations, and to the riverbed substrate. The collection of bank toe gravel data was conducted for similar purposes and using similar methods to those documented by CDM and AGI (2010). The bank toe gravel investigation involved excavation of test pits near the streambank until gravels were encountered, sampling the gravel, and submitting the sample to a laboratory for sieve analyses.

As part of the floodplain tailings test pit sampling, the depths to floodplain gravel and groundwater were documented. These depths provide i) additional information related to the extent and depth variability of the floodplain gravel across the impacted portion of the meander belt, and ii) information for design and construction planning.

This section also includes an analysis of the correlation between the size of the riverbed substrate (measured with Wolman pebble counts) to the sizes of gravels near the bank toe and buried in the floodplain. Finally, these gravel sizes were compared to the calculated particle sizes at incipient motion for several flow events. These correlations provide insight into the expected availability of floodplain gravel in the meander belt and whether that material is consistent with the bed substrate. This information will be used for selection of materials during design and construction planning.

In addition to gravels, several samples were collected from other materials encountered at the site including clay that forms prominent sills along many eroding banks and sands deposited on a point bar. These samples were analyzed for gradation, organic content, and Atterberg limits. These limited data may need to be supplemented during design and will be used to evaluate streambank treatments where a clay sill is present and for material selection at point bars if impacted by remedial action. The data can also be used to compare on-site and imported materials for use during remedial action.

The locations of the bank toe gravel samples, other floodplain material samples, and the measured depths to floodplain gravel are shown on the Floodplain Materials Investigation Maps, FM-1 through FM-4. The results of the material testing of the samples are included in Appendix C Floodplain Material.

3.3.7 Bank Toe Gravel

Bank toe gravel is considered the same material as the floodplain gravel with the exception that bank toe gravel is typically exposed at the toe of the river bank. Bank toe gravel samples were collected at multiple locations along the river banks. The bank toe gravel samples were collected approximately 5 to10 feet behind the existing bank and at the depth where floodplain gravels were first encountered (Figure 24). Bank toe gravel samples were initially collected at frequent locations along both sides of the river in Phase 5. Due to the consistency of the results, the frequency was reduced along the east side of Phase 5 and for all of Phase 6. The initial sampling was conducted along all elements of the river corridor including inside bends, outside bends, on the transitions between bends, and at point bars. The sampling on Phase 6 was performed mainly on outside bends. Bank toe gravel samples were taken from 36 locations in Phase 5 and seven (7) locations in Phase 6 as shown on the Floodplain Materials Investigation Maps, FM-1 through FM-5.

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3.3.7.1 Bank Toe Gravel Gradations

Bank toe gravel samples were taken at the base of the floodplain investigation test pits. The bank toe gravel samples were screened in the field for cobbles larger than approximately 5 inches in diameter. The field-screened cobbles ranged in size up to approximately 18 inches. The screened bank toe gravel samples were sent to Energy Laboratories for gradation analysis by Method ASTM C136/C117. The results of the gradation analyses for bank toe gravel samples are shown in Appendix C Floodplain Material and Table 8 provides a summary of the results.

Table 8. Summary of Bank toe gravel Gradations

Percent Passing	Particle Size Range (inches)
D_{16}	0.047 to 0.004
D_{50}	0.75 to 0.023
D_{84}	3 to 0.375

Figure 24. Typical bank toe gravel/floodplain gravel at base of excavation (TP 05-255)

The bank toe gravels were classified as GP (Poorly Graded Gravel with Sand), GW (Well Graded Gravel with Sand), and SP (Poorly Graded Sand with Gravel) in accordance with the

Unified Soil Classification System. The average depth to the bank toe gravel is similar to the depth to floodplain gravel as discussed in Section 3.3.7.2.

3.3.7.2 Bank Toe Gravel Relative Elevations

The depth where bank toe gravel was encountered in test pits was compared to the bank toe and groundwater elevations. The elevation at the top of the bank toe gravel was found to be, on average, 0.5 feet higher than the elevation at the bank toe. Significantly deeper floodplain gravel, greater than 6 inches below the bank toe and overlain by a layer of finer alluvial material, was observed in one location. The finer river alluvium consists of sands, silts, and clay and sits above the elevation of the bank toe gravel and bank toe. Since the floodplain has aggraded with the deposition of tailings, and because shear stresses increase with depth, a coarsening of the bed substrate is expected. The data showing the comparison of bank toe gravel to the bank toe elevations for each sample is included in Appendix C Floodplain Material.

Although the data indicate a relatively uniform layer of floodplain gravel across the tailings-impacted portion of the meander belt, finer material may exist at or below the bank toe elevation, and therefore additional test pitting during design may be necessary. Additionally, the gradations of the bank toe gravels show that a large percentage of the material is fine gravel and sand that is susceptible to mobilization during the design events. It may be necessary during design to evaluate the use of coarser to material to reduce erosion rates and increase the stability of some streambanks.

The depth to groundwater varies significantly from the high during spring runoff to the low in late summer, fall, and winter. The floodplain surface is mostly saturated in the spring and well into summer, with pools of standing water and surface flows from elevated groundwater, runoff, and irrigation return flows. Test pit operations mostly occurred during late summer and fall, as the floodplain was generally too saturated earlier in the year to efficiently operate the backhoe. The depth from existing ground surface to groundwater was measured upon completion of the test pit excavations during the floodplain investigation. These measurements are considered more representative of low groundwater conditions. The depth to groundwater averaged around 3 feet below ground surface and varied from near the ground surface to over 6 feet deep. In comparison to the floodplain gravel depths, groundwater elevations were generally at or above the elevation at the top of the floodplain gravel.

Tailings-contaminated soil and, therefore, removals and streambank reconstruction may extend to the top of the floodplain gravel and in some cases may extend below groundwater or river water surface elevation. This may be especially true where gravel toe material is insufficient or bank migration rates need to be reduced. Groundwater management, dewatering, and wet construction techniques are likely to be needed during remedial action. Additional data regarding groundwater elevations and seasonal fluctuation is planned for collection and analysis during design.

3.3.8 Depth to Floodplain Gravel

The depth to floodplain gravel was identified for this report to provide the stratigraphy of bed material beyond actively migrating streambanks for use in evaluating remedial actions and as an indicator of the base of excavation for removal areas. The depth and extent of floodplain gravel can be used during design to evaluate the appropriateness of streambank treatments. If a reduction in streambank erosion is desired and the gravel bed either does not extend or deepens

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in the migration path then enhancement of the streambank treatment may be necessary; conversely, if the gravel bed continues and shallows in the migration path then the streambank treatment could potentially be reduced.

The depth to floodplain gravel was measured in the field during test pit sampling of the tailings-contaminated soil on the floodplain. Floodplain gravel was noted when no visible tailings were present and the soil classification changed from silt, clay, or sand to gravel. The bank toe gravel was generally encountered at depths ranging from 36 inches to 72 inches below the ground surface, with an average depth of 48 inches. On occasional instances it was up to 12 inches deeper or shallower. Upon completion of each test pit the existing ground elevation was surveyed. The surveyed ground elevation was used along with the field-measured depth to floodplain gravel to find an estimated elevation of the floodplain gravel. Based on the surveyed data and measured depth, the elevation of the floodplain gravel appears to be relatively uniform across the floodplain, with less than 2 feet of variability at most transects perpendicular to the valley slope.

The depths to floodplain gravel are shown on the Floodplain Materials Investigation Maps, FM-1 through FM-4.

3.3.9 Riverbed Substrate

The riverbed substrate was measured by pebble counts taken in the riffle sections of the river. The pebble counts and results are discussed in Section 3.1.4. The resulting gradation of the riverbed substrate by pebble count is represented by the sizes shown in Table 9.

Table 9. Average Riverbed substrate gradations

Riverbed Substrate	
D_{16}	1.1 inches
D_{50}	1.8 inches
D_{84}	2.9 inches

In comparison to the bank toe gravel gradations, the river bed substrate represents the coarser fraction of the field-screened bank toe gravel and includes some particles up to 5 inches in diameter. Bank toe gravel samples contained cobbles visually estimated to range from 5 inches to 18 inches in diameter, which were removed from the samples before laboratory analysis. The gradations of the field-screened bank toe gravel samples contained gravel up to 3 inches in diameter. Material gradations of the bank toe material are contained in Appendix C Floodplain Material. Pebble count data are shown in Appendix B.

An analysis of incipient motion was performed using the maximum shear stress from a range of peak flows from the 2-year event to the 100-year event. Maximum shear stress was used to represent the worst case scenario as a basis for design for selection of alluvial material. Incipient motion is a measure of the critical condition where the hydraulic forces acting on a particle equal the stabilizing forces of that particle to resist motion. Incipient motion, represented in a simplified form using shear stress, can be analyzed using a Sheild's diagram and an equation

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developed from the diagram as presented in HEC-20 (FHWA, 2001). From this equation, incipient motion can be expressed in terms of the diameter of the river bed material that will move related to shear stress at various flow conditions. Based on this analysis, the diameter of the bed material at the critical condition and the maximum shear stress for the range of peak flows are shown in Table 10.

Table 10. Bed material analysis

Incipient Motion of River Bed Material			
		Maximum shear stress	**Diameter at Critical**
Return Interval	**Flow**	**n (channel) =0.036**	**n (channel) =0.036**
	(cfs)	**(lb/ft^2)**	**(in)**
2-Year/Channel Forming	754	0.64	2.5
10-Year	1508	0.86	3.4
100-Year	2539	1.39	5.4

As shown in Table 10, incipient motion, in terms of riverbed material size, ranged from 2.5 inches to 5.4 inches over the range of conditions. These ranges in size are consistent with the dominant material sizes in the river bed substrate and adjacent floodplain alluvium. Larger particle sizes are present, in limited quantity, in the river alluvium. Presence and movement of the larger particles occurs due to the dynamic nature of the system and over much longer periods of time than those analyzed.

3.3.10 Other Floodplain Material

Representative samples of two additional floodplain materials were collected during the floodplain investigation. A clay material that formed prominent clay sills along many eroding banks was collected from two locations and a sand deposit sample at a point bar was collected from one location. A summary of the geotechnical analysis of the clay sill material is shown in Table 11. The test pit logs and laboratory testing results are included in Appendix C Floodplain Materials. A clay sill is shown in Figure 12. The clay sills typically protruded from the bank, indicating that they are less erosive that the overlying material.

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Table 11. Clay sill analysis

Test Pit Number	Depth below ground (in)	USCS Classification	Percent Passing No. 200 Sieve	Plasticity Index	Organic Matter (%)
05-962	24-30	CL, clay	57	21	4
05-961	36-48	CH, fat clay	65	30	5.9
05-756	18-24	CL, clay	58	19	3.3
05-332	36-48	SC, clayey sand	40	12	1.2
05-159	36-42	CL, clay	61	18	1.5

Sample 05-169-0018, shown in Appendix C, was taken from a point bar sand deposit typical of the one shown in Figure 23. The point bar sand sample was submitted to a testing laboratory for gradation analysis and the results are included in Appendix C Floodplain Materials. The sieve analysis of the point bar sand shows that it consists of about 80% sand and 20% silt/clay. By comparison to the bank toe gravel, the makeup of the point bar sand represents about 10% to 40% of the bank toe gravel.

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Section 4.0 Hydrology

Peak flood flow predictions were prepared for analysis of the river system in Phases 5 and 6, and for use as a basis for design of the remedial actions along the impacted streambanks and floodplain. Peak flood flow analyses for various recurrence intervals have been conducted previously by others for various purposes associated with the Silver Bow Creek/Butte Area and Milltown Reservoir Sediments/Clark Fork River Superfund Sites. In order to provide some insight into the development of the area's hydrology and potential trends, and to evaluate the consistency of methods by comparison, prior hydrologic analyses are summarized below. In addition, since the existence and operation of Warm Springs Ponds plays a significant role in the hydrology, hydraulics, geomorphology, and ultimately design of Phases 5 and 6, a summary of prior hydrologic analysis is warranted. A Basin Routing Map, DM-1, and Basin Area Delineation Maps, DM-2 and DM-3, are included for reference in the Drawings section of this report.

4.1 Prior Hydrologic Analysis

This summary of prior hydrologic analyses discusses the design peak flood flows upstream of Warm Springs Ponds and gage station analyses from Warm Springs to Deer Lodge prior to and after structural and hydraulic upgrades were made to Warm Springs Ponds. Upgrades were made during the 1990s to route Silver Bow Creek through the ponds for flows up to the 100-year return interval. Although not discussed in this report, prior hydrologic analyses for Silver Bow Creek, CFR, and some of their tributaries included Flood Insurance and Flood Hazard Studies prepared for the Federal Insurance Administration and the Soil Conservation Service. Subsequent to these flood studies several reports were prepared in association with the Superfund sites. The following related reports were reviewed:

- Silver Bow Creek Flood Modeling Study, Montana Department of Health and Environmental Sciences, November, 30 1989.
- Silver Bow Creek/Butte Area, Warm Springs Ponds Active Area, Operable Unit 4 ROD, USEPA, September 28, 1990.
- Second Supplemental Work Plan for Warm Springs Ponds Phase III Construction, ARCO, April 12, 1991.
- Geomorphology, Flood-Plain Tailings and Metal Transport in the Upper Clark Fork Valley, Montana, USGS in cooperation with USEPA, October 1998 (Smith et al., 1998).
- Clark Fork River Operable Unit, Part 2 Geomorphic, Hydrologic and Hydraulic Investigation for Phase 1 Remedial Design/Remedial Action, CDM and AGI, April 2010.

Peak flood flows for the 100-year event on Silver Bow Creek upstream of Warm Springs Ponds are generally accepted to be 3,300 cfs and are referenced as such in the Warm Springs Ponds ROD (USEPA, 1990) and in the Supplemental Work Plan for Warm Springs Ponds (ARCO, 1991). The Supplemental Work Plan for Warm Springs Ponds was prepared in response to the Warm Springs Ponds ROD, which describes interim measures necessary to provide increased storage and routing capacity up to the 100-year flow event. These documents reference the

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Silver Bow Creek Flood Modeling Study (MDHES, 1989) as the basis for determining the hydrology of Silver Bow Creek and the resulting 100-year peak flow rate of 3,300 cfs.

The Silver Bow Creek Flood Modeling Study (MDHES, 1989) was prepared to evaluate the effects of design floods for the 10-, 25-, and 100-year recurrence intervals and the probable maximum flood on Silver Bow Creek. This report presented the peak flood flows as a result of a hydrologic analysis using a HEC-1 model, which simulates precipitation, snowmelt, and runoff processes. The analysis included calibration of the HEC-1 model with recorded flood events and a comparison to regionalized frequency analysis conducted using data from 12 gaging stations. The regionalized frequency analysis is presented as envelope curves for drainage area versus flow and is presented in Figure 25. The design floods were computed using data from the calibration process and rainfall parameters from the National Oceanic and Atmospheric Administration Precipitation Atlas for Montana. The resulting peak flows from the regional frequency analysis and the calibrated HEC-1 models are summarized in Table 12.

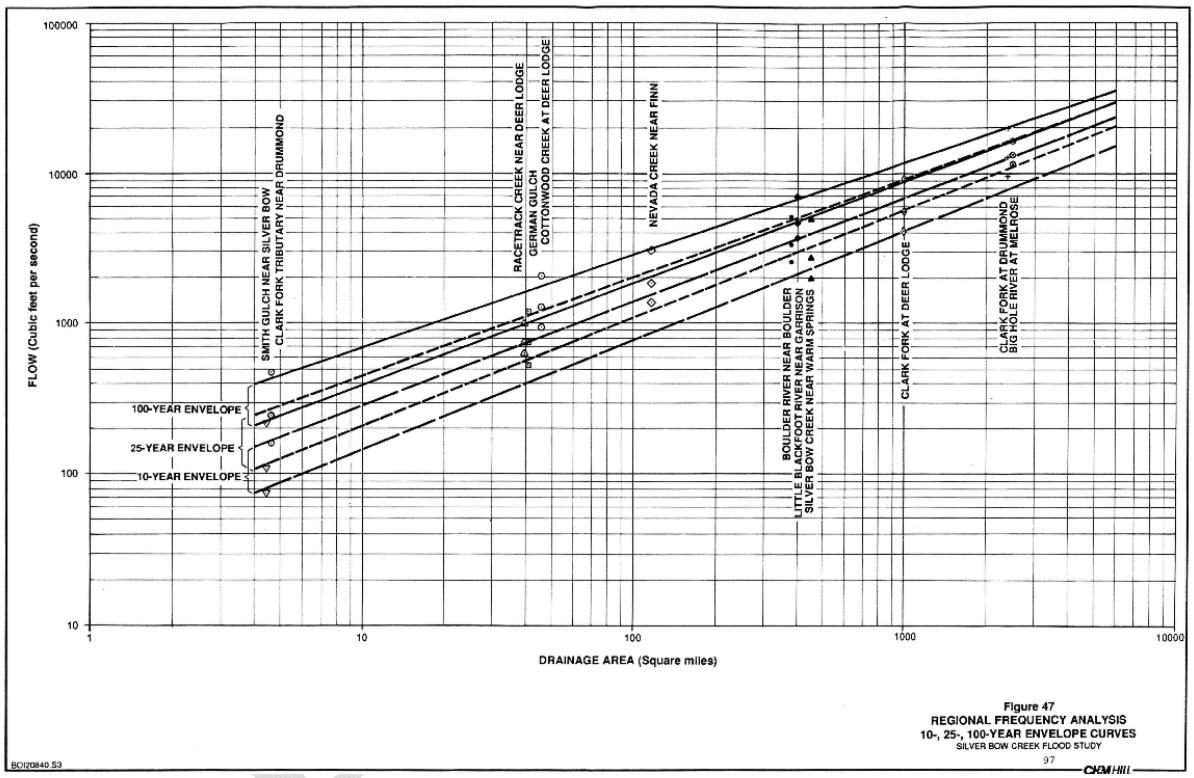

Figure 25. Regionalized frequency analysis from Silver Bow Creek Flood Model Study

Table 12. Peak Flow Summary from Silver Bow Creek Flood Model Study

Location	Gage Station	Period of Record	Area (sq mi)	Frequency Analysis			HEC-1 Model		
				10-year (cfs)	25-year (cfs)	100-year (cfs)	10-year (cfs)	25-year (cfs)	100-year (cfs)
Silver Bow Creek* above Diversion Works	12323600		347	1,900	2,700	4,300	2,190	2,820	4,000
Silver Bow Creek** near Warm Springs	12323750	1971-79	452	2,000	2,800	5,000	2,490	3,480	4,950
Clark Fork River*** at Deer Lodge	12324200	1978-86	1005	4,100	5,600	9,200			

* The gage station 12323600 was installed in 1988; therefore, the reported frequency analysis flows are taken as the lower end of the envelope curves.

** Silver Bow Creek near Warm Springs is below the ponds and includes flow from Mill and Willow Creeks.

*** The HEC-1 model included the portion of the Clark Fork River basin upstream of Deer Lodge but did not report any model results downstream of Silver Bow Creek near Warm Springs.

Although the 100-year peak flow is reported as 3,300 cfs in the ROD and Work Plan for Warm Springs Ponds, the HEC-1 model from the referenced Silver Bow Creek Flood Modeling Study (MDHES 1990) used a value of 4,000 cfs. This discrepancy was resolved in the responses to public comment section of the Warm Springs ROD, which reported that the USGS was consulted to evaluate the flood modeling and concluded that the peak discharge at this location is close to the 4,000 cfs estimated by MDHES (1990). The USGS also concluded that the flood model may have overestimated the 100-year volume of 13,000 acre-feet. As the flood volume is the most important parameter because it governs the amount to be treated, the USGS suggested that a peak design flow of 3,300 cfs, as estimated by ARCO, could be used for the Pond improvements.

A comparison of the peak flows from the frequency analysis to the calibrated HEC-1 model above and below the Warm Springs Ponds shows that the two methods are consistent with each other. The peak flows from the HEC-1 model at Silver Bow Creek at Warm Springs (USGS Station 12323750) show that the results are similar even though the period of record was short—8 years—which could have resulted in skewed results. For the location designated, Silver Bow Creek above Diversion Works (USGS Station 12323600), the correlation is also close. Gage station data did not exist at the time of the Silver Bow Creek Flood Modeling Study (MDHES 1990) and peak flows reported are estimated by interpolation using the lower end of regional frequency envelope curves. The correlation between the methods is likely due in part to the longer period of records used from other sites, above and below Warm Springs Ponds, for the regional frequency analysis.

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The Geomorphology, Flood-Plain Tailings and Metal Transport in the Upper Clark Fork Valley (Smith et al., 1998) also produced flood frequency analysis using gage station data for the CFR at Deer Lodge. This gage station data record includes16 years of flow data through 1994. Smith et al. (1998) suggest that analysis using a short period of record would be unreliable and, for the gage data at Deer Lodge, would underestimate the flows. To improve the reliability, USGS used gage information from a nearby site upstream of Missoula (station 12340500) with a longer historical record. The analysis was then performed using a log-Pearson Type 3 distribution following guidelines in Bulletin 17B, with adjustments to a longer base period available at Station 12340500 using a two-station comparison procedure (Interagency Advisory Committee on Water Data, 1982). Table 13 shows a summary of the flow data presented in the report by Smith et al. (1998) for the CFR at Deer Lodge.

Table 13. Peak Flow Summary at Deer Lodge (from Smith et al., 1998)

Recurrence Interval (years)	Peak Discharge (cfs)	
	Actual Record	Adjusted
2	891	1,060
5	1,530	1,990
10	2,010	2,750
25	2,690	3,880
50	3,240	4,840
100	3,820	5,900

CDM and AGI prepared the Geomorphic, Hydrologic and Hydraulic Investigation for Phase 1 Remedial Design/Remedial Action in preparation for the design of the remedial action on the uppermost reach of the CFROU (CDM and AGI 2010). This analysis is presented as a summary of four gage stations near the confluence of Silver Bow Creek and Clark Fork River downstream to the gage station at Deer Lodge. This analysis compared regression analysis to frequency analysis of gage station data using Bulletin 17B. In this analysis, the 20-year period of record for the CFR gage station at Galen was extended to a 72-year record using gage data from Middle Fork of Rock Creek period of record from 1938 to 1978. The results of the USGS regression analysis were considerably higher than the gage station analysis. The CDM and AGI (2010) report ultimately selected the gage station data from the CFR near Galen for design below the confluence with Warm Springs Creek for the 2-, 5-, and 10-year events and selected the extended data for the 25-, 50-, and 100-year events. The resulting recommended flows for CFR at Galen and Deer Lodge are shown in Table 14.

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Table 14. Peak Flow Summary at Galen and Deer Lodge (from CDM and AGI 2010)

Recurrence Interval (years)	Peak Discharge (cfs)	
	CFR at Galen	CFR at Deer Lodge
2	522	835
5	861	1,418
10	1,094	1,859
25	1,286	2,472
50	1,415*	2,965
100	1,533*	3,486

* CDM and AGI (2010) noted these values as provisional and not for design purposes.

4.2 Warm Springs Ponds

The operation of Warms Springs Ponds was designed to detain flows and treat runoff from the Butte/Silver Bow mining area for flows up to the volume of the 100-year return-interval event (13,000 acre-feet) or until the maximum inflow of 3,300 cfs has been reached. Flows up to 600 cfs are treated for removal of dissolved metals, and flows between 600 cfs and 3,300 cfs are treated for removal of suspended sediment. A cursory review of the gage station data upstream and downstream of Warm Springs Ponds was conducted. Based on the review a reduction in some peak flows is apparent; however, in some instances Warm Springs Ponds appear to operate as nearly a pass-through system with detention of some peak events or with releases that cause a variation in the annual peak flows.

Sediment reduction caused by Warm Springs Ponds may have significant impacts along the upper reaches of the CFR, which likely diminish downstream as sediment enters the system from eroding banks and as tributaries discharge to the main stem. This project assumes that Warm Springs Ponds will remain in place and operate as designed for the foreseeable future.

4.3 Project Hydrologic Analysis

The hydrology for Phases 5 and 6 was developed using a correlation between drainage area and peak flows from frequency analyses of gage stations upstream and downstream of the site. Provisional frequency analyses performed in accordance with Bulletin 17B of the Interagency Advisory Committee on Water Data were provided by the USGS Montana Water Science Center. The frequency analysis was performed on gage station data obtained for the period of record up to 2011 for Silver Bow Creek at Warm Springs Creek, CFR at Galen Road, and CFR at Deer Lodge. The periods of record and results of the analyses are provided in Table 15 for the three subject stations. The contributing drainage areas for each gage station and at the end of the project are also shown in Table 15. Complete peak flow analyses are shown in Appendix D.

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Table 15. Peak Flow Summary for Phases 5 and 6

	Silver Bow Creek at Warm Springs	Clark Fork River Near Galen	Downstream End of Phase 6 at Gemback Road	Clark Fork River at Deer Lodge
Gage Station ID	12323750	12323800	--	12324200
Period of Record	1972-2011	1989-2011	--	1979-2011
Number of Years	39	22	--	32
Drainage Area (sq mi)	468	677	787	916
Q2 (cfs)	428	636	754	893
Q5 (cfs)	742	936	1197	1502
Q10 (cfs)	972	1134	1508	1946
Q25 (cfs)	1285	1379	1914	2542
Q50 (cfs)	1524	1558	2224	3006
Q100 (cfs)	1772	1733	2539	3484

The peak flow results of the frequency analysis for each gage station were plotted by drainage area and are shown in Figure 26. Because a gage station does not exist at the downstream end of the project, peak flows were obtained by interpolating between the two gage stations located upstream and downstream of the site. This method of interpolation between gage stations is documented in Methods for Estimating Flood Frequency in Montana (USGS, 2004). The frequency analysis for the CFR at Galen resulted in an insignificant increase in peak floods from the upstream gage station for recurrence intervals less frequent than the 10-year event, even though the drainage area increased by 44%. This is likely due to the longer period of record for Silver Bow Creek at Warm Springs where several large storms were recorded in 1974, 1975, and 1976 prior to the current operation of Warm Springs Ponds. In addition to the shorter, drier period of record, all the gage data at CFR near Galen are affected by the improved attenuation at Warm Springs Ponds.

4.4 Hydrologic Summary

Phases 5 and 6 extend from Galen Road to the county line along the CFR. A tributary area of 384 square miles is routed through Warm Springs Ponds upstream of this site. The drainage area of this site increases from approximately 677 square miles to 787 square miles as Lost Creek and Modesty Creek flow from the west out of the foothills of the Flint Creek Range and Dry Cottonwood Creek flows from the east out of the eroded hills of the Boulder Batholith to join the main stem. As mentioned in CDM and AGI (2010), peak flows greater than the 10-year event remain suspect at the CFR at Galen gage station due to the short period of record, minimal increase in peak flows for events less frequent than the 10-year event, and the lack of an up-to-date operational analysis of Warm Springs Ponds. Additional analysis of the 100-year event may be performed for design if warranted.

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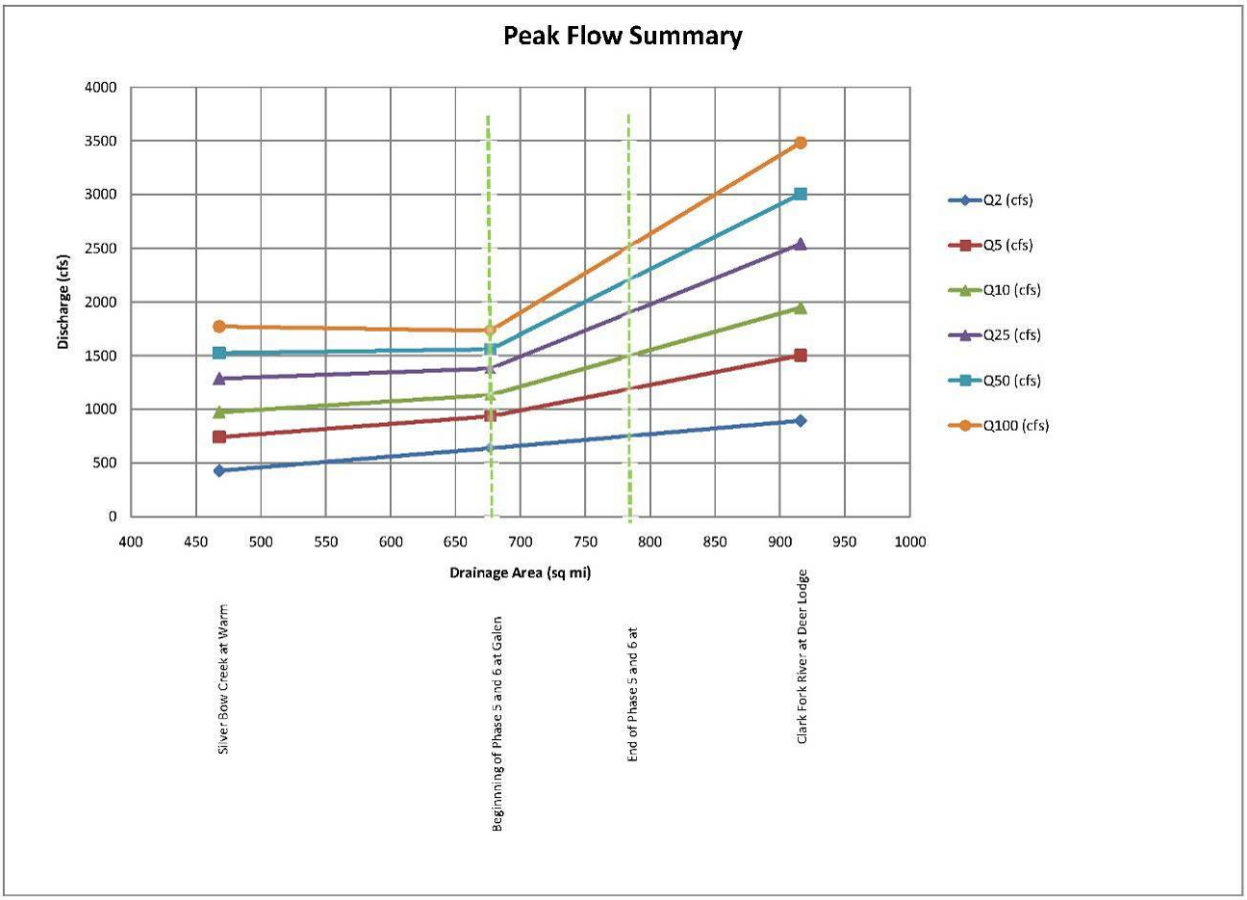

Figure 26. Peak flows along the Clark Fork River system.

For the purpose of representing optimal top-of-bank and floodplain elevations, the flow estimate for the channel forming flow is equal to the 2-year event and is based on the geomorphic indicators along the Phase 5 and 6 reach and will be used as a basis for design. A discussion of the channel forming flow estimate is included in Section 3.1.2. In order to provide streambank stability, the 10-year flow rate estimate at Gemback Road will be used as a basis for design. The peak flow rate estimate for the 100-year event at Gemback Road will be used as a basis for design analysis of the stability of existing structures and infrastructure and to meet applicable floodplain regulations. A summary of the flows for use as the basis of design are included in Table 16.

Table 16. Peak Flow Summary

Recurrence Interval	Flow (cfs)
2-year/Channel Forming	754
10-year	1508
100-year	2539

Section 5.0 River Hydraulics

The existing hydraulic conditions in Reaches 5 and 6 were modeled using the estimated peak flows for the 2-year, 10-year, and 100-year events. Calibration of the model used flow rates on days when water surface elevations were surveyed. A channel forming flow equal to the 2-year event was estimated based on geomorphic indicators in the river and on the floodplain including elevation of inset floodplains, point bars, and occurrence of persistent woody vegetation. Peak flows for the 2-year, 10-year, and 100-year events at Gemback Road of 754 cfs, 1,508 cfs, and 2,539 cfs, respectively, were analyzed using HEC-RAS V4.1.0 (USACE, 2010). The results of the analysis will be used as a basis for the design of the streambanks and floodplain, to assess the stability of structures, and to evaluate compliance with applicable floodplain regulations. The project area is within Federal Emergency Management Agency (FEMA) Zone A where water surface elevations are approximated.

5.1 Hydraulic Model Development

The HEC-RAS hydraulic model was developed from the results of the hydrologic analysis of peak flows, a ground survey of structures along the reach and cross-sections of the main channel, LiDAR survey of the floodplain, and an analysis of channel and floodplain roughness. The estimated peak flows from the hydrologic analysis are discussed in Section 4.0. The cross-section ground survey was conducted at approximately 500-foot intervals with additional cross-sections and measurements taken at two bridges, two irrigation structures, and geomorphic features. The two bridges are located at Galen Road and at Gemback Road, the upstream and downstream limit of project, respectively. The Galen Road bridge is shown in Figure 27 and the Gemback Road bridge is shown in Figure 28. The West Side diversion structure is shown in Figure 29 and the Whalen diversion structure is shown in Figure 30. The geometric data for each cross-section and the structures were input into HEC-RAS for hydraulic modeling of the flow events specified at the beginning of this section.

LiDAR data of the site were merged with ground survey points at the cross-sections and the test pit locations. The merged data were used to develop a geometric representation of the overbank portion of the floodplain at each main channel section for the HEC-RAS model. Aerial LiDAR data were collected between August 6, 2011, and August 11, 2011, by Fugro Horizons, Inc. and post processed by DJ&A, P.C. Each main channel cross-section was surveyed perpendicular to the assumed flow path and extended beyond the modeled high water surface elevation or to the limit of the LiDAR data.

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Figure 27. Galen Road Bridge

Figure 28. Gemback Road Bridge

Figure 29. West Side Ditch diversion, Station 62+00

Figure 30. Whalen Ditch diversion, Station 77+00

5.1.1 Split Flows

Due to the sinuosity of the river and the relatively wide floodplain, split flows occur at several locations during low flows and as the flows overtop the banks. Split flows were modeled as simple overbank flow and were not optimized with increasing flow depth. Additional analyses were considered unlikely to produce results that would impact design decisions. If it is discovered during design that additional detail at split flow locations is needed then optimization of the split flow characteristics may be modeled.

During low flows, split flows occur only at small islands within the main channel. During higher flows, generally beginning during the 5- to 10-year events, split flows occur as the water surface overtops the banks and flows across the floodplain or into oxbows. Split flows, which overtop the banks and flow across the floodplain, generally begin to occur at meander bend cutoffs and are evident by cutoff channels in varying stages of development on the downstream sides of meander bends. A split flow also occurs at the newly formed oxbow located at Station 107+00. This split flow begins to occur at relatively low flows, around the 2-year event, and becomes inundated at flows nearing the 100-year event. Another notable split flow begins at Station 91+00 when flooding overtops the right bank, flows into an abandoned river alignment, and rejoins the main channel at Station 15+00. The abandoned river alignment is located east of the current alignment in what is now a pasture. However, since split flow into the abandoned channel alignment will only occur at events nearing and less frequent than the 100-year event, this split flow was modeled as an ineffective flow area. The abandoned river alignment is shown on Geomorphic Floodplain Features Maps, GFF-1 and GFF-2, and is discussed in Section 3.3.

5.1.2 Roughness Coefficients

Manning's n roughness coefficients were used in the HEC-RAS model to represent the roughness characteristics of the main channel and floodplain. Since an accurate estimate of Manning's n significantly impacts the hydraulic model results and is dependent on flow depth, velocity, and resistance, several methods were used for the estimation including calibration of the hydraulic model, empirical methods, and a summary compilation of available information prepared by Chow (1959).

The hydraulic model was calibrated to known water surface elevations and gage station flow data collected during the cross-section survey of the main channel during low flow conditions between 115 and 141cfs in October 2010 and during spring runoff about 520 cfs in June 2012. The model was calibrated by varying Manning's n until the output water surface elevations represented the field-measured data for the corresponding flow rate as measured at the Galen gage station. The resulting model generated water surface elevations close to the measured water surface elevations with a Manning's n of 0.065 for the low flow condition and 0.038 for the spring runoff condition.

Empirical equations developed on gravel bed streams as prepared by Limerinos (1970), Strickler (1923), Anderson, et al. (1970), Jarrett (1984), and the U.S. Department of Agriculture (USDA, 1989) were used to estimate Manning's n for the project reach. Bray (1979) concluded, through a comparison of the methods by Limerinos, Strickler, and others, that the Limerinos expression was the most acceptable because it included flow depth as an element for determining roughness. An analysis was performed for the project site using the peak flow from the 2-year flood event and is included in Appendix E. The results of these analyses are shown in Table 17.

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Table 17. Mannings n estimates

Manning's n Estimate by Empirical Methods for the 2-year Event	
Anderson	0.029
Limerinos	0.033
Strickler	0.032
Jarrett	0.028
USDA	0.028
Average	0.031

Chow (1959) compiled information from various sources and produced a table titled "Values of the Roughness Coefficient n." This table by Chow is widely accepted and used for the estimation of Manning's n at flows in excess of about the 2-year event. Using this table, a Manning's n for the main channel ranges from 0.035 to 0.040 based on a description of the channel being "clean, winding, full stage, some stones, vegetation, pools, and shoals."

5.1.3 Selected Manning's n

Based on the results of the analysis, a Manning's n of 0.036 was selected to represent channel roughness as a basis for design analysis for the 10- to 100-year flow events. This value was well represented by the empirical analysis, Chow's table on Values of the Roughness Coefficient, and the calibration of the model at a spring runoff flow of 520 cfs.

Manning's n for the overbank areas of the floodplain selected in CDM and AGI (2010) are considered consistent with the conditions at this site with the addition of 0.06 to represent light to medium brush. Manning's n values selected for representation of the overbank roughness are shown in Table 18.

5.2 Hydraulic Model Results

HEC-RAS hydraulic modeling was performed using the parameters discussed above for the 2-year, 10-year, and 100-year events for Phases 5 and 6. Inundation areas for these three return interval flow rates are shown on 2-Year Floodplain Inundation Maps, FP-1 and FP-2, 10-Year Floodplain Inundation Maps, FP-3 and FP-4, and the 100-Year Floodplain Inundation Maps, FP-5 and FP-6. Cross-section locations for the HEC-RAS Model are shown on Geomorphic and Floodplain Features Maps, GFF-1 and GFF-2. The results from hydraulic analysis for these events at each section are tabulated in Appendix E, Hydraulics. A general discussion of the flood inundation area and tabulation of the reach average hydraulic conditions are included in the sections below. In addition, the hydraulic model was used to help estimate the channel forming flow, Q_{cf}.

Table 18. Overbank Manning's n values

Site Condition	Manning's n
Slickens	0.020
Pastures and grass	0.035
Light to Medium brush	0.060
Medium to Dense Brush with some Trees	0.100
Dense Brush and Trees (willows and birch)	0.150

5.2.1 10-year Event Results

The majority of the flow from the 10-year event is contained within the main channel, with out-of-bank flow ranging from tens to a few hundred cubic feet per second. Flow is subcritical throughout the reach with velocities ranging from 3 to 5 feet per second. The 10-year event passes under Galen Road Bridge and flows out of bank onto portions of the floodplain scarred by the river as wide as 1,500 feet from Station 23+00 at Galen Road to approximately Station 170+00 where the floodplain becomes constricted as it passes the alluvial fan from Dry Cottonwood Creek to the east. Overland flow during the 10-year event in this upper reach is characterized by shallow split flows, ponding, occasional high banks along the river, and high ground throughout the floodplain, representative of the numerous meander paths left by the river and deposition along the banks and within the central portion of the active floodplain tabs. As the floodplain corridor becomes constricted from Dry Cottonwood Creek alluvial fan, out-of-bank flow is primarily contained to the channel and across each floodplain tab from the outside of the bend to the downstream end of the bend where cutoffs generally develop. This narrower floodplain corridor persists beyond the alluvial fan, due to a historical shift in the river alignment, for the remainder of the study reach. The characteristic high ground above the 10-year water surface elevation that exists within the central portion of active floodplain tabs in the reach above the alluvial fan also exists along and below the alluvial fan. The historical shift of the river alignment from the east side to the west side of the floodplain occurred at approximately Station 95+00 and continues until rejoining the older meander belt at various locations below Station 50+00 to Gemback Road. This older meander belt is separated from active alignment for about 3,000 feet by higher ground and generally conveys little flow during the 10-year event. The older meander belt was modeled as ineffective flow area because it likely becomes at least partially inundated as groundwater rises in association with spring runoff and the water surface elevation in the river. The study reach ends near Gemback Road where the peak flows pass under the bridge.

The average and maximum hydraulic conditions for the 10-year events are summarized in

Table 19 and Table 20, respectively, and included for each cross-section in Appendix E, Hydraulics.

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Table 19. 10-Year Reach Average Hydraulics

Runoff Event	Flow (cfs)	Velocity (fps)	Shear Stress (lbs/sq ft)	Hyd. Depth (ft)	Energy Gradient (ft/ft)
Left Overbank	153	0.6	0.05	0.60	--
Channel	1,285	4.2	0.42	4.4	0.0016
Right Overbank	116	0.8	0.06	0.63	--

Table 20. 10-Year Reach Maximum Hydraulics

Runoff Event	Flow (cfs)	Velocity (fps)	Shear Stress (lbs/sq ft)	Hyd. Depth (ft)	Energy Gradient (ft/ft)
Left Overbank	555	1.5	0.15	2.0	--
Channel	1,508	6.1	0.86	6.1	0.0043
Right Overbank	307	1.8	0.18	1.6	--

5.2.2 100- Year Event Results

As with the 10-year event, the majority of the 100-year flow is contained within the main channel. However, due to the higher water surface elevations, significantly more out of bank flow occurs, which generally inundates the extent of the floodplain such that the occasional high banks and high ground within the central portion of the active floodplain tabs that projects above the 10-year water surface elevation are inundated. During the 100-year event the flow regime is similar to that of the 10-year event with subcritical flow throughout the reach and only slight increases in shear stresses and velocities. The 100-year event passes under the Galen Road Bridge, spreads across the wider portion of the floodplain meander belt above Dry Cottonwood Creek alluvial fan, and becomes constricted along the right bank as it passes the alluvial fan. Below the alluvial fan, similar to the 10-year event, out-of-bank flow is primarily contained in the channel and across each floodplain tab from the outside of the bend to the location where meander bend cutoffs are generally developing. The older meander belt on the east side of the floodplain remains separated from the 100-year flows by the higher ground generally located between Station 95+00 and 25+00; however, split flows begin to occur where the old river alignment branches off to the east at about station 95+00. As with the 10-year flood model, the old meander belt was modeled as ineffective flow area because the area likely becomes at least partially inundated due to the limited split flows that occur during the 100-year event and due to

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increases in the groundwater elevation in association with spring runoff and increases in the water surface elevation during flood events. The average and maximum hydraulic conditions for the 100-year events are summarized in Table 21 and Table 22, respectively and included for each cross-section in Appendix E, Hydraulics.

Table 21. 100-Year Reach Average Hydraulics

Runoff Event	Flow (cfs)	Velocity (fps)	Shear (lbs/sq ft)	Hyd. Depth (ft)	Energy Gradient (ft/ft)
Left Overbank	479	0.8	0.09	1.0	--
Channel	1,740	4.7	0.53	5.2	0.0018
Right Overbank	410	1.1	0.10	1.1	--

Table 22. 100-Year Reach Maximum Hydraulics

Runoff Event	Flow (cfs)	Velocity (fps)	Shear (lbs/sq ft)	Hyd. Depth (ft)	Energy Gradient (ft/ft)
Left Overbank	1,254	1.8	0.21	2.2	--
Channel	2,539	7.71	1.39	7.34	0.0058
Right Overbank	410	1.1	0.10	1.1	--

5.2.3 Channel Forming and Bankfull Discharge

An analysis was conducted using HEC-RAS to determine the discharge values associated with bankfull and channel-forming flows. Bankfull flow (Q_{bf}) is an estimated discharge that most closely matches the elevations along the reach where water begins to leave the channel and is often found to be around the 1.5- to 2-year event. A bankfull discharge in excess of the 2-year event typically indicates an incised channel or, in the case of this reach, an aggraded floodplain. As discussed in Section 3.0, these bank heights are elevated due to the deposition of excess sediments and construction of berms. Channel forming flow is the dominant flow that transports the greatest amount of sediment over a long period of time and has the most significant impact on channel geometry. Since the floodplain on this reach is aggraded additional analysis was done to estimate the channel-forming flow (Q_{cf}). The estimate is based on the elevations of low floodplain features such as small inset floodplains and point bars, which typically develop at channel forming flow, and the pre-mining floodplain elevation. The pre-mining floodplain elevation was estimated based on measured depths of contaminated soil. Cross-sections shown in Drawings CS-1 and CS-2 indicate that pre-mining bank heights were variable but generally

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lower than they are now. The assumptions used in estimating Q_{cf} were that the floodplain historically sloped, on average, very slightly toward the river, and that the depth of contamination is slightly deeper than the old floodplain due to leaching and mixing. In this reach Q_{bf} is approximately 1200 cfs, which is about the 5-year flow and Q_{cf} is 750 cfs, which is about the 2-year flow.

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Section 6.0 Summary Discussion

Aggradation of the floodplain with fine-grained mine tailings occurred as a result of extremely high sediment loading during the mining era and subsequent annual spring runoff and flood events which carried silt sized mine tailings downstream and deposited them on the floodplain where overbank flows were slow and the tailings could settle out. This condition created an entrenched river system, which in addition to increasing shear stresses on the bed and banks, has disconnected the river hydrology from floodplain vegetation, and, along with the tailings toxicity, has weakened and caused mortality of the floodplain vegetation. This condition is supported by the field investigations and subsequent analysis of data summarized in the report.

In general, tailings are deposited in a layer across the meander belt of the floodplain as wide as 1,200 feet and as narrow as 300 feet. Tailings are deposited in areas along the floodplain to varying depths under a variety of conditions, which may have included contributing factors such as: frequency of overbank flow, aggradational features, developing cutoffs, ground elevations below the 100-year effective flow area, dense vegetation, beaver ponds, and oxbows. . The wider deposits are mainly located in Phase 5 where the floodplain is wider and lower; downstream in Phase 6, the deposits narrow as the meander belt narrows and are mainly limited to the active floodplain tabs and one recently avulsed floodplain tab. In almost all locations along Phases 5 and 6, newly formed point bars are contaminated with tailings. The average depth of tailings deposited on the contaminated portion of the floodplain in Phases 5 and 6 is 1.8 feet, with large areas of deposits ranging up to 48 inches deep.

With the cessation of tailings disposal in the river system and construction of Warm Springs Ponds, sediment loads and flood and annual peak flows in the system have been reduced to below pre-mining conditions, especially in the upper reaches below the ponds. Although Warm Springs Ponds attenuate flow and remove sediment from the 384-square-mile basin of Silver Bow Creek, these effects become muted in Phase 5 and 6 as unregulated drainages of Mill, Willow, Warm Springs, Lost, Modesty, and Dry Cottonwood Creeks enter the CFR, increasing the drainage area to 787 square miles at the downstream end. Increased flows and sediment inputs from these tributaries and erosion from the cut banks in the upper 8 river miles below Warm Springs Ponds have contributed to depositional development of the point bars. Point bars have advanced at an average rate of 0.5 feet per year since 1947. Vegetation encroachment by shrubs and herbaceous communities in varying densities also appears to have occurred on what were open depositional surfaces of the point bars in 1947. Test pit sample results from the post-1947 vegetated and depositional surfaces of the point bars show that they are contaminated.

Bank erosion is occurring at most outer bend cut banks along Phases 5 and 6. Tailings-contaminated soils were observed in most of the eroding banks along the floodplain and were found in the floodplain sampling in most areas adjacent to the river. However, some banks, including eroding banks, showed no visible sign of tailings and the adjacent floodplain sampling was clean. These banks that did not have any sign of tailings, regardless of vegetation cover or migration rate, were usually associated with meander bend cut banks at floodplain benches and associated with the cut bank into the Dry Cottonwood Creek alluvial fan. The floodplain benches were typically elevated enough that they are disconnected from the river hydrology and mostly covered with upland grasses. Some floodplain benches have a thin veneer of tailings, and are, or would otherwise be, even if the tailings were removed, disconnected from the river's

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hydrology. Although bank erosion was evaluated, the rate of migration could not be attributed to the presence of tailings. Smith and Griffin (2001) concluded that bank erosion rates decrease with increasing density of vegetation. Since most eroding banks were associated with the presence of tailings and/or a lack of streambank vegetation, the conclusions by Smith and Griffin appear to be supported in this reach.

Although impacts from mining activities have ceased, their effects linger with the continued operation of Warm Springs Ponds and the existence of tailings deposited on the floodplain; to a lesser degree, but in conjunction with other manmade conditions, they continue to shape the current geomorphic setting. As is typical of an entrenched river channel, an inset floodplain is developing near water surface elevation of the channel-forming flow elevation. A significant reduction in beaver population and the introduction of excess sedimentation during the mining era have slowed floodplain morphology by reducing split flows and ponded water on the floodplain, resulting in lower groundwater elevations on the floodplain. Limitation to migration and floodplain flows are also present due to infrastructure associated with road crossings at Galen and Gemback Roads, an abandoned railroad embankment, irrigation diversions, and irrigation ditch embankments. Land use practices, primarily associated with ranching and farming, reduce vegetation where grazing and crop lands encroach on riparian areas, reduce stream flows due to irrigation, and lower groundwater elevations in areas of the floodplain that are drained.

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DRAWINGS

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Appendix A

Survey Data Summary

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		FIELD SURVEYED DATA - 9/24/2010 TO 10/8/2010														
									Water Surface Elevation (Flow Range 115 to 141 cfs)							
		Topographic features							Main Channel				Split flow			
Phase	Cross-section Number	River Station	Left Bank Elevation	Right Bank Elevation	Thalweg Elevation	Left Bank Station	Right Bank Station	Elev at BF indicators	LEW Station	LEW Elevation	REW Station	REW Elevation	LEW Station	LEW Elevation	REW Station	REW Elevation
		ft	ft	ft	ft	ft	ft	ft	ft	ft	ft	ft	ft	ft	ft	ft
5	2	23282.1	4716.4	4716.4	4709.3	26.0	96.3		28.5	4713.4	78.8	4713.5				
5	3	23212.0	4722.8	4723.7	4709.8	7.9	128.6		30.1	4713.2	95.4	4713.3				
5	4	23173.7	4720.2	4719.1	4709.2	16.4	129.2		37.9	4713.3	104.1	4713.2				
5	5	23100.0	4715.9	4715.0	4710.6	14.9	75.1		18.1	4713.0	70.6	4712.9				
5	6	22956.3	4716.5	4714.4	4709.5	12.6	65.0		16.4	4712.8	61.6	4712.8				
5	7	22606.0	4714.2	4714.4	4710.6	28.7	92.3		31.6	4712.1	87.7	4712.0				
5	8	22349.9	4713.5	4715.4	4708.6	54.6	107.0		62.7	4711.8	105.1	4711.7				
5	9	22047.4	4714.0	4713.8	4707.9	29.9	80.8		35.6	4711.3	80.1	4711.3				
5	10	21661.8	4713.7	4712.9	4708.0	102.8	151.2		40.5	4711.1	84.0	4711.2				
5	11	21288.1	4712.3	4714.2	4709.1	80.7	144.8		81.6	4710.4	139.0	4710.4				
5	12	20885.9	4712.2	4712.0	4706.9	73.4	135.7		77.0	4709.5	131.9	4709.5				
5	13	20452.2	4710.3	4711.9	4704.6	55.3	111.5		65.2	4709.1	106.9	4709.2				
5	14	20152.9	4711.6	4709.8	4706.1	25.3	77.9		26.0	4708.5	69.1	4708.5				
5	15	19673.0	4709.6	4709.8	4704.0	47.2	122.3		67.9	4707.6	122.1	4707.8				
5	16	19289.8	4709.4	4709.8	4704.6	72.2	132.3		73.2	4707.1	116.0	4707.0				
5	17	18852.7	4711.0	4709.3	4702.8	76.5	137.7		85.6	4706.9	134.4	4706.7				
5	18	18469.6	4708.5	4707.5	4705.0	44.0	118.5	4707.5	45.6	4706.4	116.8	4706.4				
5	19	18351.3	4708.6	4708.7	4703.4	35.0	123.4		39.3	4706.1	74.6	4706.0				
5	20	18290.2	4709.4	4708.5	4702.4	23.5	94.8		36.4	4706.1	86.1	4706.1				
5	21	18044.8	4707.8	4708.1	4702.1	28.5	84.6		35.1	4706.1	82.0	4706.1				
5	22	17872.7	4707.9	4707.1	4703.2	35.0	209.6		40.1	4705.6	66.1	4705.6	143.4	4705.7	204.4	4705.8
5	23	17595.7	4706.9	4707.2	4703.2	29.1	112.0		29.3	4705.4	106.8	4705.4				
5	24	17396.7	4707.0	4712.8	4702.9	11.2	91.5		19.3	4704.8	82.2	4704.8				
5	25	16918.1	4706.7	4706.2	4701.8	51.7	112.9		60.2	4703.7	111.4	4703.9				
5	26	16612.2	4707.8	4705.6	4701.2	38.2	104.6		49.1	4703.6	95.5	4703.5				
5	27	16264.4	4705.7	4705.4	4700.1	38.0	99.2		46.4	4702.4	94.6	4702.4				
5	28	15947.2	4704.5	4703.8	4700.3	36.0	88.9		38.4	4701.9	86.3	4701.9				
5	29	15566.1	4703.2	4704.6	4698.3	50.5	100.1		55.9	4701.1	97.6	4701.2				
5	30	15091.5	4702.7	4703.9	4695.4	30.2	97.6		36.6	4700.7	93.9	4700.7				
5	31	14604.7	4702.8	4702.6	4697.5	32.8	96.0	4700.1	34.3	4699.7	77.1	4699.7				
5	32	14218.6	4701.6	4701.6	4695.8	30.3	83.1		34.0	4698.8	77.1	4698.9				
5	33	13905.5	4699.3	4702.2	4694.6	57.5	106.8	4699.3	62.1	4698.1	104.0	4698.3				
5	34	13422.4	4702.3	4701.1	4694.1	23.1	101.0		38.9	4697.8	88.7	4697.8				
5	35	13012.6	4701.4	4699.8	4695.5	32.7	112.1		36.8	4697.0	108.9	4697.3				
5	36	12583.6	4700.9	4698.3	4694.4	24.9	107.8		42.0	4696.4	100.7	4696.5				
5	37	12145.0	4697.7	4699.3	4690.8	50.8	126.6	4697.0	67.4	4696.0	125.6	4695.9				
5	38	11609.7	4698.4	4697.2	4693.0	37.7	112.6		53.2	4694.8	103.5	4694.8				
6	39	11181.9	4699.6	4698.9	4691.3	24.8	115.1	4694.9	30.8	4694.1	76.3	4694.0				
6	40	10736.1	4695.2	4695.4	4690.2	73.5	157.4		93.4	4693.1	155.1	4693.2				
6	41	10137.7	4696.1	4694.4	4690.5	29.1	105.1		36.3	4692.0	96.0	4692.0				

		FIELD SURVEYED DATA - 9/24/2010 TO 10/8/2010														
									Water Surface Elevation (Flow Range 115 to 141 cfs)							
		Topographic features							Main Channel				Split flow			
Phase	Cross-section Number	River Station	Left Bank Elevation	Right Bank Elevation	Thalweg Elevation	Left Bank Station	Right Bank Station	Elev at BF indicators	LEW Station	LEW Elevation	REW Station	REW Elevation	LEW Station	LEW Elevation	REW Station	REW Elevation
		ft	ft	ft	ft	ft	ft	ft	ft	ft	ft	ft	ft	ft	ft	ft
6	42	9823.3	4697.1	4693.3	4689.6	35.1	104.1		42.6	4691.3	93.7	4691.3				
6	43	9326.1	4692.4	4694.6	4687.7	56.5	120.0		59.3	4690.7	112.4	4690.6				
6	44	9106.3	4691.6	4695.3	4689.1	118.6	208.3		120.6	4690.3	193.9	4690.4				
6	45	8951.0	4693.6	4692.4	4688.0	15.6	214.2		82.5	4689.7	120.2	4689.8	150.9	4689.6	208.1	4689.7
6	46	8661.2	4690.9	4691.2	4686.9	39.0	100.2		41.7	4689.1	97.2	4689.1				
6	47	8221.4	4691.2	4690.7	4685.7	58.0	123.0		65.2	4688.2	119.0	4688.2				
6	48	7755.8	4698.0	4690.3	4685.0	25.6	121.3		52.0	4688.0	111.4	4687.9				
6	49	7614.0	4691.0	4689.2	4685.4	32.3	103.0		34.5	4687.4	98.2	4687.4				
6	50	7214.1	4687.7	4691.7	4685.3	29.5	103.3		30.5	4687.1	100.6	4687.1				
6	51	6630.6	4690.1	4687.8	4683.7	62.9	132.0		65.2	4686.9	123.6	4687.0				
6	52	6329.6	4689.0	4687.6	4684.0	46.4	128.4		47.5	4686.7	125.8	4686.9				
6	53	6070.3	4689.4	4687.4	4682.9	25.8	137.0		44.3	4685.3	135.1	4685.3				
6	54	5559.7	4686.8	4687.3	4681.5	27.8	93.8		34.2	4684.6	91.3	4684.7				
6	55	5088.6	4685.1	4686.1	4681.4	56.0	110.9		63.4	4684.0	106.1	4684.0				
6	56	4683.6	4685.6	4685.5	4682.0	28.3	112.5		34.3	4683.8	111.5	4683.7				
6	57	4235.7	4691.5	4685.5	4680.8	17.0	99.2		27.3	4683.5	87.9	4683.5				
6	58	3783.9	4686.3	4684.5	4680.7	25.8	127.0		37.2	4682.3	121.4	4682.5				
6	59	3487.5	4684.4	4683.0	4679.2	25.1	86.2		27.6	4681.7	83.8	4681.7				
6	60	3028.0	4682.4	4682.5	4679.3	33.1	111.9		35.4	4681.2	109.4	4681.1				
6	61	2786.0	4682.9	4683.0	4678.2	30.2	145.4		35.7	4680.6	84.7	4680.8	110.9	4680.7	142.5	4680.7
6	62	2645.3	4681.4	4682.7	4678.2	23.7	101.5		25.5	4680.5	97.4	4680.4				
6	63	2244.1	4683.8	4682.1	4678.0	9.6	85.6		21.2	4679.8	83.3	4679.9				
6	64	1921.5	4681.7	4681.6	4676.1	13.4	83.5		15.3	4679.0	71.1	4678.9				
6	65	1558.4	4680.5	4681.1	4675.9	32.5	103.1		37.9	4678.4	100.4	4678.5				
6	66	1224.6	4680.2	4681.3	4675.6	38.6	110.7		41.6	4677.8	98.8	4677.8				
6	67	835.5	4679.9	4679.6	4675.3	18.5	104.8	4677.4	23.1	4677.2	88.8	4677.1				
6	68	682.5	4678.5	4678.4	4673.2	13.6	69.0		15.4	4677.1	64.5	4677.0				
6	69	511.8	4685.4	4686.0	4673.7	10.2	85.9		20.4	4676.8	69.8	4677.0				
6	70	481.5	4685.4	4686.4	4673.2	13.2	89.3		23.1	4676.9	78.8	4677.1				

Appendix B

Pebble Count Data

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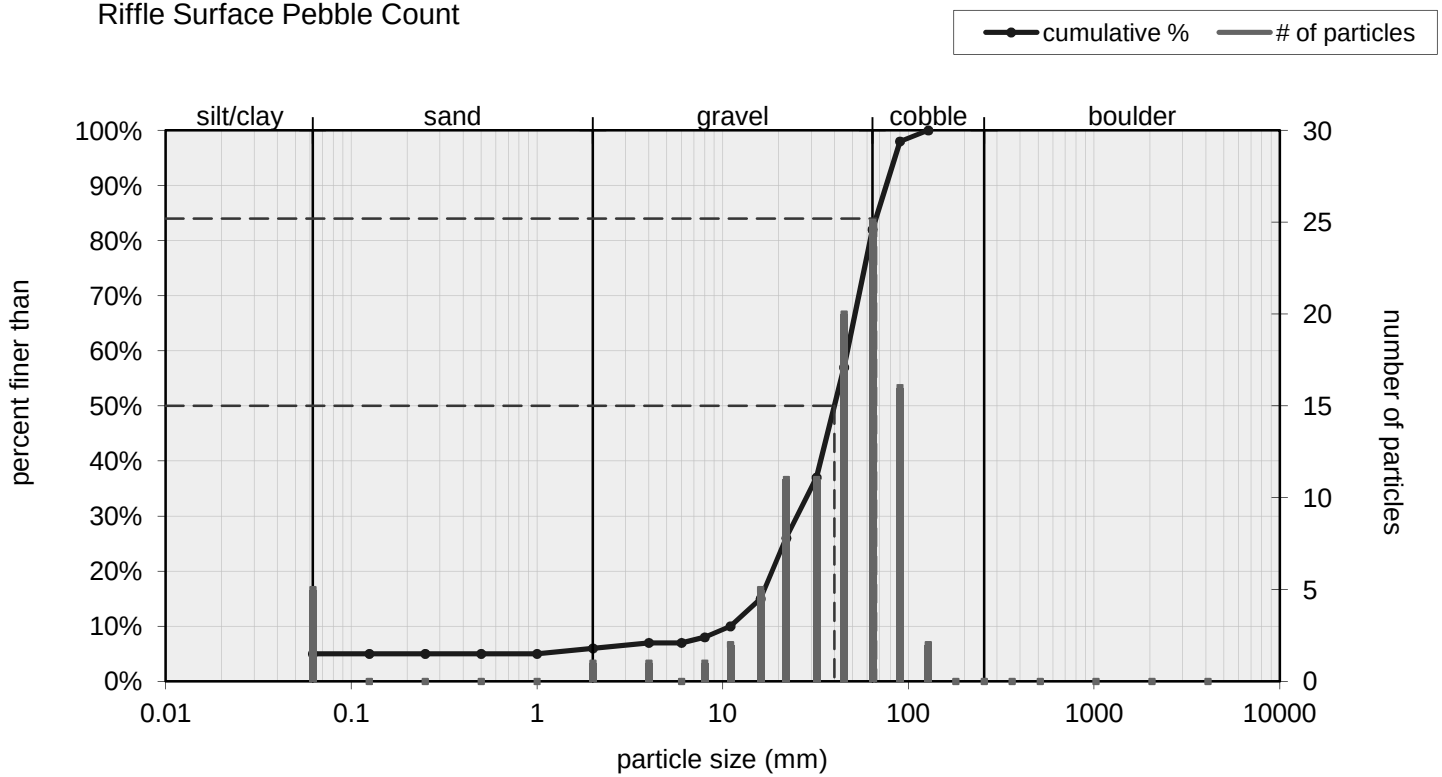
XS 07 Station 226+06
Riffle Surface Pebble Count

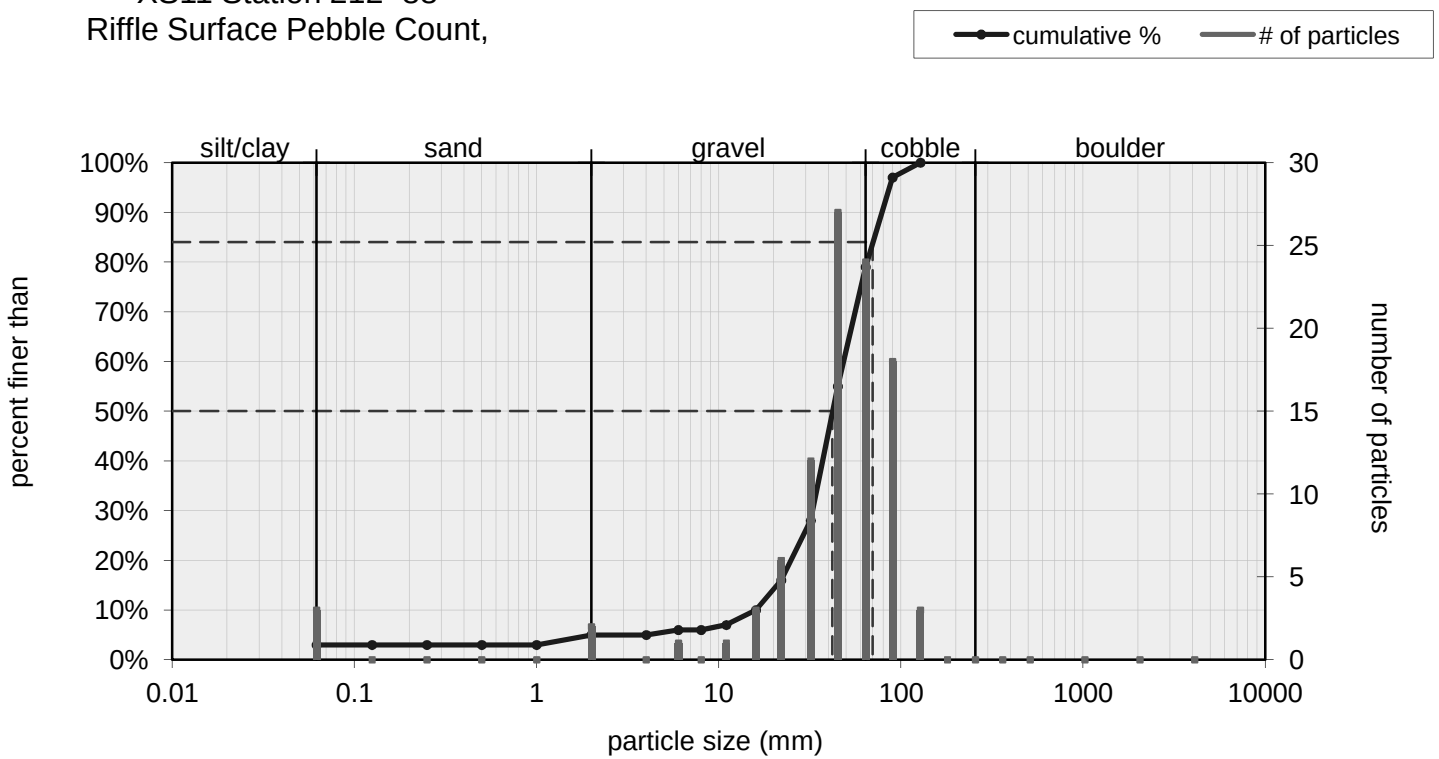


Size (mm)	
D16	16
D35	30
D50	40
D65	50
D84	67
D95	84

Size Distribution	
mean	32.7
dispersion	2.1
skewness	-0.11

Type	
silt/clay	5%
sand	1%
gravel	76%
cobble	18%
boulder	0%

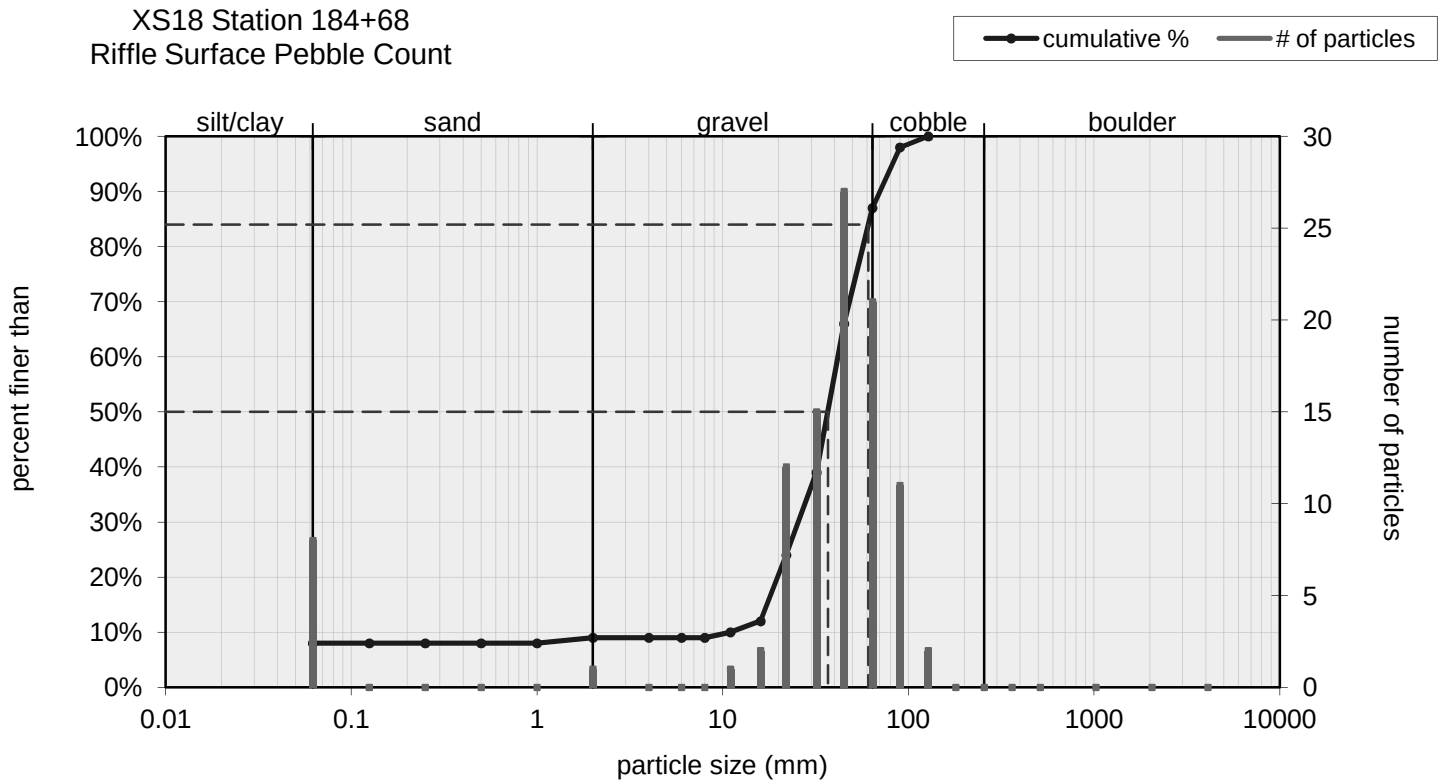
XS11 Station 212+88
Riffle Surface Pebble Count,



Size (mm)	
D16	22
D35	35
D50	42
D65	52
D84	70
D95	87

Size Distribution	
mean	39.2
dispersion	1.8
skewness	-0.04

Type	
silt/clay	3%
sand	2%
gravel	74%
cobble	21%
boulder	0%

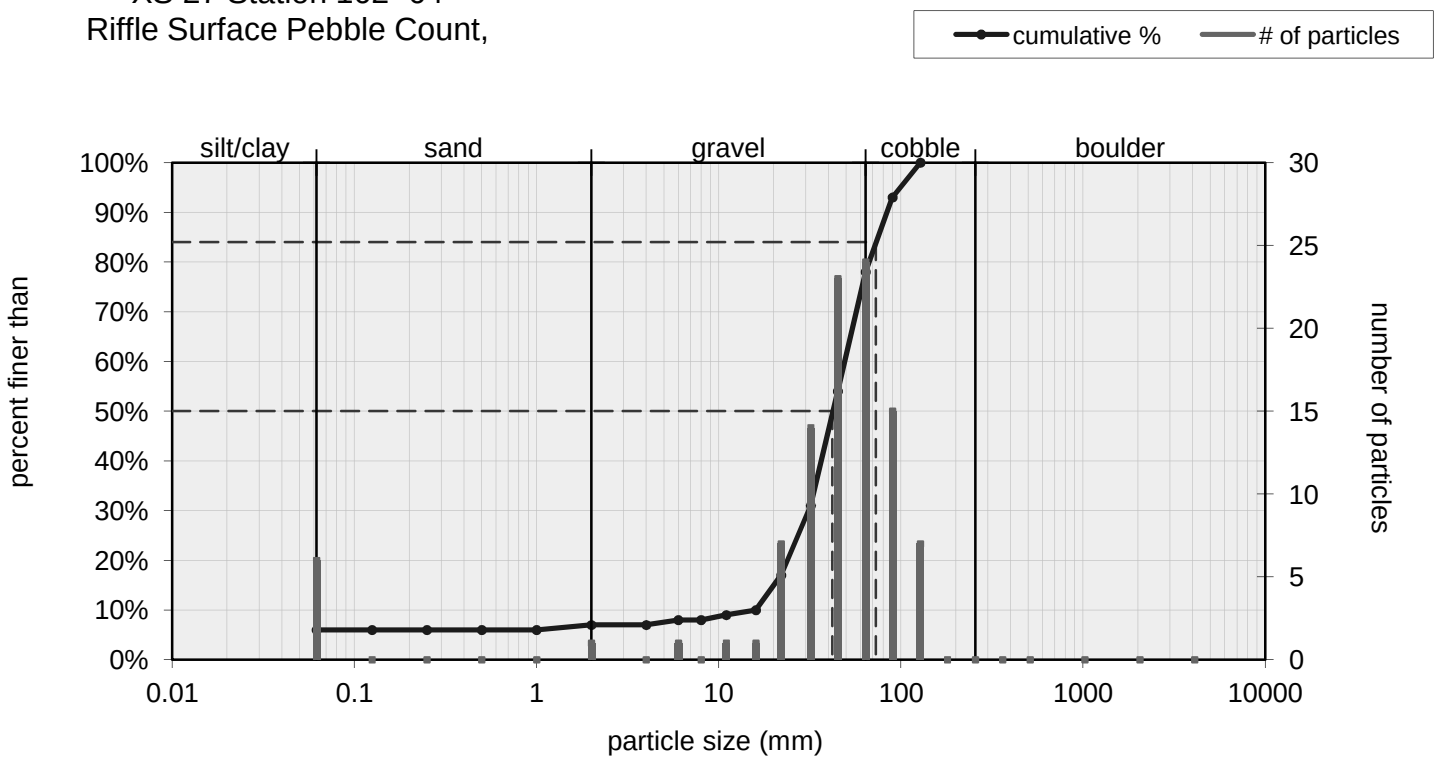


Size (mm)	
D16	18
D35	29
D50	37
D65	44
D84	61
D95	82

Size Distribution	
mean	33.1
dispersion	1.9
skewness	-0.07

Type	
silt/clay	8%
sand	1%
gravel	78%
cobble	13%
boulder	0%

XS 27 Station 162+64
Riffle Surface Pebble Count,

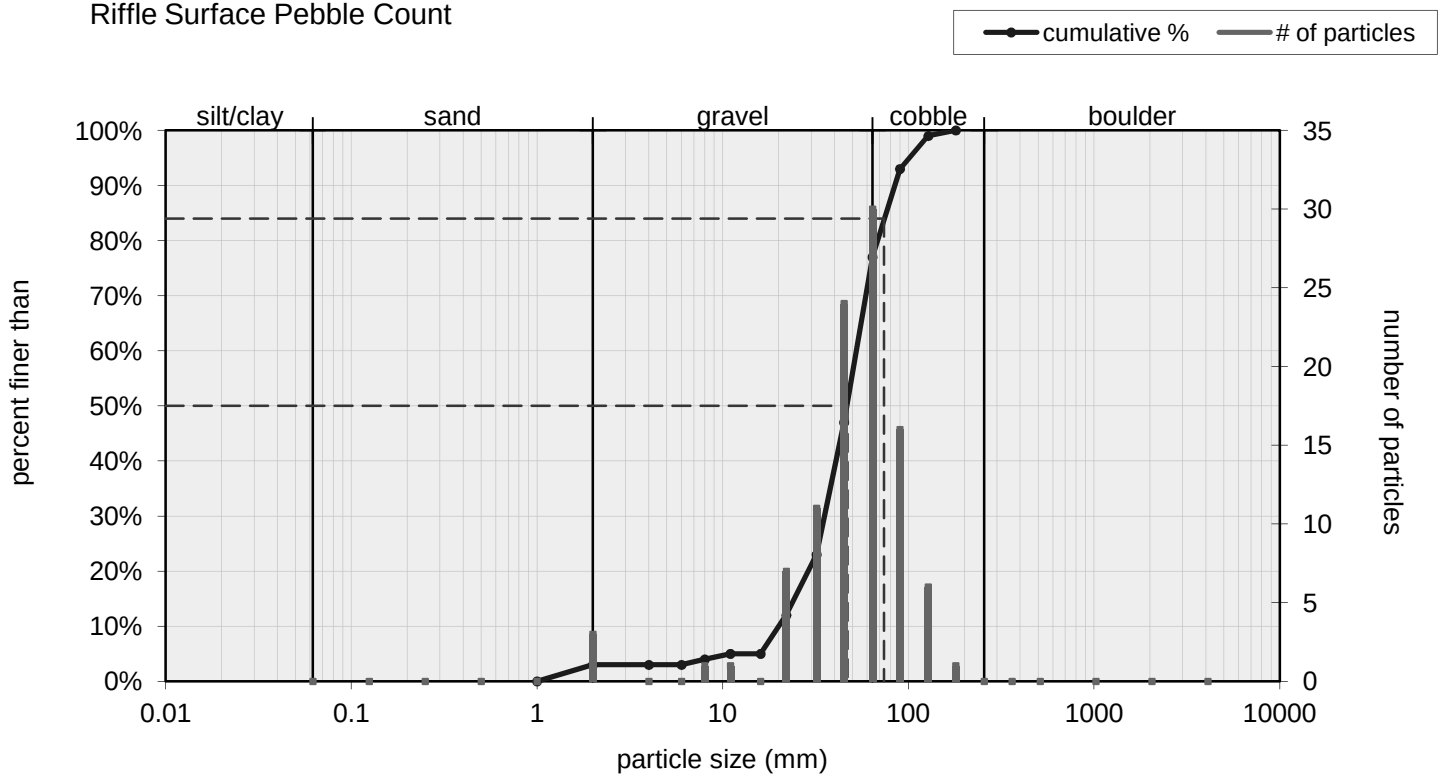


Size (mm)	
D16	21
D35	34
D50	42
D65	53
D84	73
D95	100

Size Distribution	
mean	39.2
dispersion	1.9
skewness	-0.04

Type	
silt/clay	6%
sand	1%
gravel	71%
cobble	22%
boulder	0%

XS37 Station 121+45
Riffle Surface Pebble Count

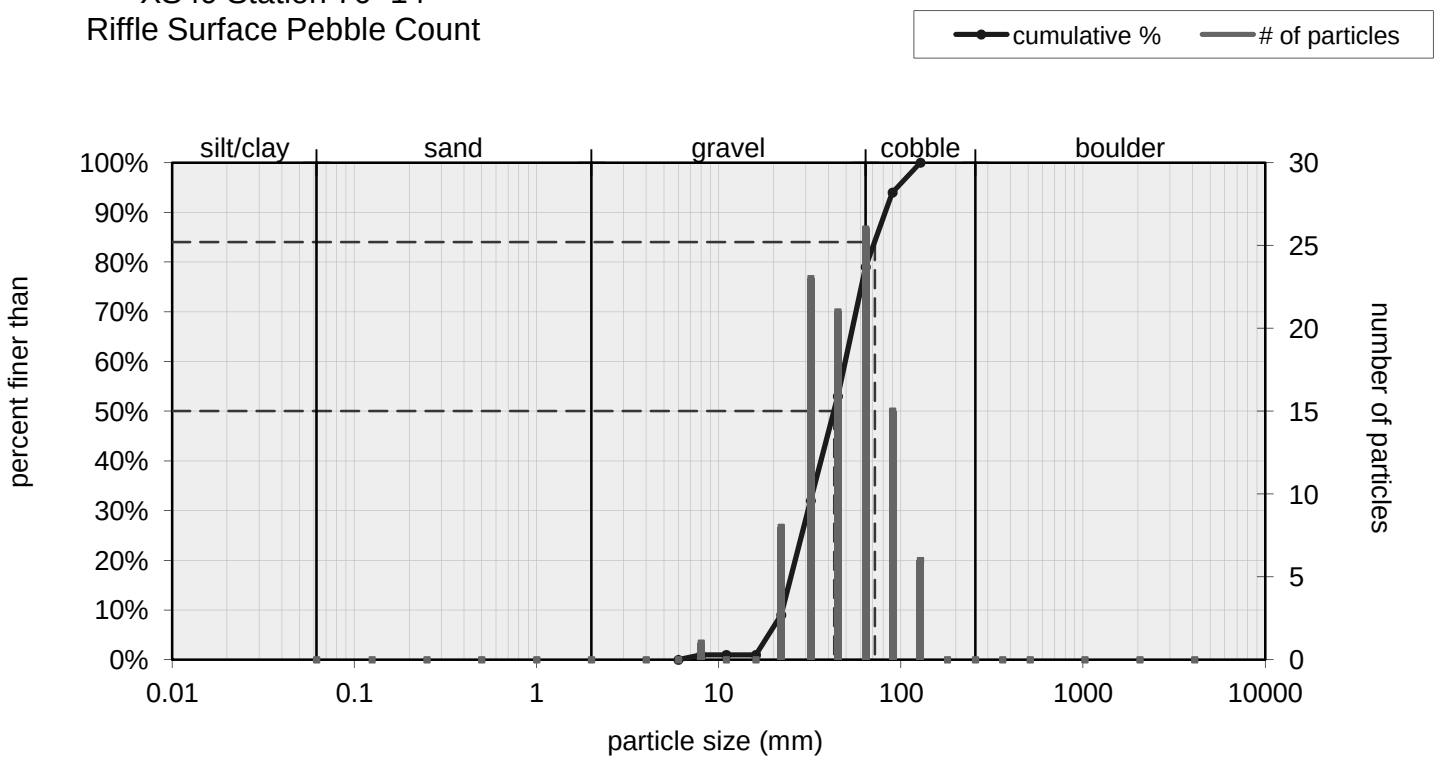


Size (mm)	
D16	25
D35	38
D50	47
D65	56
D84	74
D95	100

Size Distribution	
mean	43.0
dispersion	1.7
skewness	-0.06

Type	
silt/clay	0%
sand	3%
gravel	74%
cobble	23%
boulder	0%

XS49 Station 76+14
Riffle Surface Pebble Count

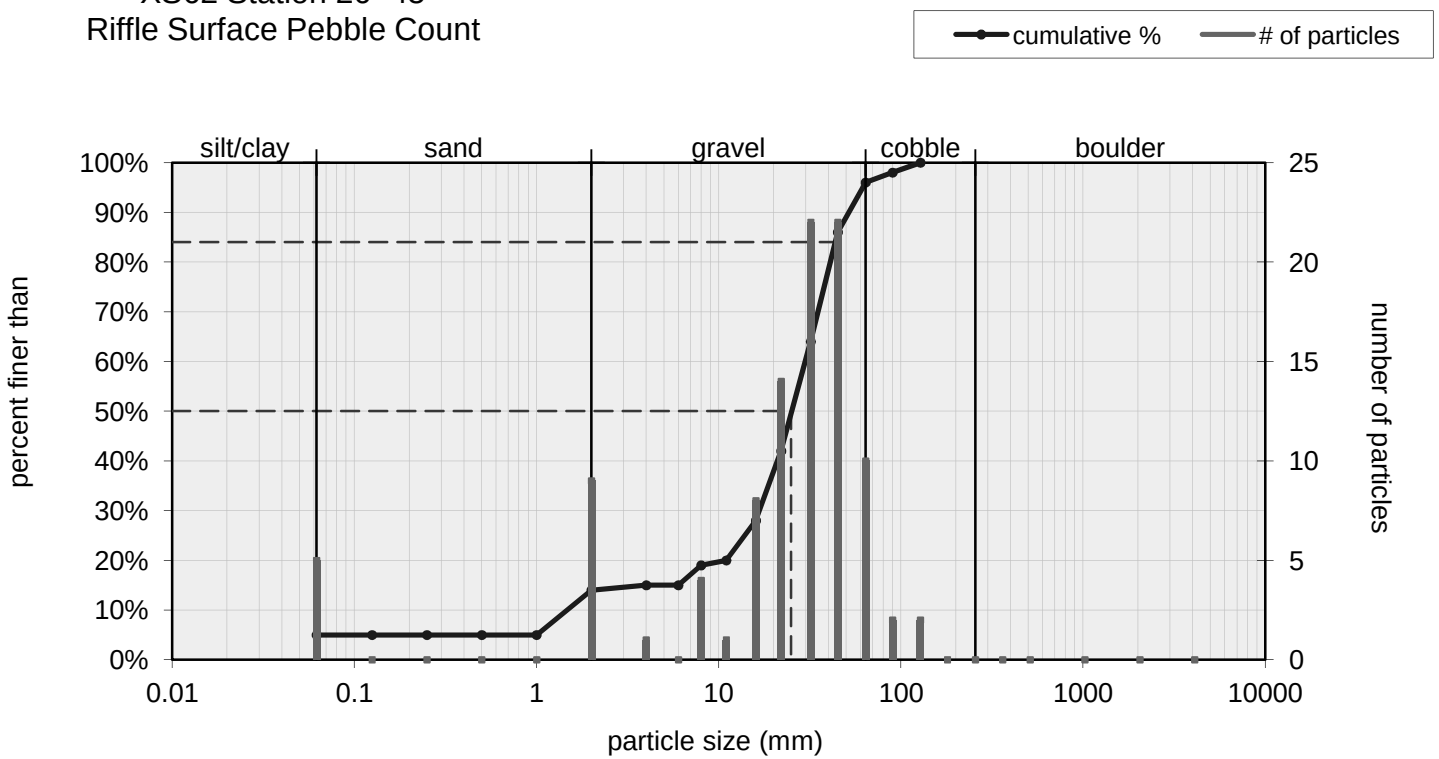


Size (mm)	
D16	25
D35	34
D50	43
D65	53
D84	72
D95	95

Size Distribution	
mean	42.4
dispersion	1.7
skewness	-0.01

Type	
silt/clay	0%
sand	0%
gravel	79%
cobble	21%
boulder	0%

XS62 Station 26+45
Riffle Surface Pebble Count



Size (mm)	
D16	6.4
D35	19
D50	25
D65	32
D84	44
D95	62

Size Distribution	
mean	16.8
dispersion	2.8
skewness	-0.19

Type	
silt/clay	5%
sand	9%
gravel	82%
cobble	4%
boulder	0%

Appendix C

Floodplain Material

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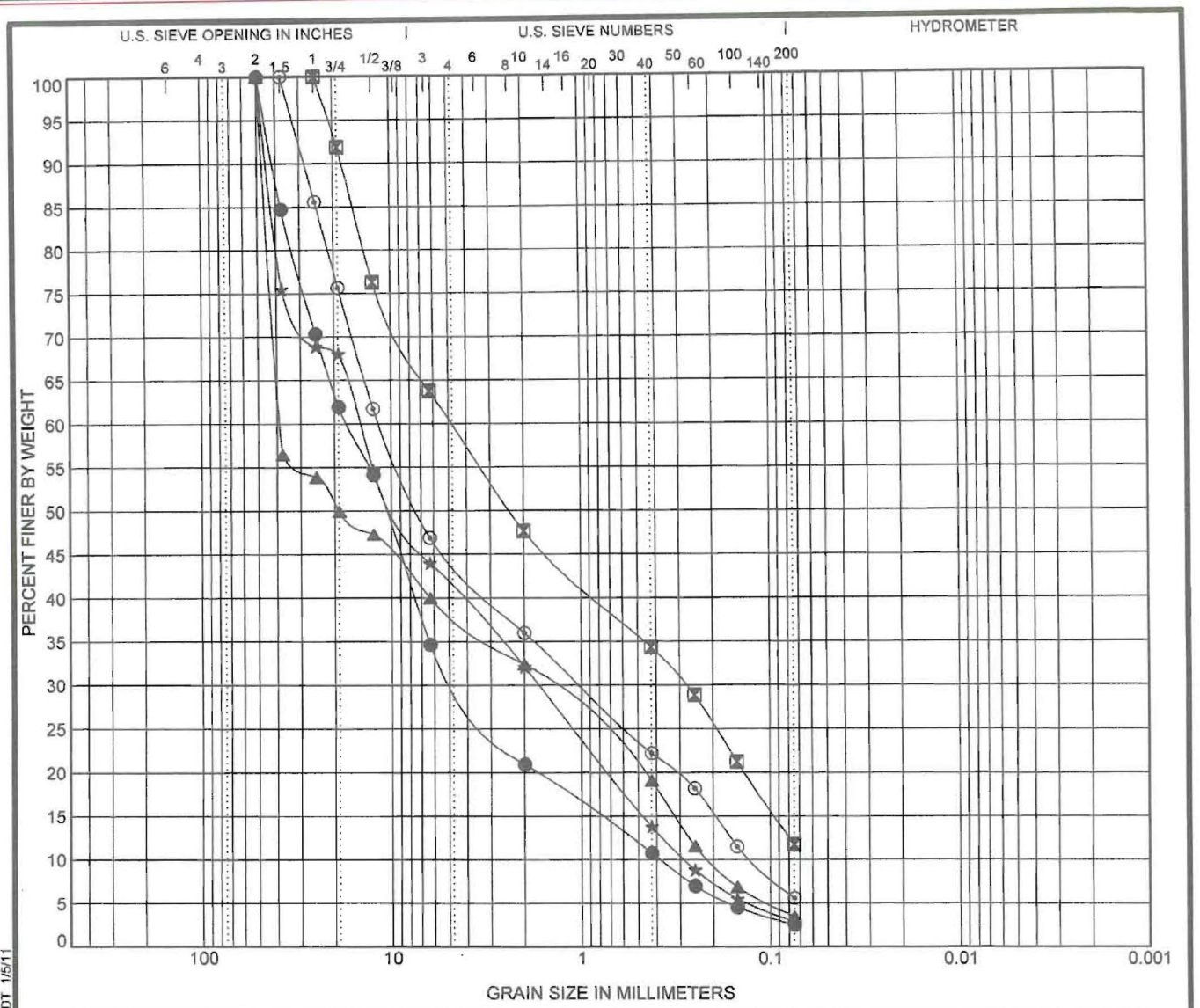
Clark Fork River Operable Unit, Phase 5 and 6
Comparision of river gravel elevation to bank toe
TerraGraphics Environmental Engineer

TG_Lab_Id	Depth	Elev at ground	Elev at RG	Section Designation	Approximate Hec Station	Left or Right	Est bank toe elevation	**RG minus BT (Positive = RG above BT)**	Notes
05-019-4854	48	4715.87	4711.87		22797	L			
05-122-4854	48	4710.50	4706.5		19569	L			
05-159-4852					18739	L			no elevation data
05-169-0018	0	4708.45	4708.45		18625	R			
05-169-3036	30	4708.45	4705.95		18625	R			
05-169-3642	36	4708.45	4705.45		18625	R			Point bar profile
05-200-3642	36	4705.89	4702.89						US 500ft on Modesty outfall 1
05-216-5258	52	4706.37	4702.04		16147	L			Modesty outfall 1
05-332		4700.80				L			Clay sill
05-673-4248	42	4709.31	4705.81	XS17	18852	L	4705.7	**0.11**	
05-756		4700.30				L			Clay sill
05-900-4854	48	4716.72	4712.72	XS06	23099	L	4711.67	**1.05**	
05-902-4854	48	4714.98	4710.98	XS07	22605	L	4711.1	**-0.12**	
05-905-4854	48	4714.80	4710.8		22235	L			
05-906-4654	48	4714.29	4710.29		22150	R			Missing Gradation graph
05-907-4854	48	4713.89	4709.89	XS09	22047	L	4708	**1.89**	
05-909-4248	42	4713.49	4709.99	XS10	21661	L	4710	**-0.01**	
05-913-4248	42	4712.53	4709.03	XS12	20885	L	4708.2	**0.83**	
05-915-6066	60	4712.48	4707.48	XS13	20452	R	4706.7	**0.78**	
05-916-4854	48	4712.44	4708.44		20294	L			
05-919-3642	36	4710.40	4707.4		19569	R			
05-921-4854	48	4710.21	4706.21	XS16	19289	L	4705.93	**0.28**	
05-922-5460	54	4710.31	4705.81		19174	L			
05-926-4248	42	4708.25	4704.75	XS20	18290	R	4704.6	**0.15**	
05-927-4248	42	4708.16	4704.66	XS21	18044	L	4703.72	**0.94**	Lab misslabeled as 05-946-4248
05-929-4248	42	4707.51	4704.01	XS22	17872	L	4703.74	**0.27**	
05-937-3642	36	4706.76	4703.76		17063	L			
05-946-4854	48	4705.62	4701.62	XS28	15947	L	4701.09	**0.53**	
05-947-4248	42	4704.38	4700.88		15799	L			
05-949-6066	60	4705.03	4700.03	XS29	15566	R	4700.1	**-0.07**	
05-950-4854	48	4704.37	4700.37		15514	L			
05-951-4450	44	4704.11	4700.44		15255	L			
05-952-5460	54	4703.40	4698.9	XS30	15091	R	4698.43	**0.47**	
05-954-4854	48	4702.98	4698.98	XS31	14604	R	4698.8	**0.18**	
05-956-4248	42	4701.40	4697.9	XS32	14218	R	4698.3	**-0.40**	
05-958-4854	48	4700.90	4696.9		13666	L			
05-959-4854	48	4700.85	4696.85	XS34	13422	L	4696.62	**0.23**	
05-960-5460	54	4699.90	4695.4		13350	R			
05-961		4701.42			13119	L			Clay sill
05-962		4700.32			12938	L			Clay sill
05-963-4854	48	4699.75	4699.75	XS36	12583	L	4695.7	**4.05**	
05-964-6672	66	4698.80	4693.3	XS36	12583	R	4695.99	**-2.69**	
05-967-7278	72	4700.11	4694.11		11977	R			
06-900-7278	72	4699.17	4693.17		11081	L			
06-901-3642	36	4695.65	4692.65		10957	R			
06-902-5460	54	4696.45	4691.95		10021	L			
06-903-6672	66	4695.00	4689.5		9214	R			
06-904-4248	42	4691.42	4687.92	XS46	8661	L	4687.9	**0.02**	
06-905-4854	48	4690.84	4686.84	XS49	7614	L	4685.44	**1.40**	
06-910-6066	60	4681.22	4676.22		1367	R			
							Average	**0.47**	
							Max	**4.05**	
							Min	**-2.69**	

Phase 5 Toe Sieve Geotechnical Samples



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

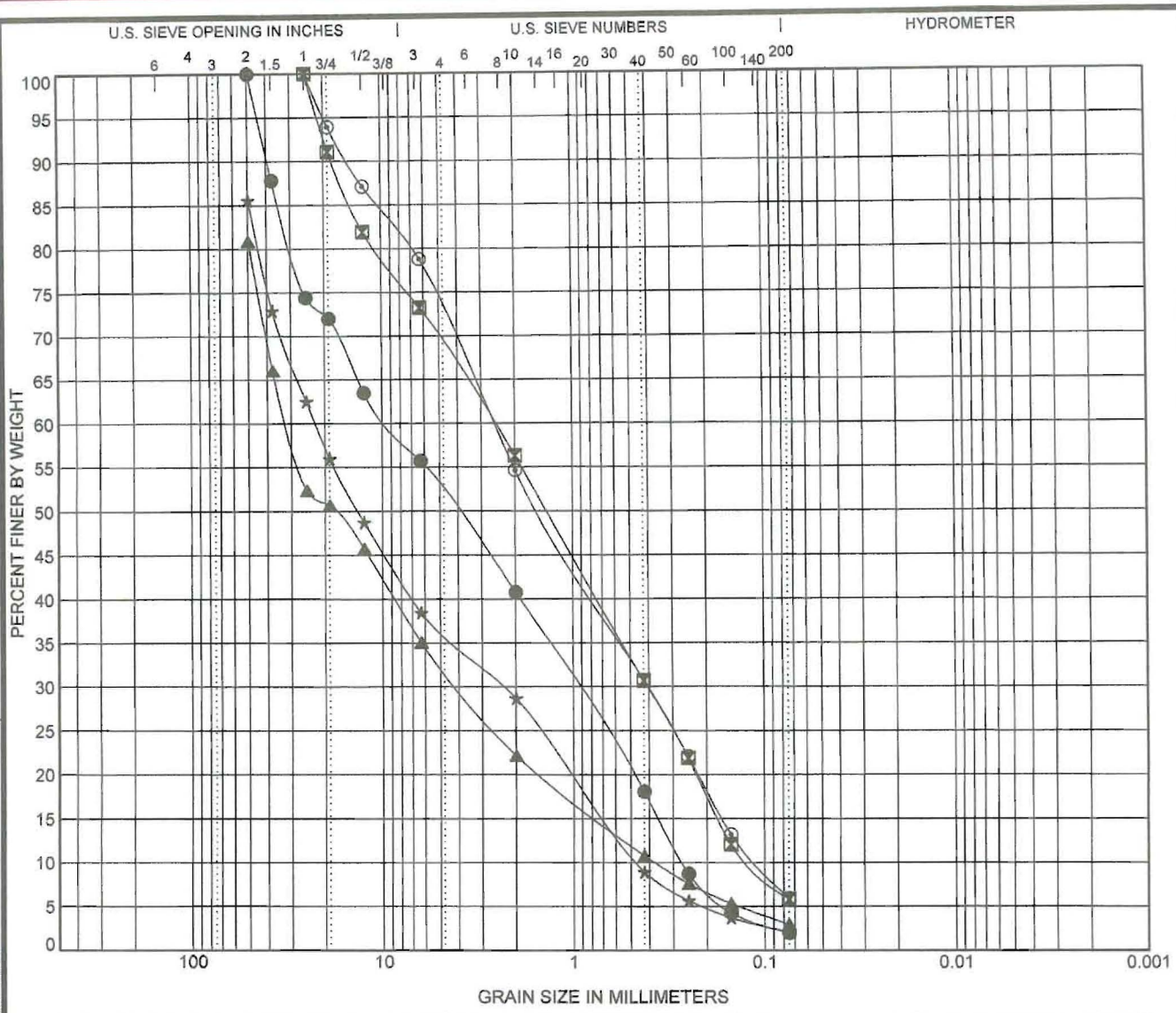
	Specimen Identification	Classification	LL	PL	PI	Cc	Cu
●	001A (05-946-4854) 0.0	WELL-GRADED GRAVEL with SAND(GW)				2.80	45.07
⊠	002A (05-946-4248) 0.0					0.25	73.15
▲	003A (05-947-4248) 0.0	POORLY GRADED GRAVEL with SAND(GP)				0.28	182.92
★	004A (05-929-4248) 0.0	POORLY GRADED GRAVEL with SAND(GP)				0.67	52.29
⊙	005A (05-950-4854) 0.0					0.72	92.06

	Specimen Identification	D100	D50	D15	D10	%Gravel	%Sand	%Silt	%Clay
●	001A (05-946-4854) 0.0	50	10.805	0.806	0.38	68.7	28.8	2.5	
⊠	002A (05-946-4248) 0.0	25	2.36	0.095		40.2	48.0	11.8	
▲	003A (05-947-4248) 0.0	50	19.064	0.317	0.21	61.9	34.7	3.5	
★	004A (05-929-4248) 0.0	50	9.26	0.469	0.282	58.9	38.2	2.9	
⊙	005A (05-950-4854) 0.0	37.5	7.262	0.195	0.125	55.8	38.6	5.6	

GRAIN SIZE DISTRIBUTION

Project: Clark Fork River O.U Reach A, Phase 5

Number: H10110010



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

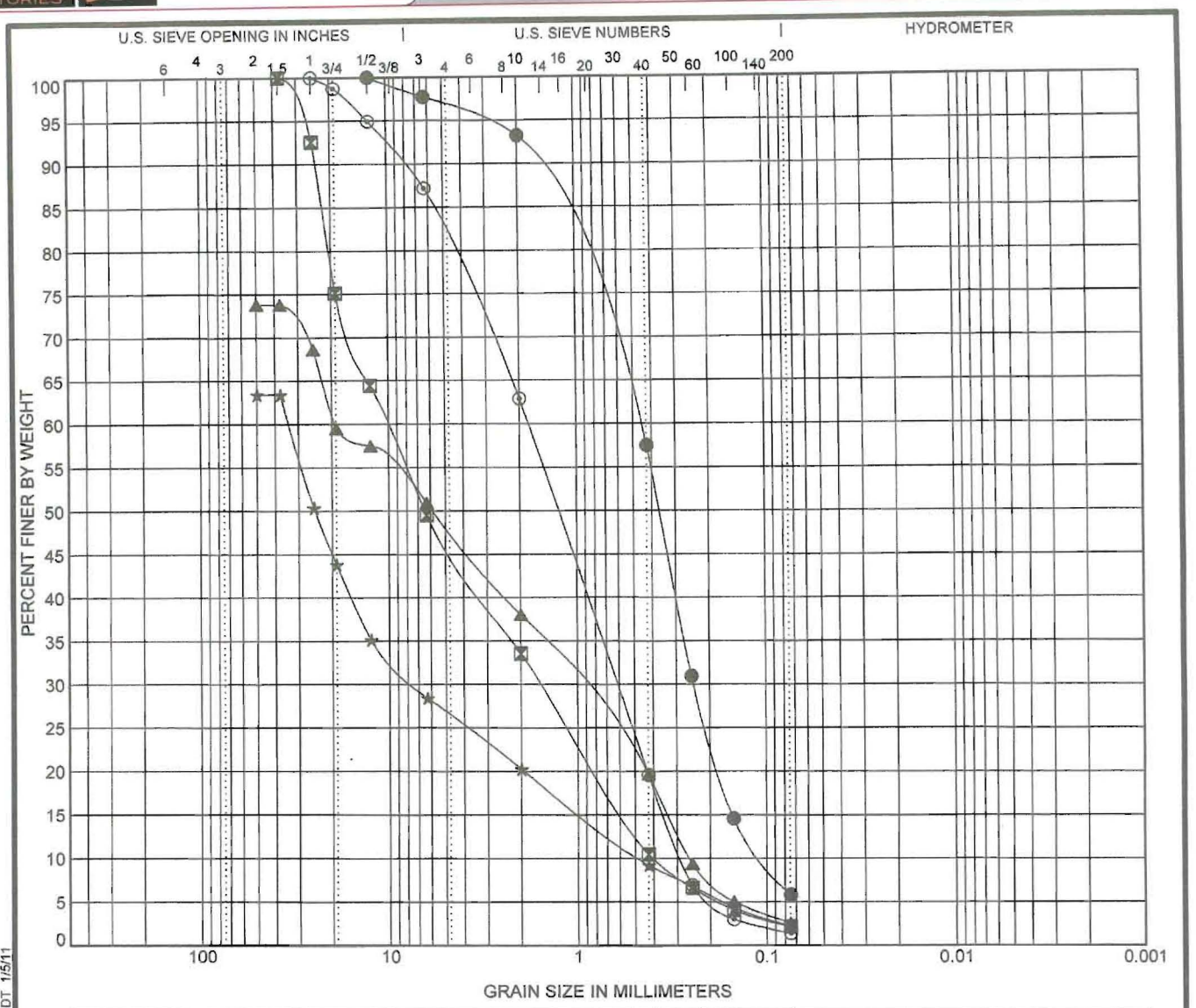
	Specimen Identification	Classification	LL	PL	PI	Cc	Cu
●	006A (05-216-5258) 0.0	POORLY GRADED SAND with GRAVEL(SP)				0.37	34.16
⊠	007A (05-937-3642) 0.0					0.54	21.55
▲	008A (05-200-3642) 0.0	WELL-GRADED GRAVEL with SAND(GW)				1.38	84.09
★	009A (05-921-4854) 0.0	POORLY GRADED GRAVEL with SAND(GP)				0.52	48.69
⊙	010A (05-916-4854) 0.0					0.58	23.38

	Specimen Identification	D100	D50	D15	D10	%Gravel	%Sand	%Silt	%Clay
●	006A (05-216-5258) 0.0	50	4.058	0.357	0.269	47.9	50.0	2.0	
⊠	007A (05-937-3642) 0.0	25	1.366	0.175	0.119	30.9	63.3	5.8	
▲	008A (05-200-3642) 0.0	50	17.908	0.753	0.372	49.0	29.0	2.9	
★	009A (05-921-4854) 0.0	50	13.434	0.684	0.462	49.6	34.0	2.1	
⊙	010A (05-916-4854) 0.0	25	1.479	0.166	0.11	27.1	66.9	6.0	

GRAIN SIZE DISTRIBUTION

Project: Clark Fork River O.U Reach A, Phase 5

Number: H10110010



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

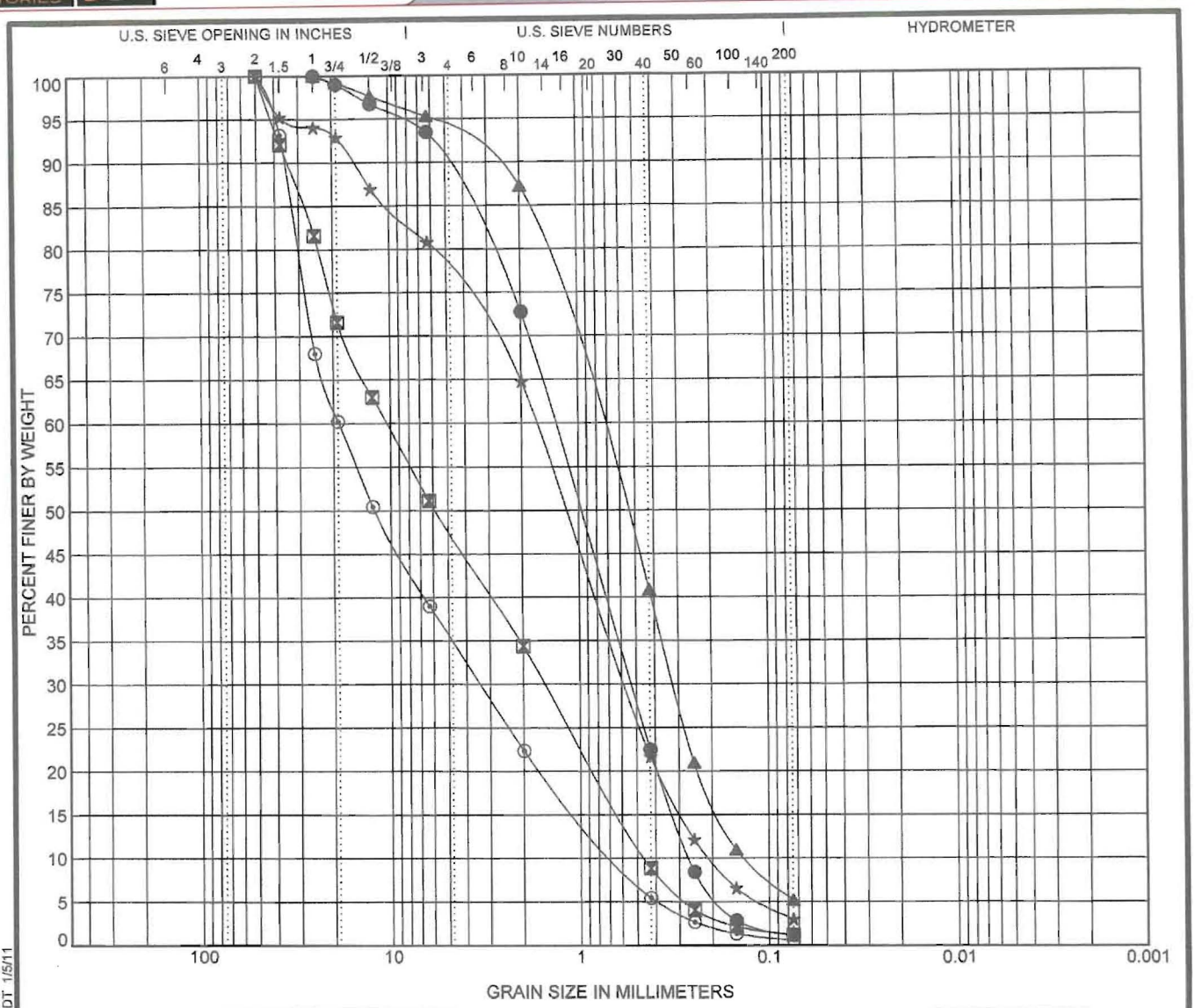
	Specimen Identification	Classification	LL	PL	PI	Cc	Cu
●	011A (05-122-4854) 0.0					1.19	4.54
⊠	012A (05-673-4248) 0.0	POORLY GRADED GRAVEL with SAND(GP)				0.61	25.60
▲	013A (05-922-5460) 0.0	POORLY GRADED GRAVEL with SAND(GP)				0.21	74.93
★	014A (05-902-4854) 0.0	POORLY GRADED GRAVEL with SAND(GP)				3.42	71.20
⊙	015A (05-900-4854) 0.0	POORLY GRADED SAND with GRAVEL(SP)				0.74	6.35

	Specimen Identification	D100	D50	D15	D10	%Gravel	%Sand	%Silt	%Clay
●	011A (05-122-4854) 0.0	12.5	0.366	0.152	0.104	3.4	90.8	5.9	
⊠	012A (05-673-4248) 0.0	37.5	6.432	0.576	0.398	54.4	43.4	2.2	
▲	013A (05-922-5460) 0.0	50	5.786	0.334	0.258	26.0	45.2	2.6	
★	014A (05-902-4854) 0.0	50	24.588	0.955	0.474	37.0	24.2	2.2	
⊙	015A (05-900-4854) 0.0	25	1.261	0.35	0.284	18.8	79.8	1.4	

GRAIN SIZE DISTRIBUTION

Project: Clark Fork River O.U Reach A, Phase 5

Number: H10110010



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

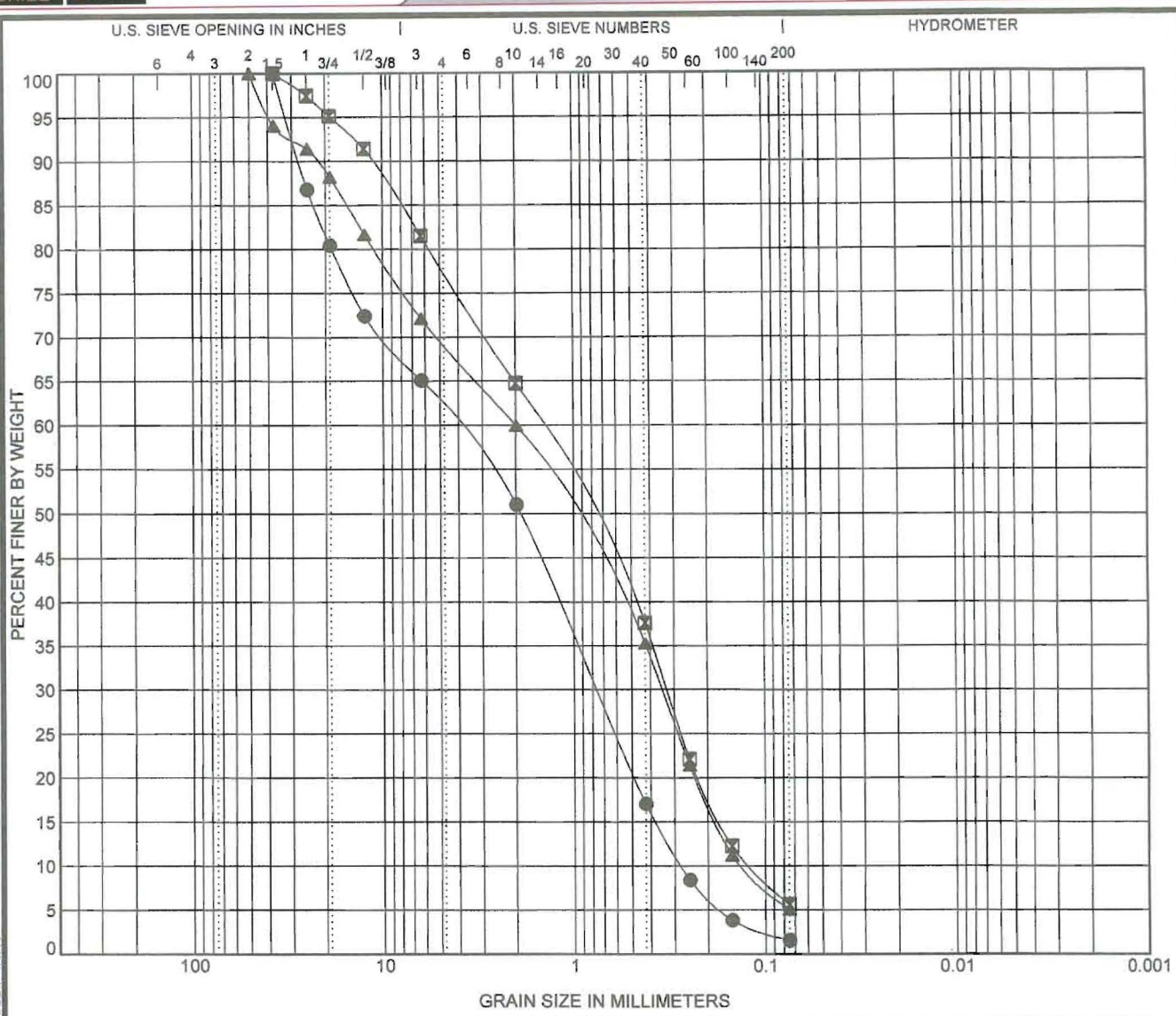
	Specimen Identification	Classification	LL	PL	PI	Cc	Cu
●	016A (05-907-4854) 0.0	POORLY GRADED SAND(SP)				0.80	5.09
⊠	017A (05-019-4854) 0.0	POORLY GRADED GRAVEL with SAND(GP)				0.49	23.03
▲	018A (05-909-4248) 0.0					0.94	6.06
★	019A (05-905-4854) 0.0	POORLY GRADED SAND with GRAVEL(SP)				0.95	8.21
⊙	020A (05-913-4248) 0.0	POORLY GRADED GRAVEL with SAND(GP)				0.95	29.22

	Specimen Identification	D100	D50	D15	D10	%Gravel	%Sand	%Silt	%Clay
●	016A (05-907-4854) 0.0	25	0.991	0.32	0.265	11.6	87.2	1.2	
⊠	017A (05-019-4854) 0.0	50	5.826	0.617	0.456	53.0	45.8	1.2	
▲	018A (05-909-4248) 0.0	25	0.576	0.184	0.133	6.7	88.1	5.2	
★	019A (05-905-4854) 0.0	50	1.176	0.293	0.205	23.1	73.8	3.1	
⊙	020A (05-913-4248) 0.0	50	12.146	1.018	0.644	65.1	34.3	0.6	

GRAIN SIZE DISTRIBUTION

Project: Clark Fork River O.U Reach A, Phase 5

Number: H10110010



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

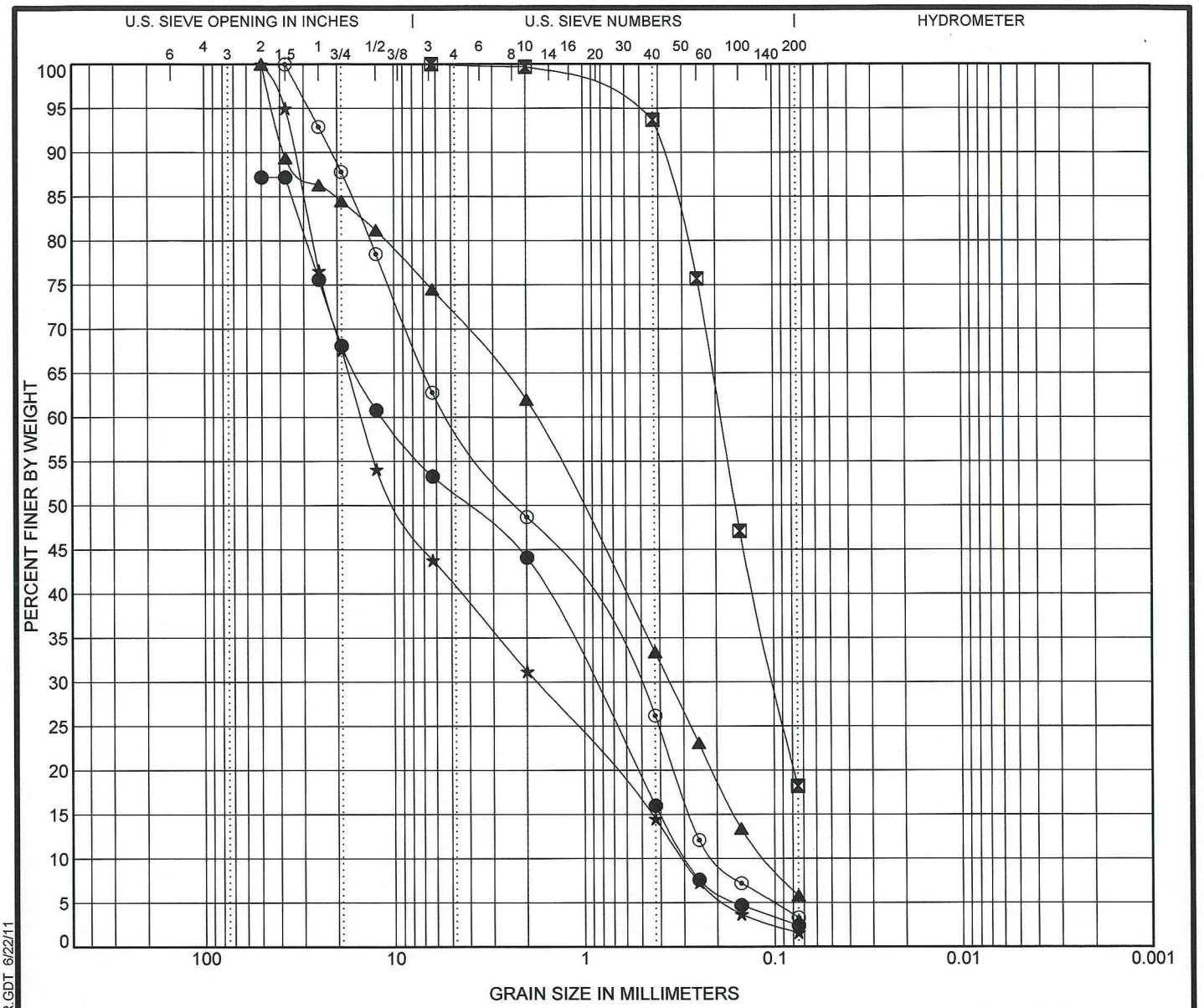
	Specimen Identification	Classification	LL	PL	PI	Cc	Cu
●	001A (05-958-4854) 0.0	POORLY GRADED SAND with GRAVEL(SP)				0.51	15.06
⊠	002A (05-959-4854) 0.0					0.59	12.87
▲	003A (05-951-4450) 0.0					0.46	15.37

	Specimen Identification	D100	D50	D15	D10	%Gravel	%Sand	%Silt	%Clay
●	001A (05-958-4854) 0.0	37.5	1.907	0.375	0.276	38.4	60.1	1.6	
⊠	002A (05-959-4854) 0.0	37.5	0.861	0.173	0.118	22.6	71.8	5.6	
▲	003A (05-951-4450) 0.0	50	1.07	0.181	0.13	30.9	64.0	5.1	

GRAIN SIZE DISTRIBUTION

Project: Energy Labs - MT DEQ

Number: H10110015



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification	Classification	LL	PL	PI	Cc	Cu
●	001 (05-169-3036) 0.0	POORLY GRADED GRAVEL with SAND(GP)				0.25	39.94
⊠	002 (05-169-0018) 0.0						
▲	003 (05-169-3642) 0.0					0.64	16.31
★	004 (05-915-6066) 0.0	POORLY GRADED GRAVEL with SAND(GP)				0.70	49.21
⊙	005 (05-919-3642) 0.0	POORLY GRADED SAND with GRAVEL(SP)				0.30	24.98

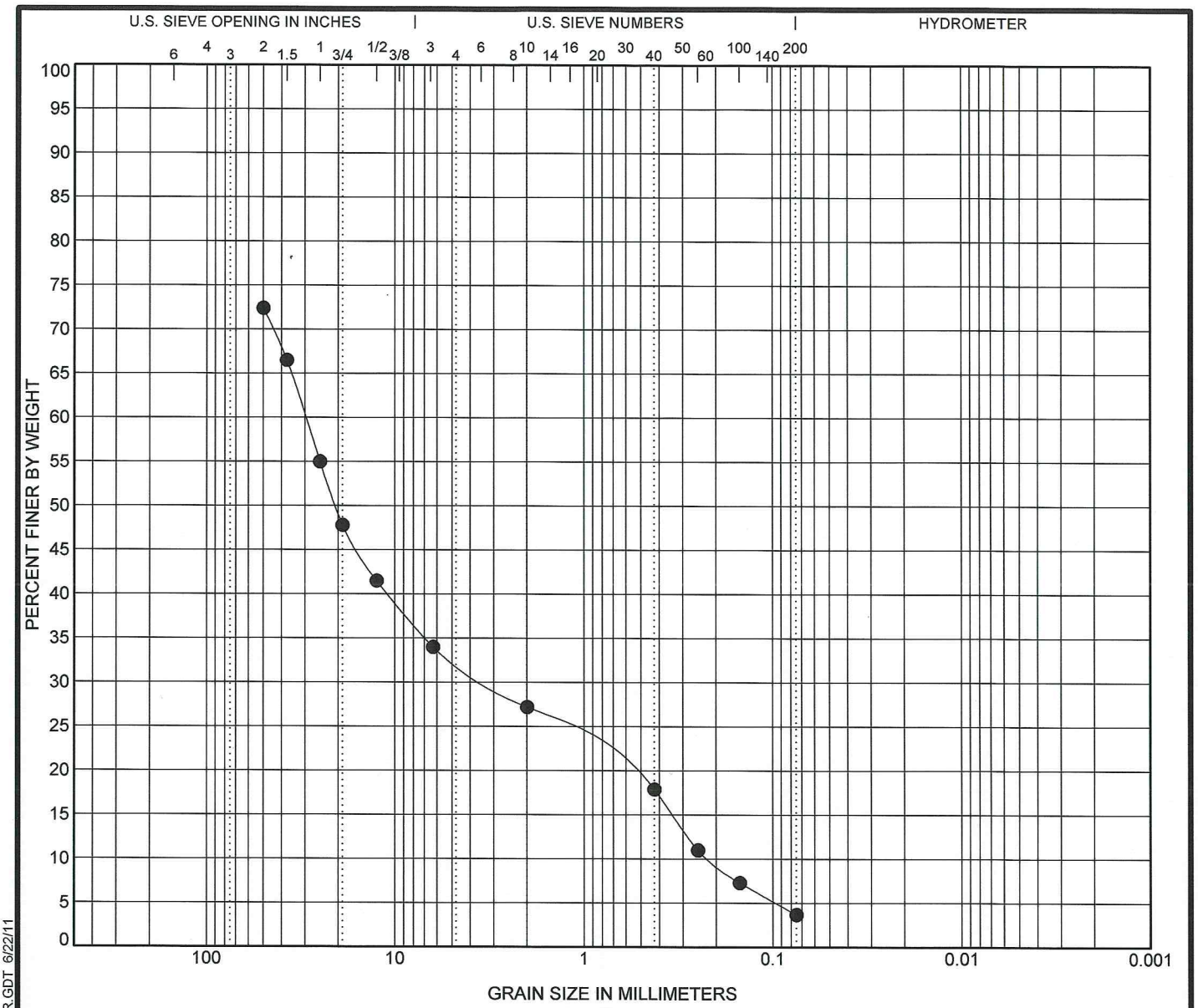
	Specimen Identification	D100	D50	D15	D10	%Gravel	%Sand	%Silt	%Clay
●	001 (05-169-3036) 0.0	50	4.174	0.399	0.291	36.2	48.6	2.4	
⊠	002 (05-169-0018) 0.0	6.3	0.158			0.1	81.7	18.2	
▲	003 (05-169-3642) 0.0	50	1.044	0.163	0.11	28.6	65.6	5.8	
★	004 (05-915-6066) 0.0	50	9.516	0.445	0.305	59.3	39.1	1.6	
⊙	005 (05-919-3642) 0.0	37.5	2.223	0.279	0.201	40.7	56.0	3.3	

GRAIN SIZE DISTRIBUTION

Project: Energy Labs - MT DEQ

Number: H11050419

US GRAIN SIZE ASTM ENERGY CLARK FORK RIVER O.U REACH A, PHASE 5 (3).GPJ PIONEER.GDT 6/22/11



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification	Classification	LL	PL	PI	Cc	Cu
●	**006 (05-926-4248) 0.0**	**WELL-GRADED GRAVEL with SAND(GW)**				**1.58**	**136.94**

	Specimen Identification	D100	D50	D15	D10	%Gravel	%Sand	%Silt	%Clay
●	**006 (05-926-4248) 0.0**	**50**	**20.662**	**0.34**	**0.218**	**40.1**	**28.6**	**3.7**	

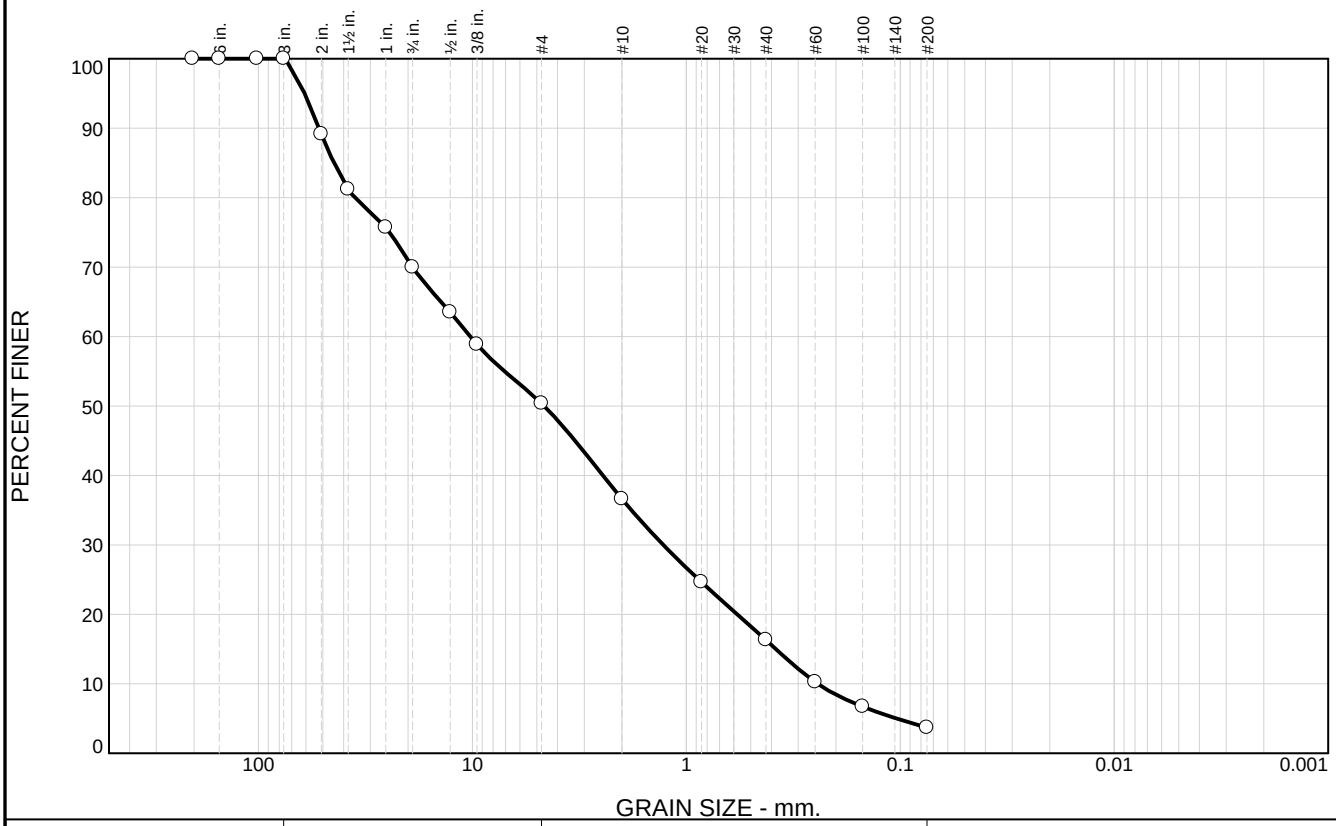
GRAIN SIZE DISTRIBUTION

Project: Energy Labs - MT DEQ

Number: H11050419

US_GRAIN_SIZE_ASTM ENERGY CLARK FORK RIVER O.U REACH A, PHASE 5 (3).GPJ PIONEER.GDT 6/22/11

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	30.0	19.6	13.8	20.3	12.6	3.7	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
8	100.0		
6	100.0		
4	100.0		
3	100.0		
2	89.1		
1.5	81.2		
1	75.7		
.75	70.0		
.5	63.5		
.375	58.8		
#4	50.4		
#10	36.6		
#20	24.6		
#40	16.3		
#60	10.3		
#100	6.7		
#200	3.7		

* (no specification provided)

Soil Description

poorly graded gravel with sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 44.4593 D_{60}= 10.2536 D_{50}= 4.6222
D_{30}= 1.2816 D_{15}= 0.3816 D_{10}= 0.2432
C_u= 42.16 C_c= 0.66

Classification

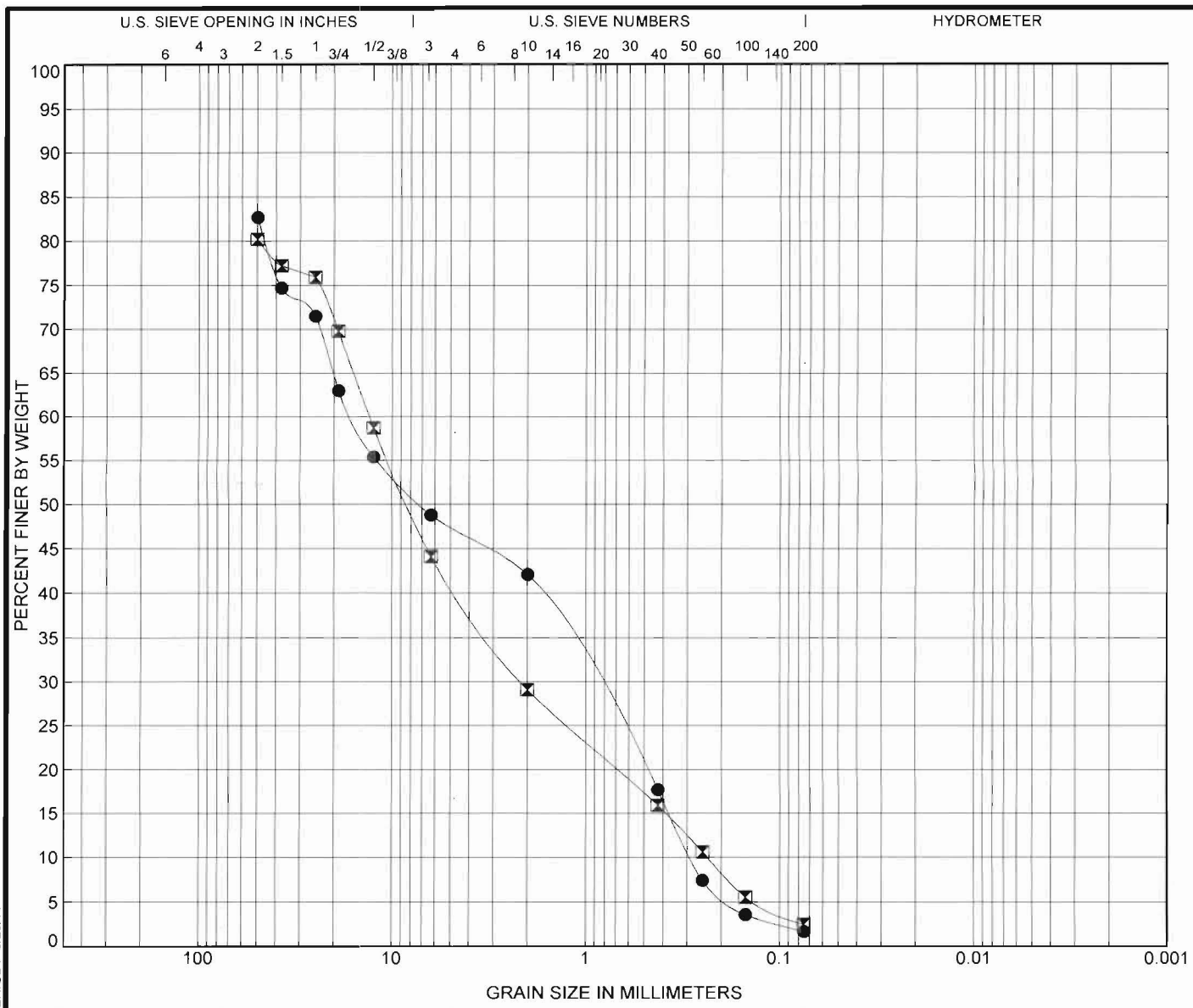
USCS= GP AASHTO=

Remarks

Sample No.: **Source of Sample:** 05-963 **Date:**
Location: **Elev./Depth:** 48-54"

PIEDMONT ENGINEERING, INC.
1215 Apple's Way - Belgrade, MT 59714
Ph. 406-388-8578 - Fax 406-388-8579

Client: Terragraphics
Project: CFR Phase 5
Project No: 10074 **Figure**



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	LL	PL	PI	Cc	Cu
●	**001 (05-949-6066)**	**0.0**					**0.19**	**56.35**
⊠	**002 (05-964-6672)**	**0.0**					**1.49**	**55.77**

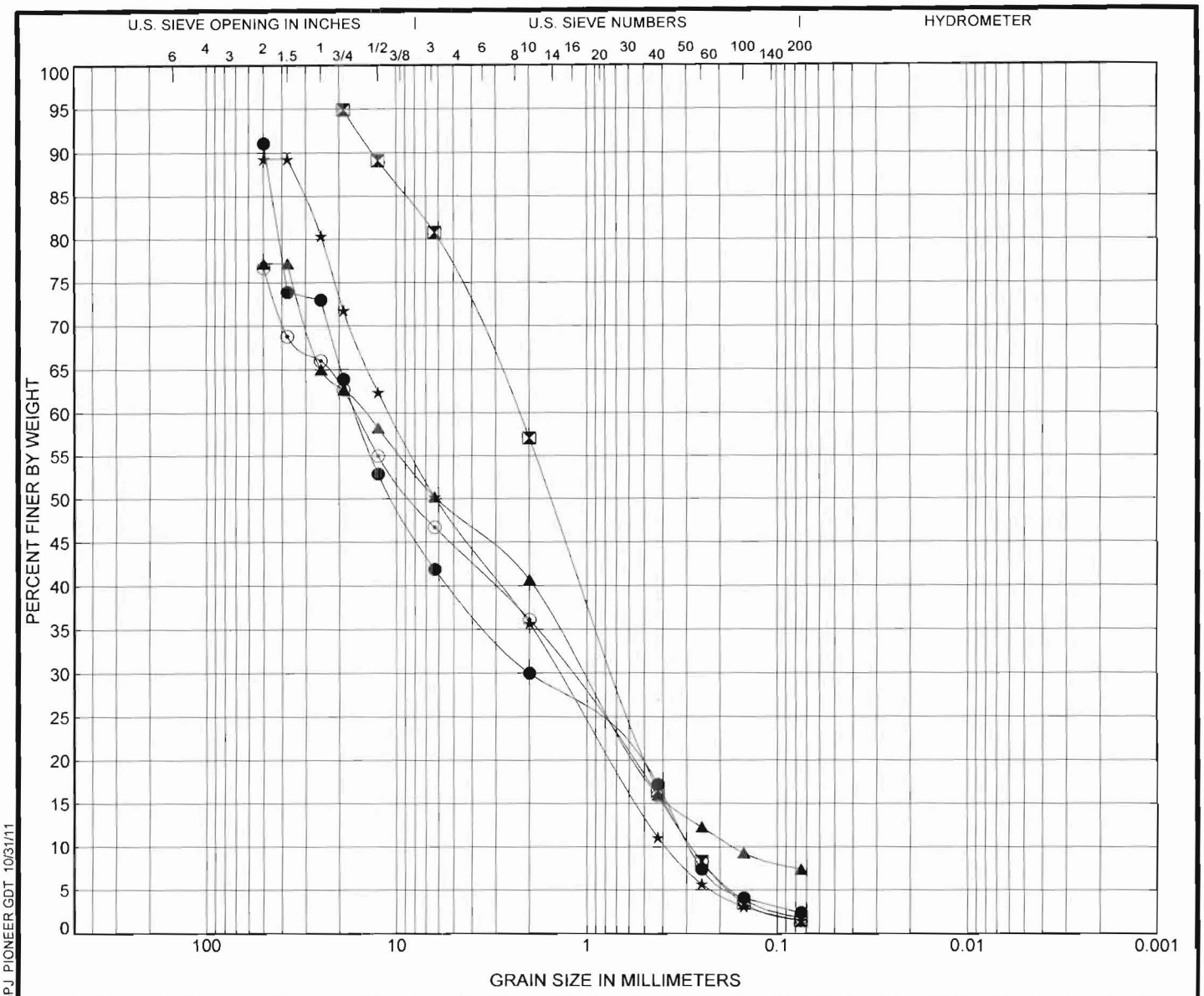
	Specimen Identification		D100	D50	D15	D10	%Gravel	%Sand	%Silt	%Clay
●	**001 (05-949-6066)**	**0.0**	**50**	**7.136**	**0.37**	**0.286**	**35.5**	**45.5**	**1.7**	
⊠	**002 (05-964-6672)**	**0.0**	**50**	**8.31**	**0.388**	**0.235**	**39.8**	**37.9**	**2.5**	

GRAIN SIZE DISTRIBUTION

Project: Energy Labs - MT DEQ

Number: H11080275

US GRAIN SIZE AASHTO ENERGY CLARK FORK RIVER O.U REACH A, PHASE 5 (4).GPJ PIONEER.GDT 8/25/11



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	LL	PL	PI	Cc	Cu
●	001 (05-967-7278)	0.0	POORLY GRADED GRAVEL with SAND(GP)				0.85	56.91
⊠	002 (05-956-4248)	0.0	POORLY GRADED SAND with GRAVEL(SP)				0.79	8.25
▲	003 (05-960-5460)	0.0					0.42	86.96
★	004 (05-952-5460)	0.0	POORLY GRADED GRAVEL with SAND(GP)				0.47	28.64
⊙	005 (05-954-4854)	0.0	POORLY GRADED GRAVEL with SAND(GP)				0.34	58.28

	Specimen Identification		D100	D50	D15	D10	%Gravel	%Sand	%Silt	%Clay
●	001 (05-967-7278)	0.0	50	10.434	0.377	0.288	52.1	36.6	2.4	
⊠	002 (05-956-4248)	0.0	19	1.525	0.386	0.279	19.9	73.5	1.5	
▲	003 (05-960-5460)	0.0	50	6.15	0.368	0.169	29.3	40.5	7.4	
★	004 (05-952-5460)	0.0	50	6.201	0.543	0.381	42.7	45.1	1.5	
⊙	005 (05-954-4854)	0.0	50	8.273	0.399	0.282	32.6	42.3	1.8	

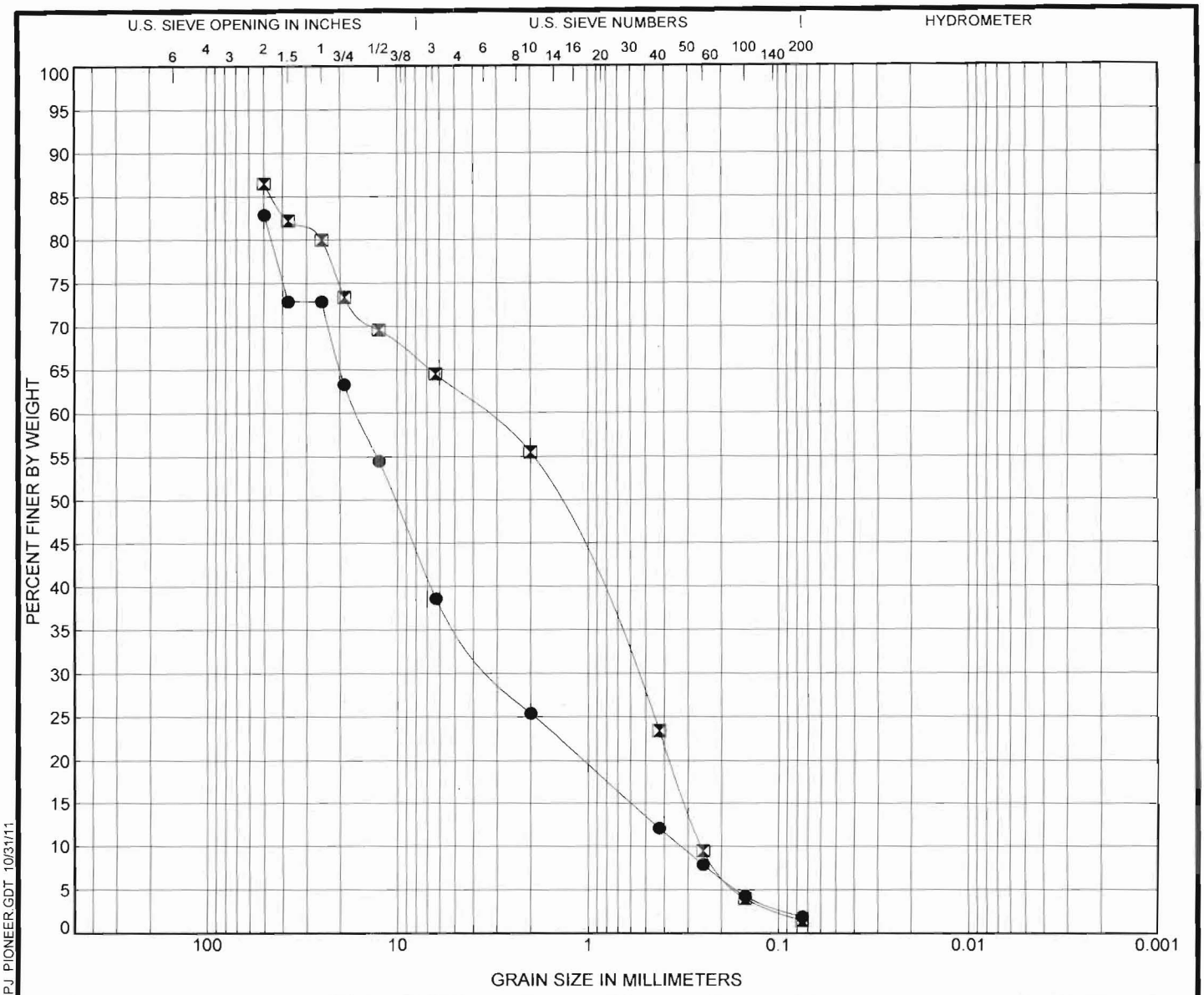
GRAIN SIZE DISTRIBUTION

Project: Energy Labs - MT DEQ

Number: H11080102

US GRAIN SIZE ASTM ENERGY CLARK FORK RIVER O U REACH A, PHASE 5 WO H11080102.GPJ PIONEER GDT 10/31/11

Phase 6 Toe Sieve Geotechnical Samples



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	LL	PL	PI	Cc	Cu
●	001 (06-901-3642)	0.0	**WELL-GRADED GRAVEL with SAND(GW)**				1.68	49.82
⊠	002 (06-903-6672)	0.0	**POORLY GRADED SAND with GRAVEL(SP)**				0.38	13.93

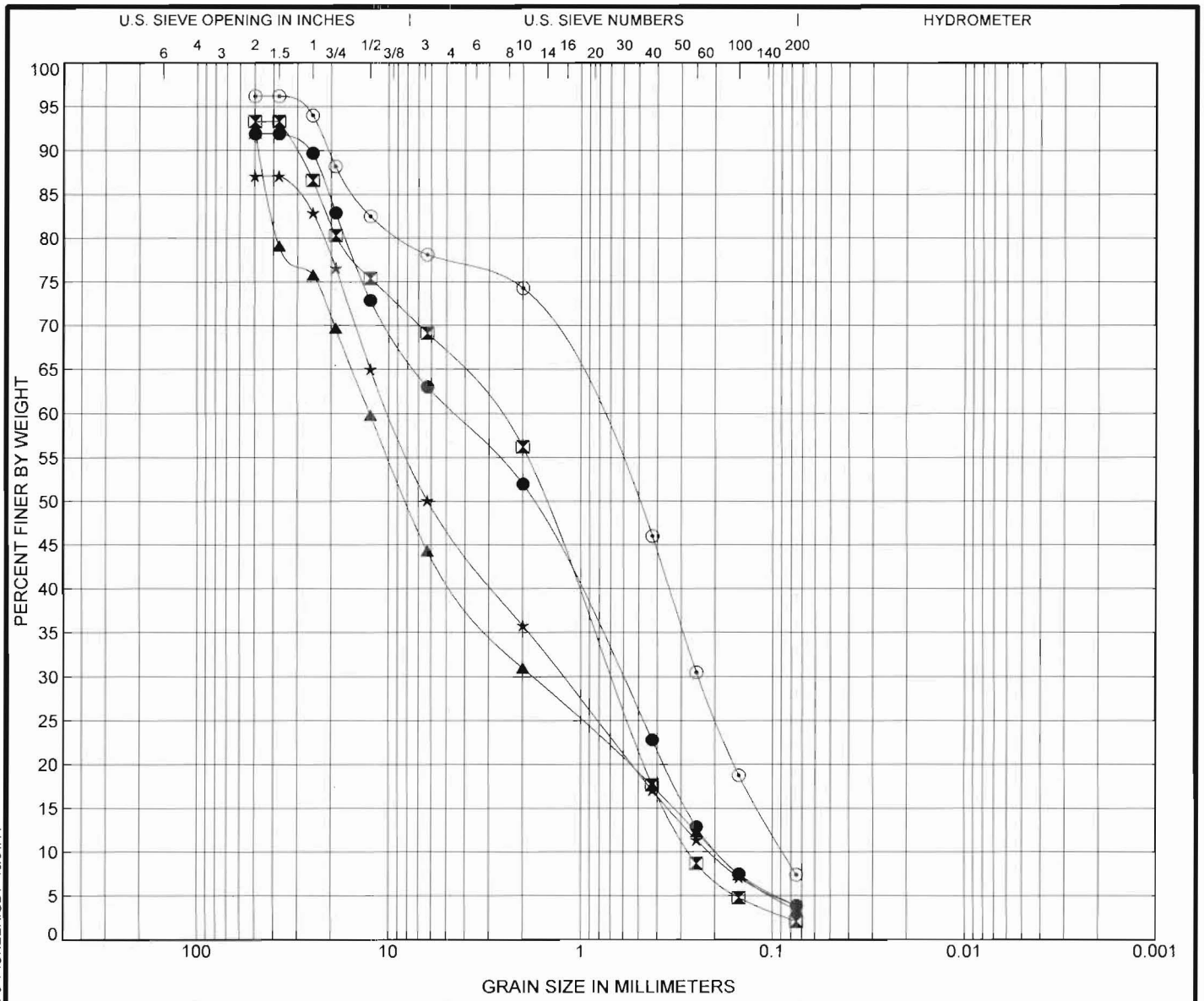
	Specimen Identification		D100	D50	D15	D10	%Gravel	%Sand	%Silt	%Clay
●	001 (06-901-3642)	0.0	50	10.297	0.596	0.326	47.5	33.5	1.9	
⊠	002 (06-903-6672)	0.0	50	1.534	0.308	0.255	24.2	60.8	1.5	

GRAIN SIZE DISTRIBUTION

Project: Energy Labs - MT DEQ

Number: H11090174

US GRAIN SIZE ASTM ENERGY CLARK FORK RIVER O.U REACH A, PHASE 5 WO H11090174.GPJ PIONEER.GDT 10/31/11



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	LL	PL	PI	Cc	Cu
●	001 (06-905-4854)	0.0	POORLY GRADED SAND with GRAVEL(SP)				0.44	24.25
⊠	002 (06-904-4248)	0.0	POORLY GRADED SAND with GRAVEL(SP)				0.64	10.39
▲	003 (06-900-7278)	0.0	WELL-GRADED GRAVEL with SAND(GW)				1.28	64.09
★	004 (06-902-5460)	0.0	POORLY GRADED GRAVEL with SAND(GP)				0.73	46.92
⊙	005 (06-910-6066)	0.0					0.74	10.41

	Specimen Identification		D100	D50	D15	D10	%Gravel	%Sand	%Silt	%Clay
●	001 (06-905-4854)	0.0	50	1.799	0.28	0.19	31.6	56.4	3.9	
⊠	002 (06-904-4248)	0.0	50	1.559	0.362	0.27	27.4	63.8	2.1	
▲	003 (06-900-7278)	0.0	50	8.105	0.328	0.197	51.0	37.6	3.4	
★	004 (06-902-5460)	0.0	50	6.25	0.35	0.212	40.5	42.7	3.9	
⊙	005 (06-910-6066)	0.0	50	0.529	0.119	0.088	19.0	69.8	7.4	

GRAIN SIZE DISTRIBUTION

Project: Energy labs - MT DEQ

Number: H11100310

US_GRAIN_SIZE_ASTM_ENERGY_CLARK FORK RIVER O.U REACH A, PHASE 5 WO H11100310.GPJ PIONEER.GDT 10/31/11

Clay Sill Test Pit Logs

DRAFT

TerraGraphics
Environmental Engineering, Inc.

TEST PIT NUMBER 756

PROJECT NUMBER 10074
PROJECT NAME CFR PHASE 5
LOCATION Powell County, Montana
EXCAVATION METHOD MINI EXC
SAMPLING METHOD GRAB
GROUND ELEVATION

DATE STARTED
DATE COMPLETED
DEPTH TO WATER ---
GROUNDWATER ELEVATION ---
LOGGED BY ---
COORDINATES (NAD 83) (N, E)

REMARKS OFFSET FROM VERT BANK ~ 40' - IMPACTED POLY-CON

This log is part of a report by TerraGraphics Environmental Engineering INC. for the project and should be read with the report. The summary applies only at the location of the boring and at the time of the drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplication of actual conditions encountered.

GRAPHIC LOG LOOKING	DEPTH (FT)	U.S.C.S.	SAMPLE ID	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS/TESTING
0 - 6"				LT BROWN/TAN SILT (TAILINGS SOME ORGANICS					
	5								
18 -24				DK BROWN ALMOST BLK SILT W/ CLAY LITTLE ORGANICS					ORGANICS % PASSING 200 LL + PL
	10								
48 - 54				DK BROWN GRAVEL W/ CLAY/SILT					GRADATION W/ % PASSING 200
	15								
	20								

TerraGraphics
Environmental Engineering, Inc.

TEST PIT NUMBER 962

PROJECT NUMBER 10074
PROJECT NAME CFR PHASE 5
LOCATION Powell County, Montana
EXCAVATION METHOD MINI BXC
SAMPLING METHOD GRAB
GROUND ELEVATION
REMARKS OFFSET FROM VERTICAL BANK ~ 5' w/ CLAY SILL VISIBLE AT TOE

DATE STARTED
DATE COMPLETED
DEPTH TO WATER ---
GROUNDWATER ELEVATION ---
LOGGED BY ---
COORDINATES (NAD 83) (N, E)

This log is part of a report by TerraGraphics Environmental Engineering INC. for the project and should be read with the report. The summary applies only at the location of the boring and at the time of the drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplication of actual conditions encountered.

GRAPHIC LOG LOOKING	DEPTH (FT)	U.S.C.S.	SAMPLE ID	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS/TESTING
0 - 6"				DK BROWN w/ AREAS OF TAN (TAILINGS) SILT w/ some SAND ORGANICS - LOTS					
	5								
24 - 30"				DK BROWN ALMOST BLK w/ TINT OF GRAY SILT w/ CLAY ORGANICS - some					ORGANICS ✓ % PASSING -200 LL + PL ✓
	10								
48 - 54				DK BROWN GRAVEL w/ some CLAY/SILT					GRADATION w/ % PASSING 200
	15								
	20								

TerraGraphics
Environmental Engineering, Inc.

TEST PIT NUMBER 961

PROJECT NUMBER 10074
PROJECT NAME CFR PHASE 5
LOCATION Powell County, Montana
EXCAVATION METHOD BACKHOE / MINI EXC
SAMPLING METHOD GRAB
GROUND ELEVATION
REMARKS OFF SET FROM VERTICAL BANK ~ 5' - CLAY SILT VISIBLE IN BANK TOE

DATE STARTED
DATE COMPLETED
DEPTH TO WATER ---
GROUNDWATER ELEVATION ---
LOGGED BY ---
COORDINATES (NAD 83) (N, E)

This log is part of a report by TerraGraphics Environmental Engineering INC. for the project and should be read with the report. The summary applies only at the location of the boring and at the time of the drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplication of actual conditions encountered.

GRAPHIC LOG LOOKING	DEPTH (FT)	U.S.C.S.	SAMPLE ID	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS/TESTING
0 - 6				LT BROWN (TAILINGS) SILT w/ SOME SAND AND FEW GRAVEL ORGANICS					
	5			~~DK~~ BLACK - CLAY w/ SILT + FEW SAND . ORGANICS					ORGANICS % PASSING 200 LL + PL
36 - 48									
	10			GRAYISH BLACK GRAVEL w/ COBBLES SAND + CLAY/SILT					GRADATION w/ % PASSING 200
66 - 72									
	15								
	20								

TerraGraphics
Environmental Engineering, Inc.

TEST PIT NUMBER 159

PROJECT NUMBER 10074
PROJECT NAME CFR PHASE 5
LOCATION Powell County, Montana
EXCAVATION METHOD MINI EXC
SAMPLING METHOD GRAB
GROUND ELEVATION
REMARKS OFFSET FROM VERT BANK ~20'

DATE STARTED
DATE COMPLETED
DEPTH TO WATER ---
GROUNDWATER ELEVATION ---
LOGGED BY ---
COORDINATES (NAD 83) (N, E)

This log is part of a report by TerraGraphics Environmental Engineering INC. for the project and should be read with the report. The summary applies only at the location of the boring and at the time of the drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplication of actual conditions encountered.

GRAPHIC LOG LOOKING	DEPTH (FT)	U.S.C.S.	SAMPLE ID	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS/TESTING
0 - 6"				GRAYISH BROWN SILT w/ FINESAND AND CLAY LOTS ORGANICS					
	5								ORGANICS PASSING 200 LL + PL
36 - 42				GRAY - CLAY w/ LITTLE SAND ORGANICS					
	10								
48 - 52				BROWN GRAVEL w/ CLAY SILTY SAND					GRADATION w/ % PASSING 200
	15								
	20								

TerraGraphics
Environmental Engineering, Inc.

TEST PIT NUMBER 332

PROJECT NUMBER 10074
PROJECT NAME CFR PHASE 5
LOCATION Powell County, Montana
EXCAVATION METHOD BACKHOE / MINI EXC
SAMPLING METHOD GRAB
GROUND ELEVATION
REMARKS OFFSET FROM VERTICAL BANK ~ 40'

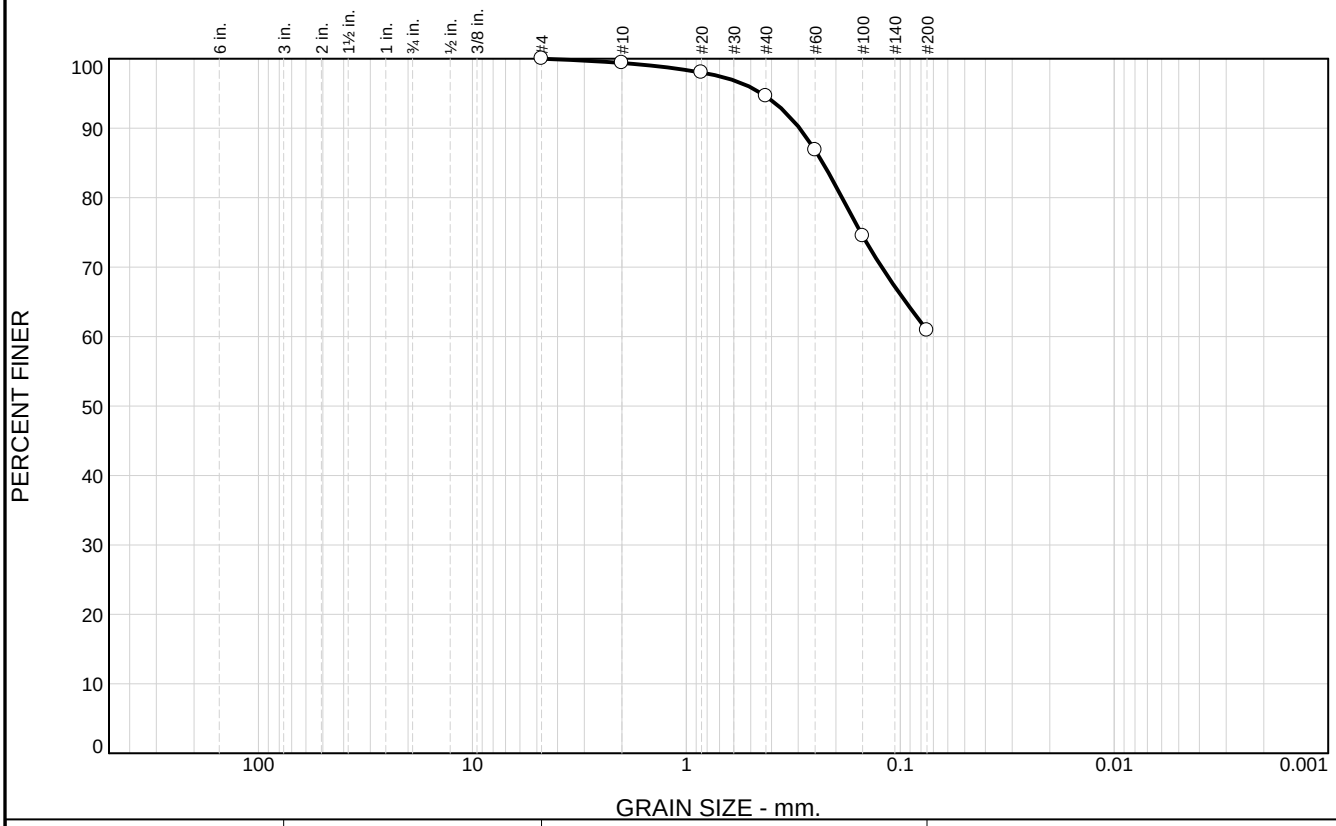
DATE STARTED
DATE COMPLETED
DEPTH TO WATER ---
GROUNDWATER ELEVATION ---
LOGGED BY ---
COORDINATES (NAD 83) (N, E)

This log is part of a report by TerraGraphics Environmental Engineering INC. for the project and should be read with the report. The summary applies only at the location of the boring and at the time of the drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplication of actual conditions encountered.

GRAPHIC LOG LOOKING	DEPTH (FT)	U.S.C.S.	SAMPLE ID	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS/TESTING
0 - 6"				LIGHT BROWN (TAILINGS) SILT w/ LITTLE FINE SAND AND ORGANICS					
	5								
36" - 48"				GRAY - CLAYEY SILTY w/ LITTLE SAND					ORGANICS % PASSING 200 LL + PL
	10								
54" - 60"				DK BROWN - GRAVEL w/ SAND + SOME SILTY CLAY					GRADATION w/ % PASSING 200
	15								
	20								

Clay Sill Geotechnical Samples

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.6	4.8	33.7	60.9	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#10	99.4		
#20	98.0		
#40	94.6		
#60	86.9		
#100	74.5		
#200	60.9		

* (no specification provided)

Soil Description

sandy lean clay

Atterberg Limits

PL= 18 LL= 36 PI= 18

Coefficients

D_{85}= 0.2299 D_{60}= D_{50}=
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CL AASHTO= A-6(8)

Remarks

Sample No.: **Source of Sample:** 05-159 **Date:**
Location: **Elev./Depth:** 36-42"

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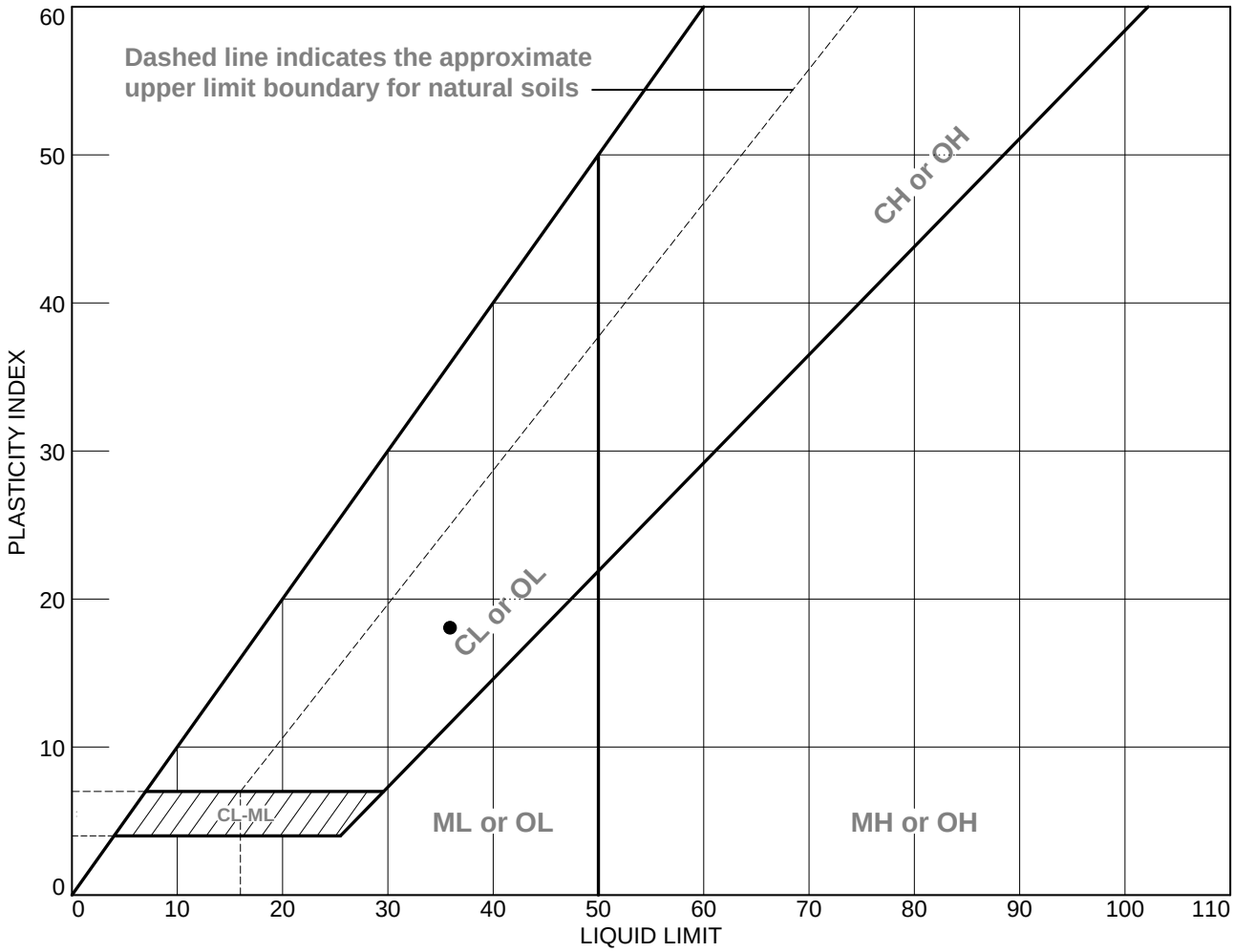
1215 Apple's Way - Belgrade, MT 59714
Ph. 406-388-8578 - Fax 406-388-8579

Client: Terragraphics
Project: CFR Phase 5
Project No: 10074 **Figure**

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA

SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	05-159		36-42"		18	36	18	CL

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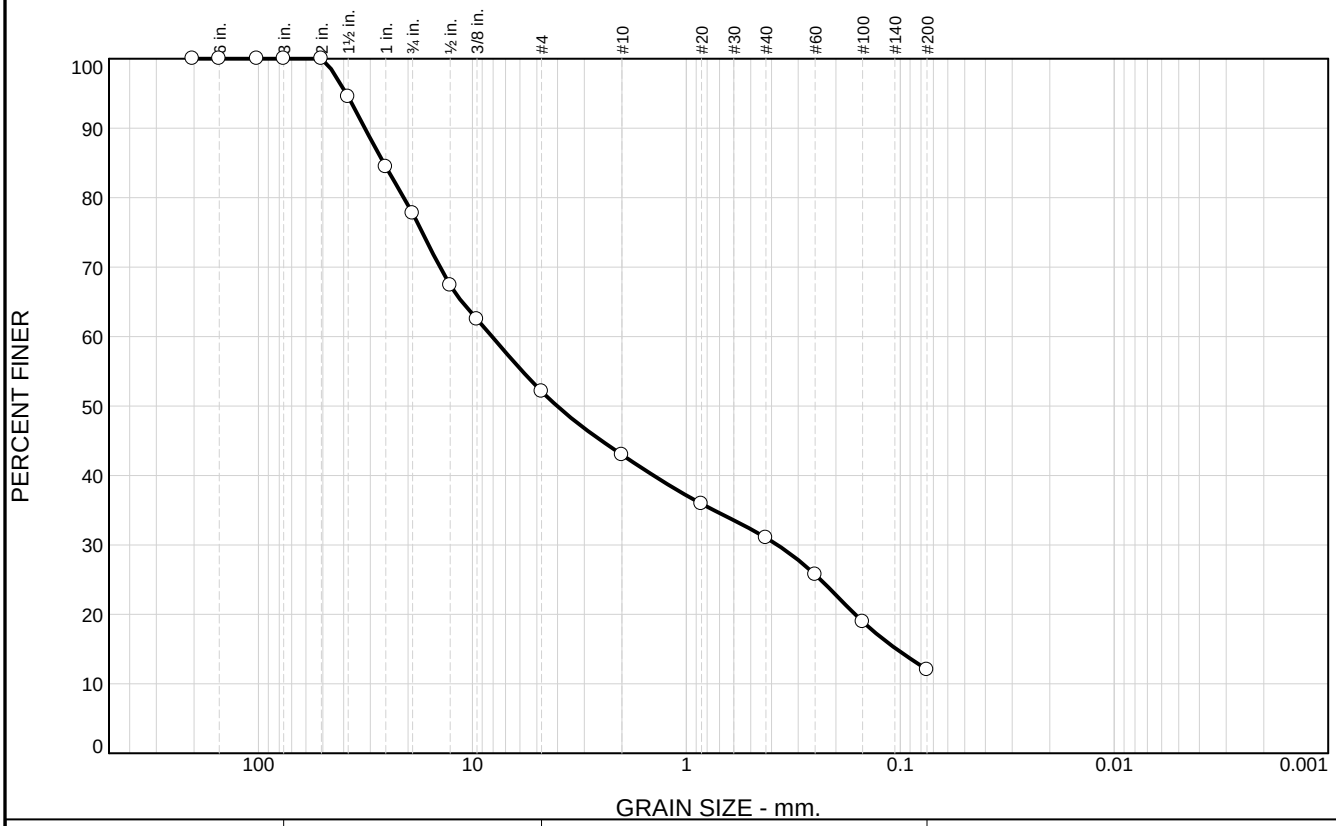
Client: Terragraphics
Project: CFR Phase 5

Project No.: 10074 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	22.3	25.6	9.1	12.0	19.0	12.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
8	100.0		
6	100.0		
4	100.0		
3	100.0		
2	100.0		
1.5	94.5		
1	84.4		
.75	77.7		
.5	67.4		
.375	62.5		
#4	52.1		
#10	43.0		
#20	35.9		
#40	31.0		
#60	25.7		
#100	18.9		
#200	12.0		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 26.0086 D_{60}= 8.0994 D_{50}= 4.0224
D_{30}= 0.3753 D_{15}= 0.1042 D_{10}=
C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Sample No.: **Source of Sample:** 05-159 **Date:**
Location: **Elev./Depth:** 48-52

PIEDMONT ENGINEERING, INC.
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Client: Terragraphics
Project: CFR Phase 5
Project No: 10074 **Figure**

PIEDMONT ENGINEERING, Inc.

1215 Apples Way
Belgrade, MT 59714
Office: (406) 388-8578
Fax: (406) 388-8579

Organic Content by Loss on Ignition

Client: Terragraphics

Project: CFR Phase 5

Project Number:

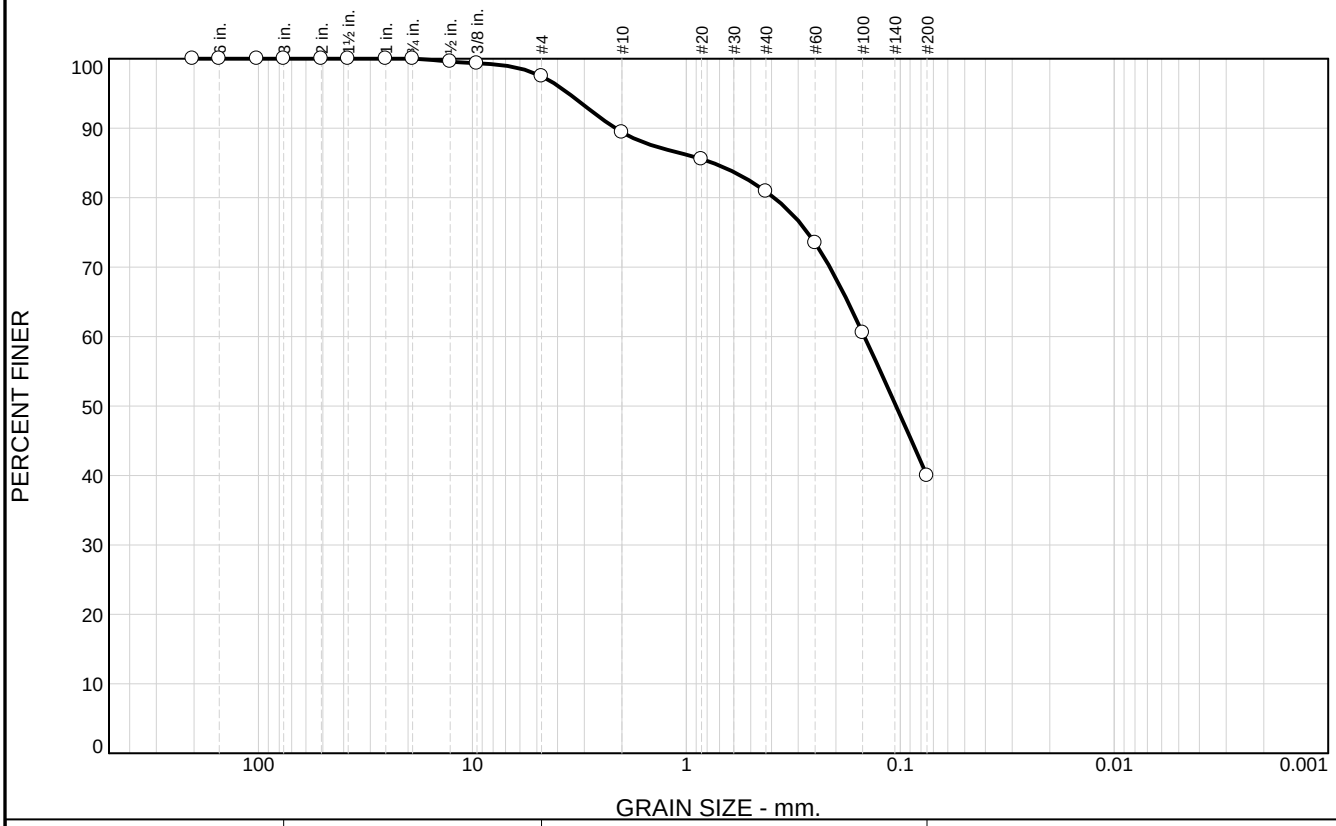
Tested By: NKG

Date of Testing: 1/13/2011

Sample Description: 05-159 36-42"

Tare Number			
Oven Dry + Tare	327.82		
Ignited Dry + Tare	325.43		
Tare	167.40		
Ash Content %	98.51	#DIV/0!	#DIV/0!
% Organic Matter	1.49	#DIV/0!	#DIV/0!

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	2.5	8.1	8.5	40.9	40.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
8	100.0		
6	100.0		
4	100.0		
3	100.0		
2	100.0		
1.5	100.0		
1	100.0		
.75	100.0		
.5	99.6		
.375	99.3		
#4	97.5		
#10	89.4		
#20	85.6		
#40	80.9		
#60	73.5		
#100	60.5		
#200	40.0		

* (no specification provided)

Soil Description

clayey sand

Atterberg Limits

PL= 18 LL= 30 PI= 12

Coefficients

D_{85}= 0.7530 D_{60}= 0.1472 D_{50}= 0.1047
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= SC AASHTO= A-6(1)

Remarks

Sample No.: **Source of Sample:** 05-332 **Date:**
Location: **Elev./Depth:** 36-48"

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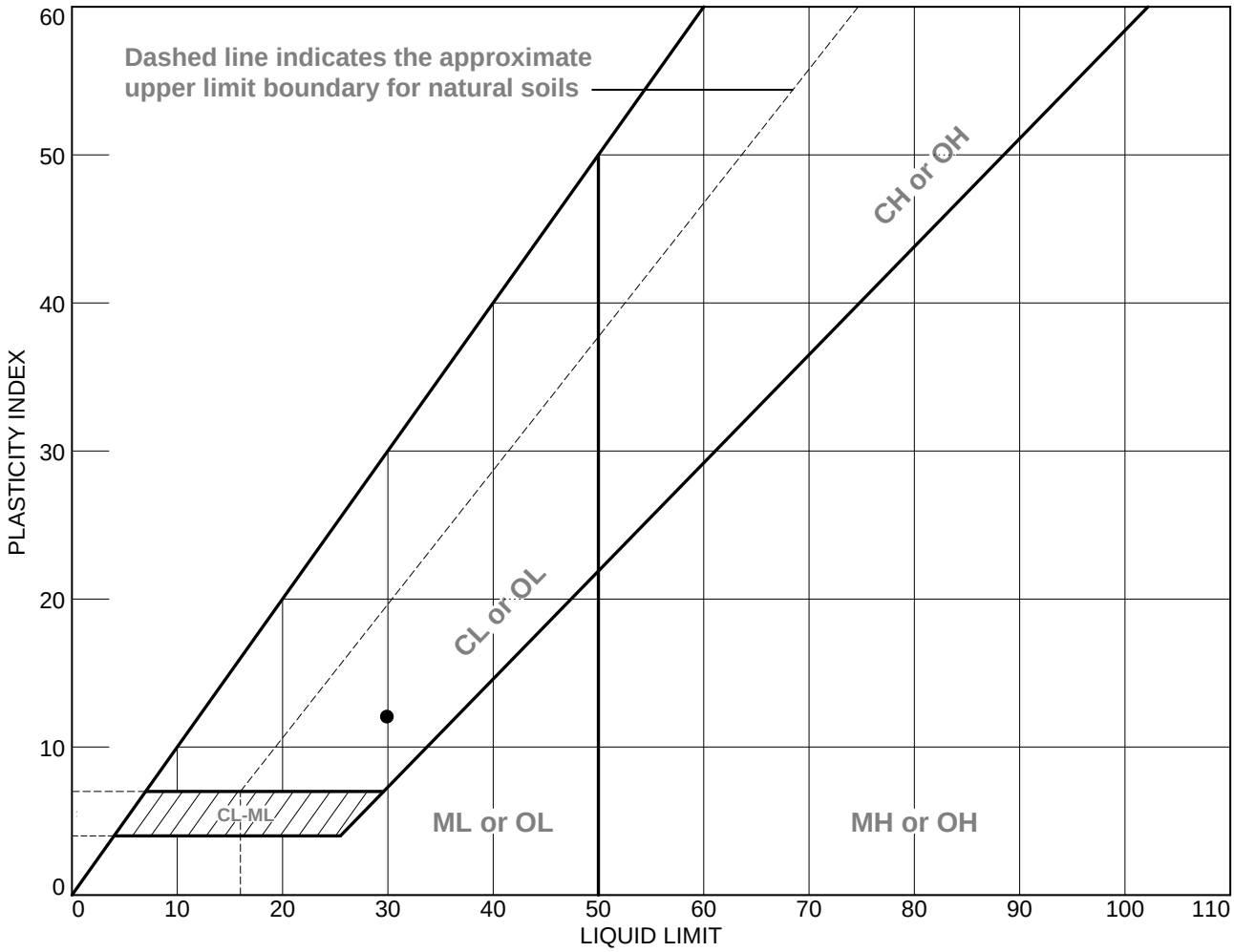
Client: Terragraphics
Project: CFR Phase 5
Project No: 10074 **Figure**

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA

SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	05-332		36-48"		18	30	12	SC

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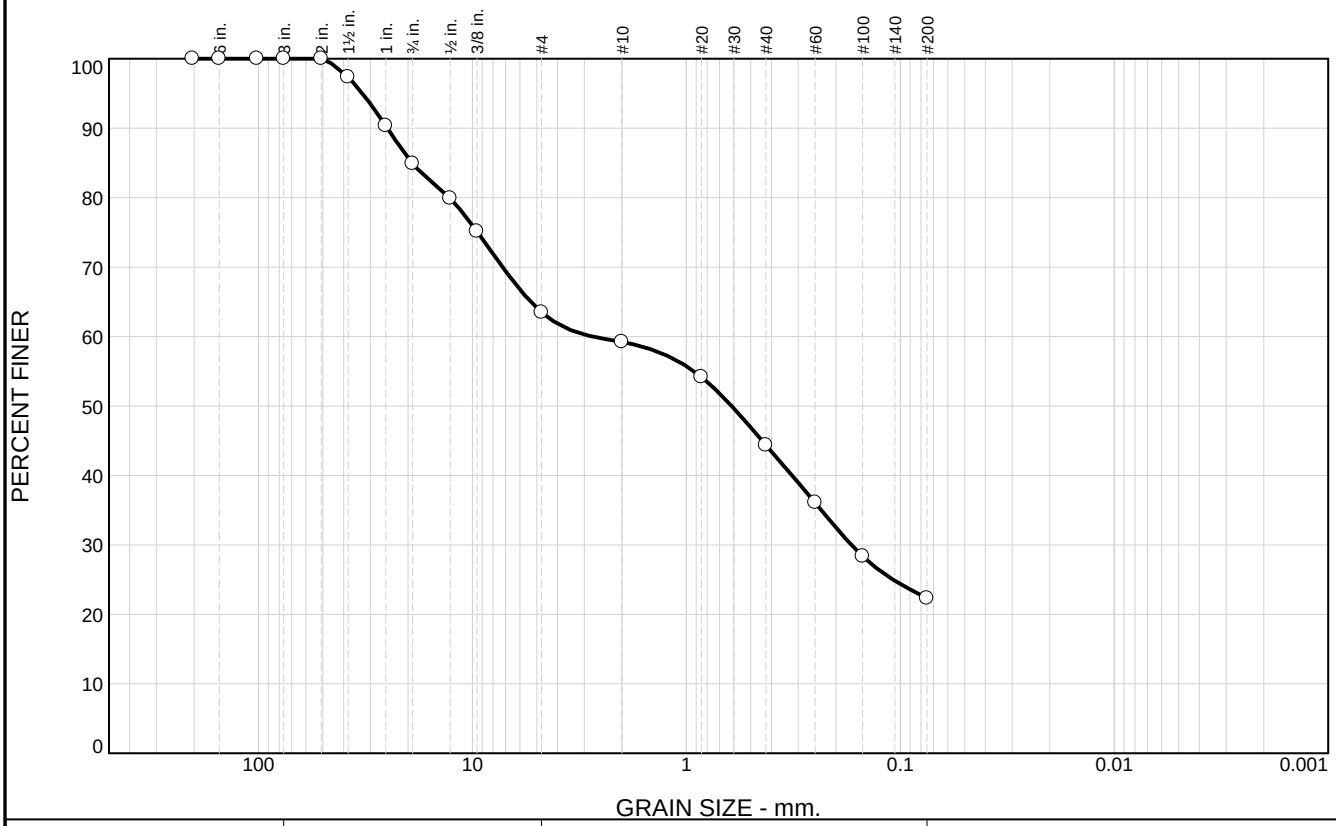
Client: Terragraphics
Project: CFR Phase 5

Project No.: 10074 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	15.1	21.4	4.3	14.8	22.1	22.3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
8	100.0		
6	100.0		
4	100.0		
3	100.0		
2	100.0		
1.5	97.3		
1	90.4		
.75	84.9		
.5	79.9		
.375	75.1		
#4	63.5		
#10	59.2		
#20	54.2		
#40	44.4		
#60	36.1		
#100	28.4		
#200	22.3		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 19.1885 D_{60}= 2.7554 D_{50}= 0.6142
D_{30}= 0.1695 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Sample No.: **Source of Sample:** 05-332 **Date:**
Location: **Elev./Depth:** 54-60"

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Client: Terragraphics
Project: CFR Phase 5
Project No: 10074 **Figure**

PIEDMONT ENGINEERING, Inc.

1215 Apples Way
Belgrade, MT 59714
Office: (406) 388-8578
Fax: (406) 388-8579

Organic Content by Loss on Ignition

Client: Terragraphics

Project: CFR Phase 5

Project Number:

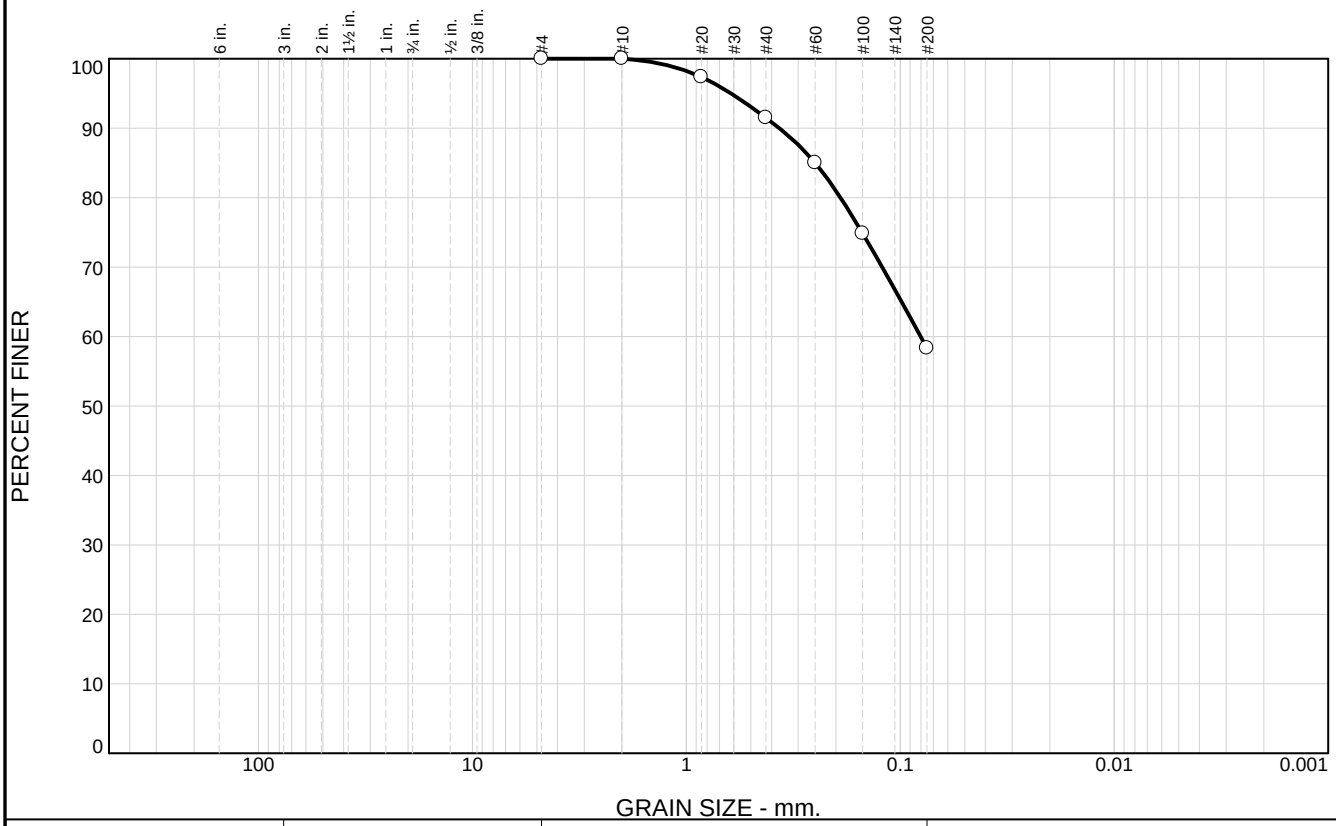
Tested By: NKG

Date of Testing: 1/13/2011

Sample Description: 05-332 36-48"

Tare Number			
Oven Dry + Tare	295.31		
Ignited Dry + Tare	293.77		
Tare	163.22		
Ash Content %	98.83		
% Organic Matter	1.17		

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	8.5	33.2	58.3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#10	100.0		
#20	97.4		
#40	91.5		
#60	85.0		
#100	74.8		
#200	58.3		

* (no specification provided)

Soil Description

sandy lean clay

Atterberg Limits

PL= 23 LL= 42 PI= 19

Coefficients

D_{85}= 0.2498 D_{60}= 0.0803 D_{50}=
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CL AASHTO= A-7-6(9)

Remarks

Sample No.: **Source of Sample:** 05-756 **Date:**
Location: **Elev./Depth:** 18-24"

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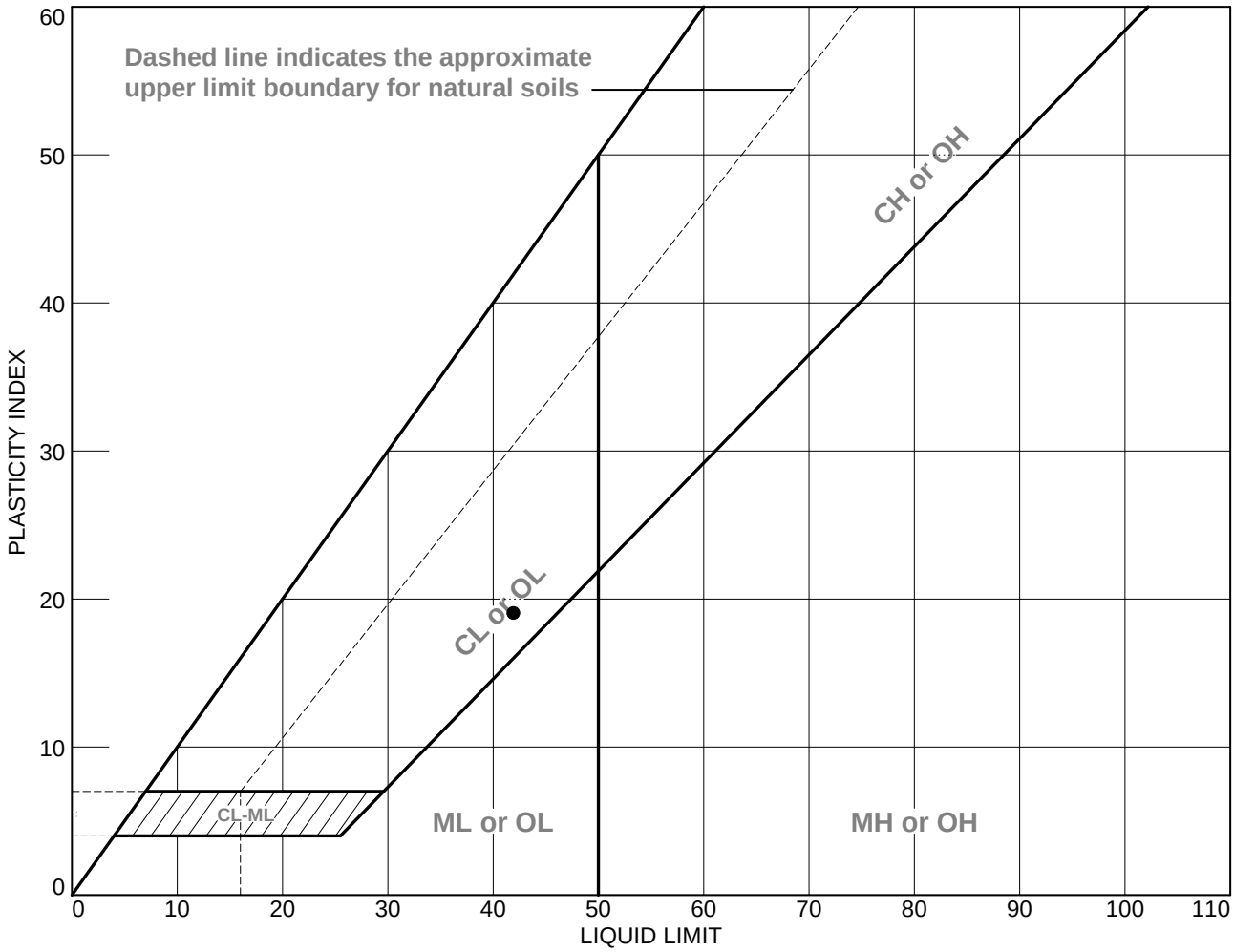
Client: Terragraphics
Project: CFR Phase 5
Project No: 10074 **Figure**

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA

SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	05-756		18-24"		23	42	19	CL

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Client: Terragraphics
Project: CFR Phase 5

Project No.: 10074 **Figure**

PIEDMONT ENGINEERING, Inc.

1215 Apples Way
Belgrade, MT 59714
Office: (406) 388-8578
Fax: (406) 388-8579

Organic Content by Loss on Ignition

Client: Terragraphics

Project: CFR Phase 5

Project Number:

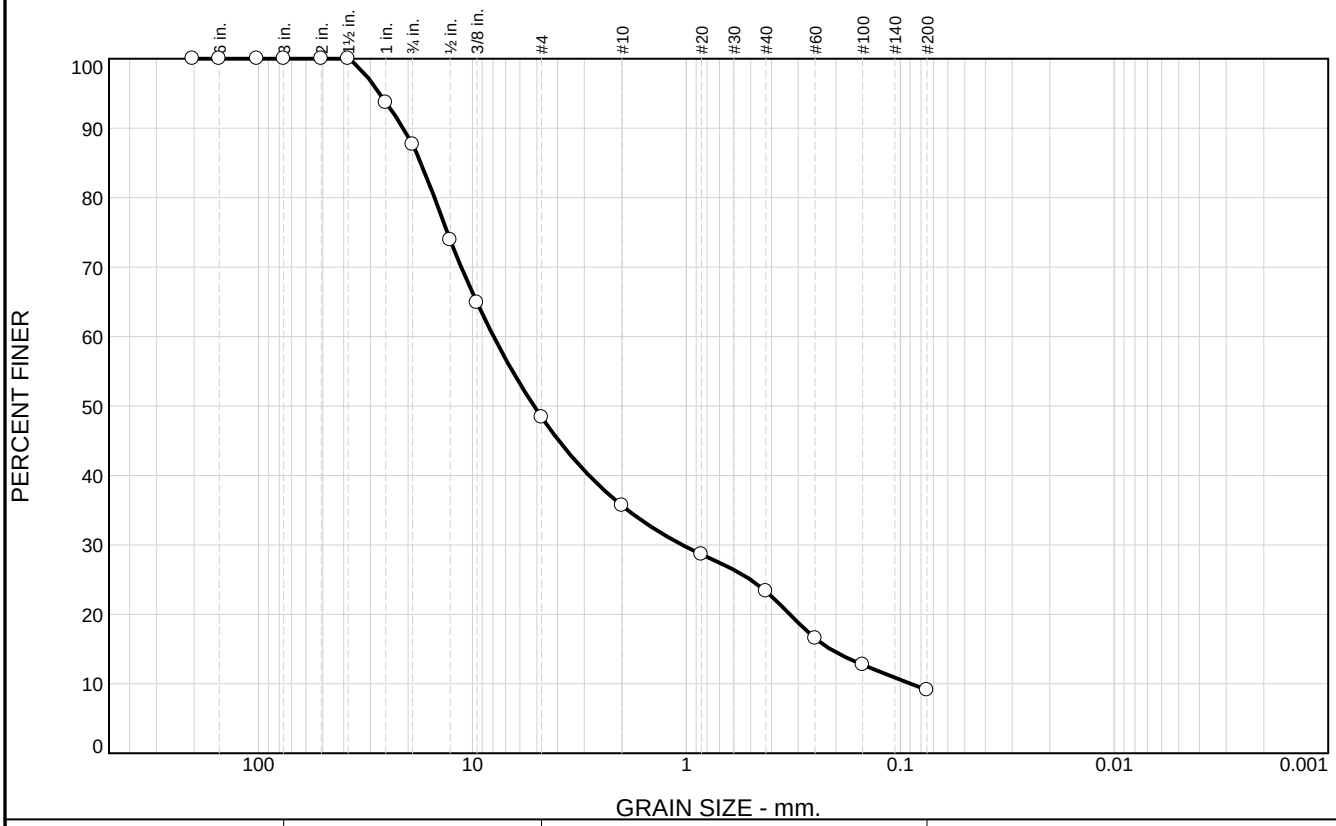
Tested By: NKG

Date of Testing: 1/19/2011

Sample Description: 05-756 18-24"

Tare Number			
Oven Dry + Tare	335.07		
Ignited Dry + Tare	329.22		
Tare	157.40		
Ash Content %	96.71		
% Organic Matter	3.29		

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	12.3	39.3	12.7	12.3	14.3	9.1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
8	100.0		
6	100.0		
4	100.0		
3	100.0		
2	100.0		
1.5	100.0		
1	93.7		
.75	87.7		
.5	73.9		
.375	64.9		
#4	48.4		
#10	35.7		
#20	28.6		
#40	23.4		
#60	16.5		
#100	12.8		
#200	9.1		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 17.4029 D_{60}= 7.9614 D_{50}= 5.1577
D_{30}= 1.0450 D_{15}= 0.2122 D_{10}= 0.0893
C_u= 89.15 C_c= 1.54

Classification

USCS= AASHTO=

Remarks

Sample No.: **Source of Sample:** 05-756 **Date:**
Location: **Elev./Depth:** 48-54"

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1215 Apple's Way - Belgrade, MT 59714
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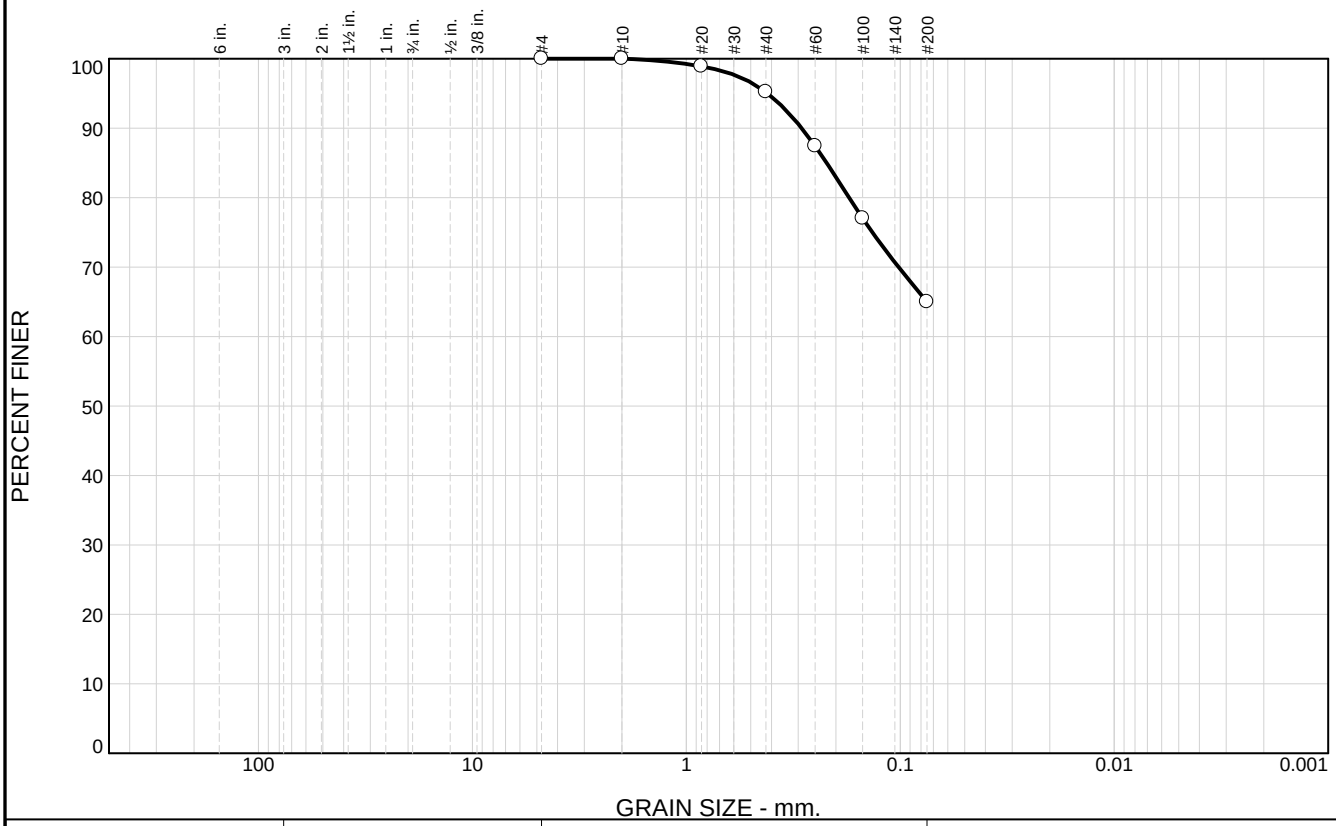
Client: Terragraphics
Project: CFR Phase 5
Project No: 10074 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	4.8	30.2	65.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#10	100.0		
#20	98.9		
#40	95.2		
#60	87.4		
#100	77.0		
#200	65.0		

* (no specification provided)

Soil Description

sandy fat clay

Atterberg Limits

PL= 27 LL= 57 PI= 30

Coefficients

D_{85}= 0.2209 D_{60}= D_{50}=
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CH AASHTO= A-7-6(19)

Remarks

Sample No.: **Source of Sample:** 05-961 **Date:**
Location: **Elev./Depth:** 36-48"

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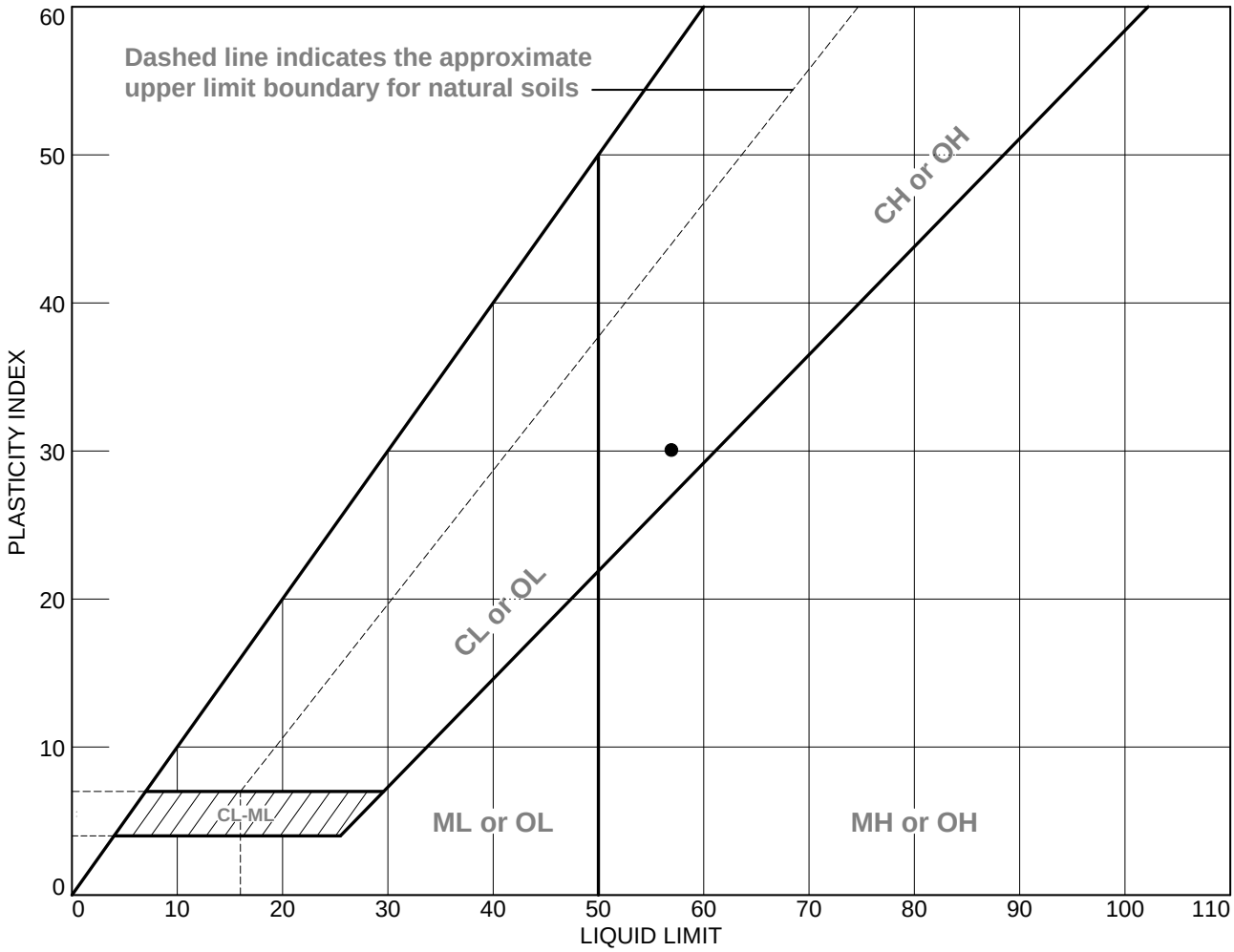
Client: Terragraphics
Project: CFR Phase 5
Project No: 10074 **Figure**

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	05-961		36-48"		27	57	30	CH

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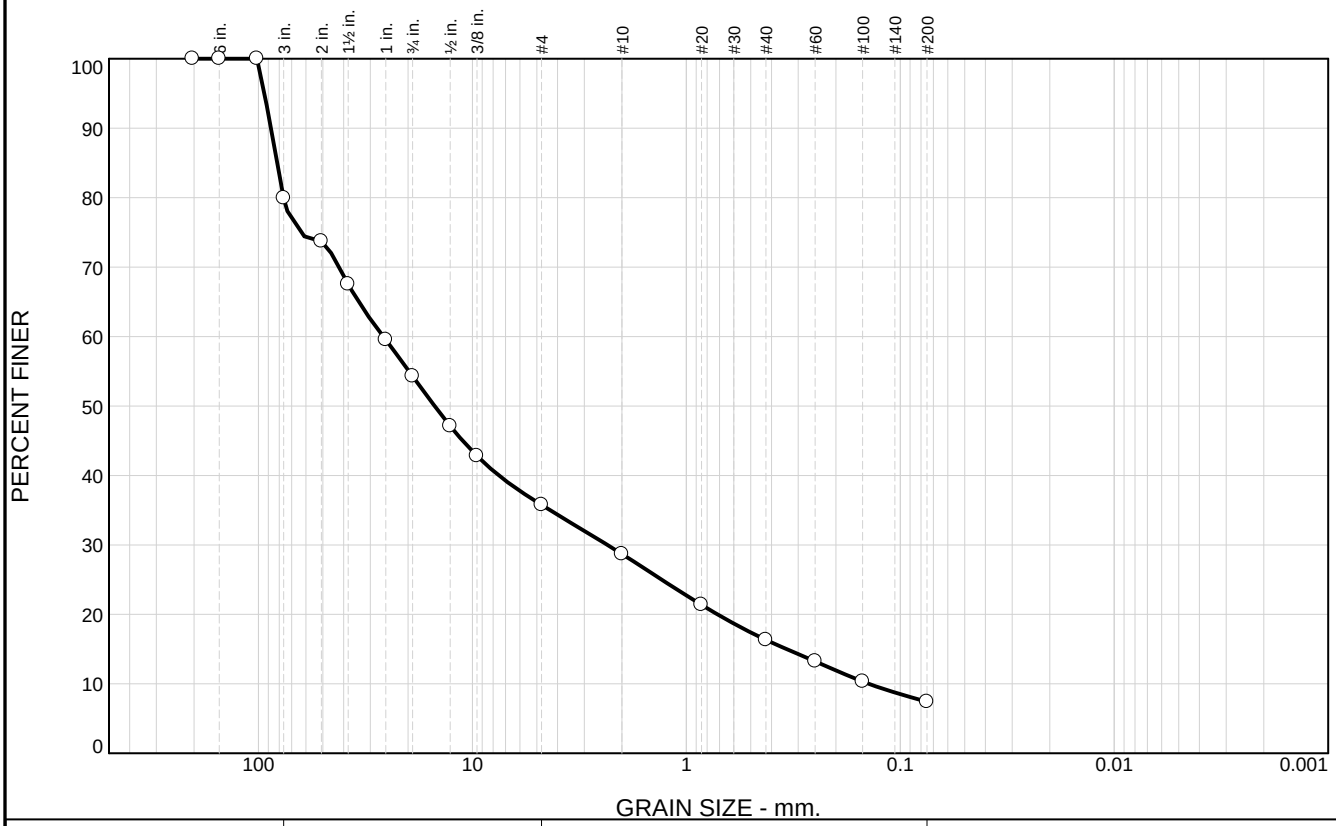
Client: Terragraphics
Project: CFR Phase 5

Project No.: 10074 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
20.1	25.6	18.5	7.1	12.4	8.9	7.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
8	100.0		
6	100.0		
4	100.0		
3	79.9		
2	73.7		
1.5	67.6		
1	59.5		
.75	54.3		
.5	47.1		
.375	42.8		
#4	35.8		
#10	28.7		
#20	21.4		
#40	16.3		
#60	13.2		
#100	10.3		
#200	7.4		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 82.2754 D_{60}= 26.0762 D_{50}= 15.0310
D_{30}= 2.3405 D_{15}= 0.3403 D_{10}= 0.1403
C_u= 185.83 C_c= 1.50

Classification

USCS= AASHTO=

Remarks

Sample No.: **Source of Sample:** 05-961 **Date:**
Location: **Elev./Depth:** 66-72"

PIEDMONT ENGINEERING, INC.
1215 Apple's Way - Belgrade, MT 59714
Ph. 406-388-8578 - Fax 406-388-8579

Client: Terragraphics
Project: CFR Phase 5
Project No: 10074 **Figure**

PIEDMONT ENGINEERING, Inc.

1215 Apples Way
Belgrade, MT 59714
Office: (406) 388-8578
Fax: (406) 388-8579

Organic Content by Loss on Ignition

Client: Terragraphics

Project: CFR Phase 5

Project Number:

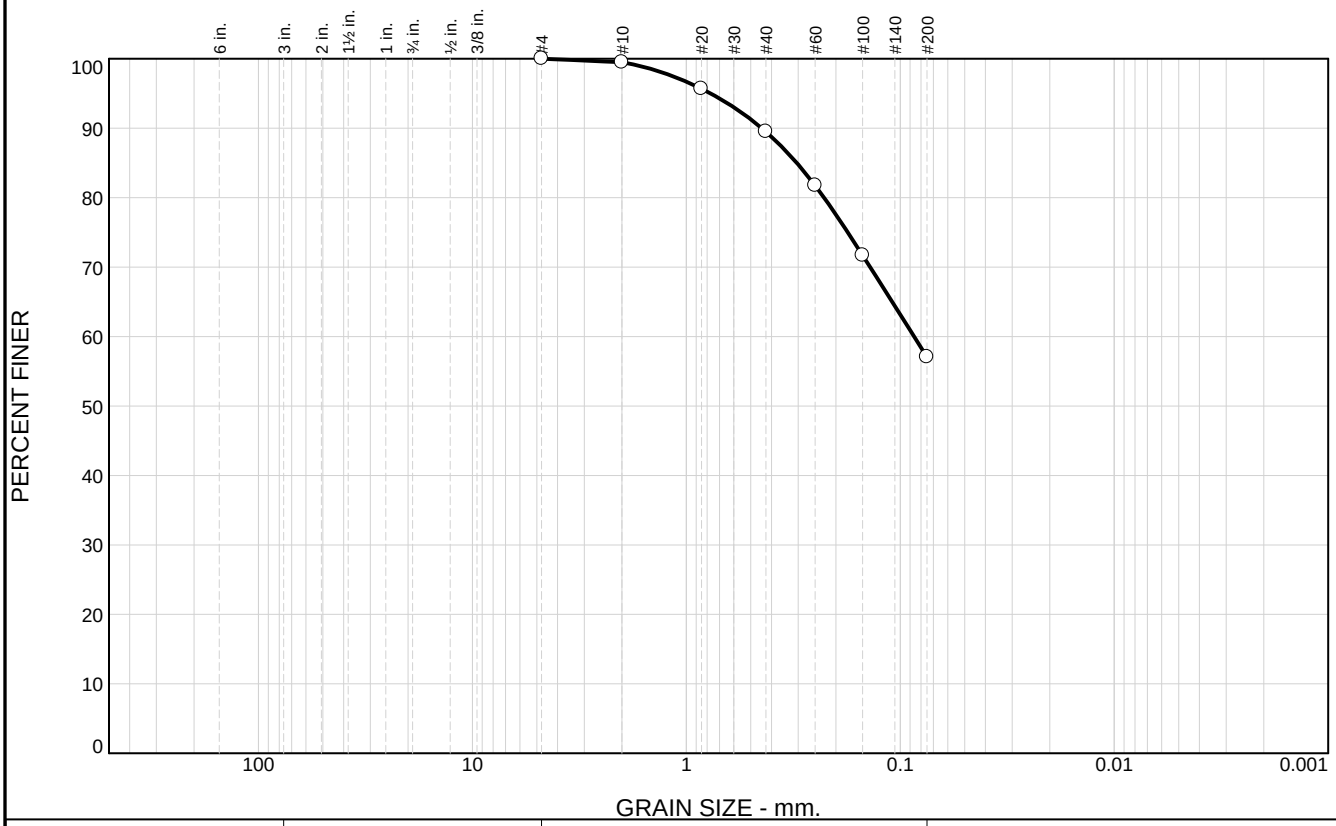
Tested By: NKG

Date of Testing: 1/13/2011

Sample Description: 05-961 36-48"

Tare Number			
Oven Dry + Tare	268.90		
Ignited Dry + Tare	262.81		
Tare	164.84		
Ash Content %	94.15	#DIV/0!	#DIV/0!
% Organic Matter	5.85	#DIV/0!	#DIV/0!

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.5	10.0	32.5	57.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#10	99.5		
#20	95.7		
#40	89.5		
#60	81.7		
#100	71.7		
#200	57.0		

* (no specification provided)

Soil Description

sandy lean clay

Atterberg Limits

PL= 23 LL= 44 PI= 21

Coefficients

D_{85}= 0.3046 D_{60}= 0.0862 D_{50}=
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CL AASHTO= A-7-6(9)

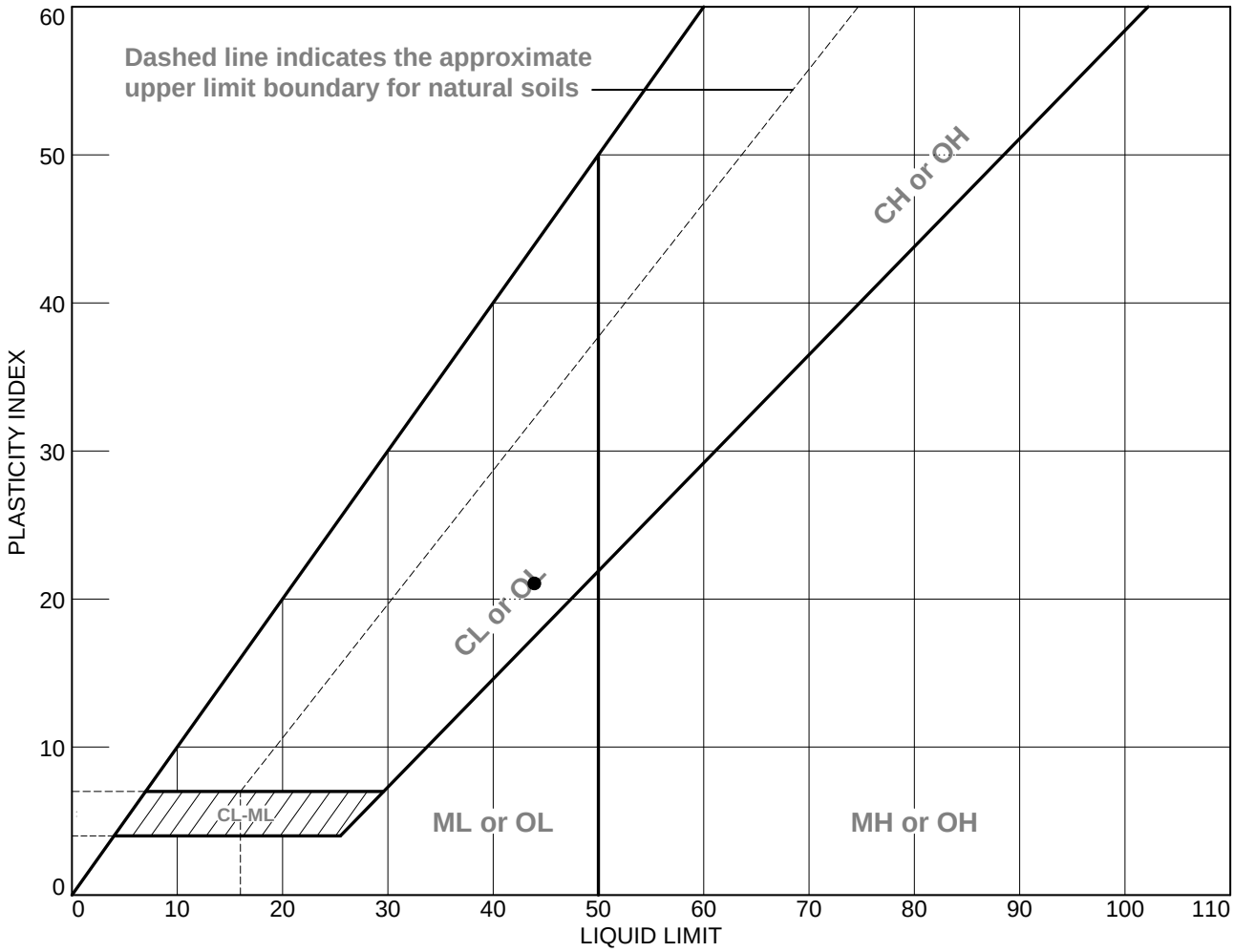
Remarks

Sample No.: **Source of Sample:** 05-962 **Date:**
Location: **Elev./Depth:** 24-30"

PIEDMONT ENGINEERING, INC.
1215 Apple's Way - Belgrade, MT 59714
Ph. 406-388-8578 - Fax 406-388-8579

Client: Terragraphics
Project: CFR Phase 5
Project No: 10074 **Figure**

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA

SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	05-962		24-30"		23	44	21	CL

PIEDMONT ENGINEERING, INC.

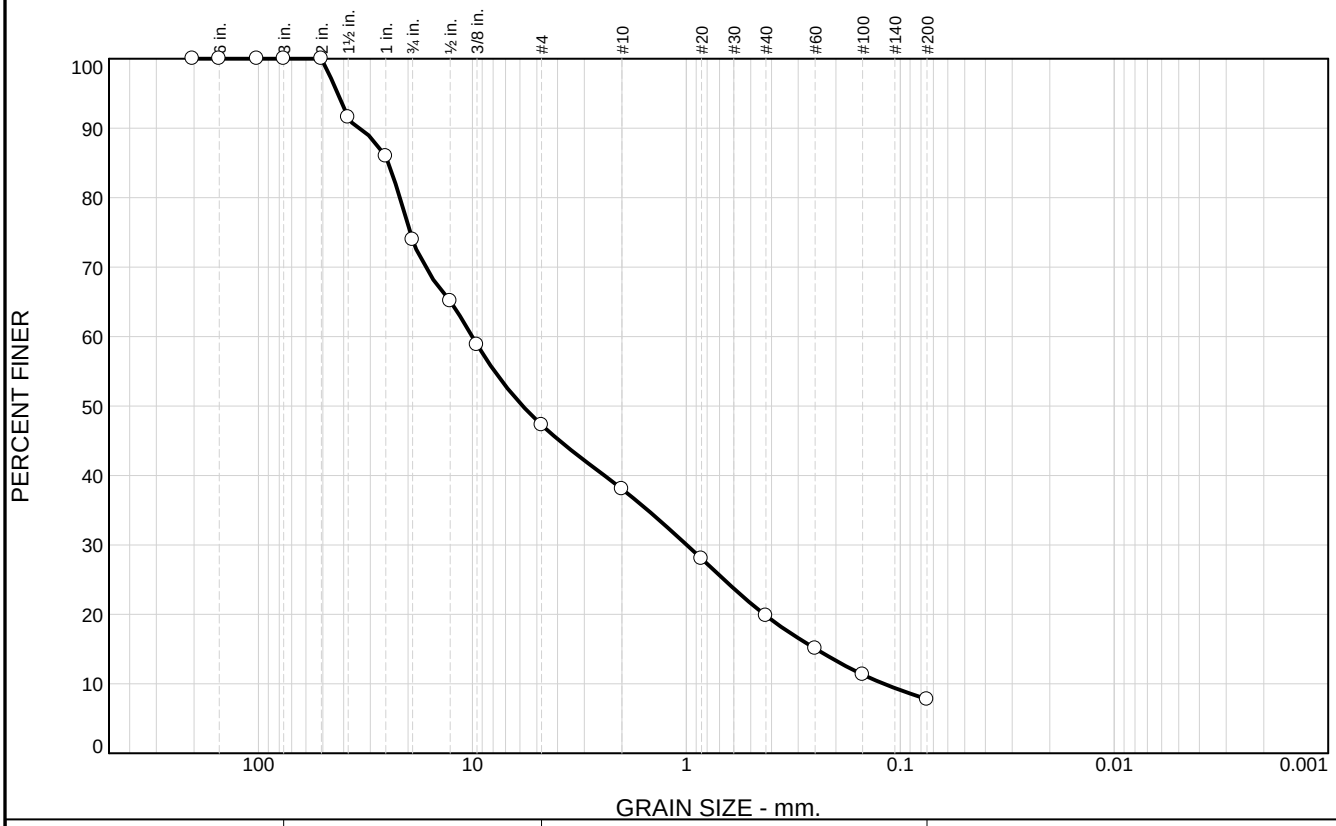
1215 Apple's Way - Belgrade, MT 59714

Ph. 406-388-8578 - Fax 406-388-8579

Client: Terragraphics
Project: CFR Phase 5

Project No.: 10074 **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	26.0	26.7	9.3	18.2	12.0	7.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
8	100.0		
6	100.0		
4	100.0		
3	100.0		
2	100.0		
1.5	91.6		
1	86.0		
.75	74.0		
.5	65.1		
.375	58.8		
#4	47.3		
#10	38.0		
#20	28.0		
#40	19.8		
#60	15.1		
#100	11.3		
#200	7.8		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 24.6562 D_{60}= 10.0327 D_{50}= 5.8204
D_{30}= 0.9958 D_{15}= 0.2474 D_{10}= 0.1194
C_u= 84.02 C_c= 0.83

Classification

USCS= AASHTO=

Remarks

Sample No.: **Source of Sample:** 05-962 **Date:**
Location: **Elev./Depth:** 48-54"

PIEDMONT ENGINEERING, INC.
1215 Apple's Way - Belgrade, MT 59714
Ph. 406-388-8578 - Fax 406-388-8579

Client: Terragraphics
Project: CFR Phase 5
Project No: 10074 **Figure**

PIEDMONT ENGINEERING, Inc.

1215 Apples Way
Belgrade, MT 59714
Office: (406) 388-8578
Fax: (406) 388-8579

Organic Content by Loss on Ignition

Client: Terragraphics

Project: CFR Phase 5

Project Number:

Tested By: NKG

Date of Testing: 1/18/2011

Sample Description: 05-962 24-30"

Tare Number			
Oven Dry + Tare	268.99		
Ignited Dry + Tare	264.92		
Tare	167.41		
Ash Content %	95.99	#DIV/0!	#DIV/0!
% Organic Matter	4.01	#DIV/0!	#DIV/0!

Appendix D

Hydrology

DRAFT

```
1
  Program PeakFq           U. S. GEOLOGICAL SURVEY             Seq.000.000
  Ver. 5.2            Annual peak flow frequency analysis      Run Date / Time
  11/01/2007          following Bulletin 17-B Guidelines       03/16/2012 10:09

                         --- PROCESSING OPTIONS ---

                      Plot option         = Line printer
                      Basin char output   = None
                      Print option        = Yes
                      Debug print         = No
                      Input peaks listing = Long
                      Input peaks format  = WATSTORE peak file

                      Input files used:
                         peaks (ascii)  -
C:\USERS\PMCCARTH\DESKTOP\PEAKFQWIN_TESTFILES\12323750.CI
                         specifications - PKFQWPSF.TMP

                      Output file(s):
                         main -
C:\USERS\PMCCARTH\DESKTOP\PEAKFQWIN_TESTFILES\12323750.PRT

1


  Program PeakFq           U. S. GEOLOGICAL SURVEY             Seq.001.001
  Ver. 5.2            Annual peak flow frequency analysis      Run Date / Time
  11/01/2007          following Bulletin 17-B Guidelines       03/16/2012 10:09

            Station - 12323750  Silver Bow Creek at Warm Springs MT


                     I N P U T   D A T A   S U M M A R Y

               Number of peaks in record           =       28
               Peaks not used in analysis          =        0
               Systematic peaks in analysis        =       28
               Historic peaks in analysis          =        0
               Years of historic record            =        0
               Generalized skew                    =   -0.083
                    Standard error                 =    0.640
                    Mean Square error              =    0.410
               Skew option                         =   WEIGHTED
               Gage base discharge                 =      0.0
               User supplied high outlier threshold =   --
               User supplied low outlier criterion  =   --
               Plotting position parameter         =     0.00


  *********  NOTICE  --  Preliminary machine computations.        *********
  *********  User responsible for assessment and interpretation.  *********

    WCF134I-NO SYSTEMATIC PEAKS WERE BELOW GAGE BASE.                  0.0
    WCF195I-NO LOW OUTLIERS WERE DETECTED BELOW CRITERION.            74.7
    WCF163I-NO HIGH OUTLIERS OR HISTORIC PEAKS EXCEEDED HHBASE.      2322.1
1


  Program PeakFq           U. S. GEOLOGICAL SURVEY             Seq.001.002
  Ver. 5.2            Annual peak flow frequency analysis      Run Date / Time
  11/01/2007          following Bulletin 17-B Guidelines       03/16/2012 10:09
```

12323750 Silver Bow Creek at Warm Springs.PRT

Station - 12323750 Silver Bow Creek at Warm Springs MT

ANNUAL FREQUENCY CURVE PARAMETERS -- LOG-PEARSON TYPE III

	FLOOD BASE		LOGARITHMIC		
	DISCHARGE	EXCEEDANCE PROBABILITY	MEAN	STANDARD DEVIATION	SKEW
SYSTEMATIC RECORD	0.0	1.0000	2.6197	0.2945	-0.347
BULL.17B ESTIMATE	0.0	1.0000	2.6197	0.2945	-0.258

ANNUAL FREQUENCY CURVE -- DISCHARGES AT SELECTED EXCEEDANCE PROBABILITIES

ANNUAL EXCEEDANCE PROBABILITY	BULL.17B ESTIMATE	SYSTEMATIC RECORD	'EXPECTED PROBABILITY' ESTIMATE	95-PCT CONFIDENCE LIMITS FOR BULL. 17B ESTIMATES LOWER	UPPER
0.9950	61.7	58.3	50.2	33.8	91.9
0.9900	75.8	72.6	64.8	43.9	109.3
0.9500	130.3	128.3	121.6	86.4	173.7
0.9000	171.9	171.1	164.8	121.4	221.5
0.8000	237.9	238.9	233.0	179.2	297.5
0.6667	318.8	321.7	316.2	251.0	393.8
0.5000	428.9	433.2	428.9	346.0	533.4
0.4292	483.4	488.0	484.9	391.4	606.6
0.2000	742.2	743.4	755.6	592.6	988.0
0.1000	972.8	964.9	1006.0	757.8	1366.0
0.0400	1283.0	1255.0	1360.0	966.9	1917.0
0.0200	1524.0	1474.0	1650.0	1122.0	2374.0
0.0100	1772.0	1694.0	1964.0	1277.0	2865.0
0.0050	2027.0	1916.0	2305.0	1432.0	3391.0
0.0020	2375.0	2212.0	2801.0	1638.0	4141.0

1

Program PeakFq
Ver. 5.2
11/01/2007

U. S. GEOLOGICAL SURVEY
Annual peak flow frequency analysis
following Bulletin 17-B Guidelines

Seq.001.003
Run Date / Time
03/16/2012 10:09

Station - 12323750 Silver Bow Creek at Warm Springs MT

I N P U T D A T A L I S T I N G

WATER YEAR	DISCHARGE	CODES	WATER YEAR	DISCHARGE	CODES
1972	586.0		1998	296.0	
1973	324.0		1999	359.0	
1974	1000.0		2000	103.0	
1975	1320.0		2001	125.0	
1976	1210.0		2002	207.0	
1977	226.0		2003	457.0	
1978	637.0		2004	114.0	
1979	460.0		2005	330.0	
1989	550.0		2006	274.0	
1993	407.0		2007	330.0	
1994	217.0		2008	516.0	

1995	709.0	2009	552.0
1996	471.0	2010	651.0
1997	784.0	2011	1080.0

Explanation of peak discharge qualification codes

PeakFQ CODE	NWIS CODE	DEFINITION
D	3	Dam failure, non-recurrent flow anomaly
G	8	Discharge greater than stated value
X	3+8	Both of the above
L	4	Discharge less than stated value
K	6 OR C	Known effect of regulation or urbanization
H	7	Historic peak

- Minus-flagged discharge -- Not used in computation
  -8888.0 -- No discharge value given
- Minus-flagged water year -- Historic peak used in computation

1

Program PeakFq U. S. GEOLOGICAL SURVEY Seq.001.004
Ver. 5.2 Annual peak flow frequency analysis Run Date / Time
11/01/2007 following Bulletin 17-B Guidelines 03/16/2012 10:09

Station - 12323750 Silver Bow Creek at Warm Springs MT

EMPIRICAL FREQUENCY CURVES -- WEIBULL PLOTTING POSITIONS

WATER YEAR	RANKED DISCHARGE	SYSTEMATIC RECORD	BULL.17B ESTIMATE
1975	1320.0	0.0345	0.0345
1976	1210.0	0.0690	0.0690
2011	1080.0	0.1034	0.1034
1974	1000.0	0.1379	0.1379
1997	784.0	0.1724	0.1724
1995	709.0	0.2069	0.2069
2010	651.0	0.2414	0.2414
1978	637.0	0.2759	0.2759
1972	586.0	0.3103	0.3103
2009	552.0	0.3448	0.3448
1989	550.0	0.3793	0.3793
2008	516.0	0.4138	0.4138
1996	471.0	0.4483	0.4483
1979	460.0	0.4828	0.4828
2003	457.0	0.5172	0.5172
1993	407.0	0.5517	0.5517
1999	359.0	0.5862	0.5862
2005	330.0	0.6207	0.6207
2007	330.0	0.6552	0.6552
1973	324.0	0.6897	0.6897
1998	296.0	0.7241	0.7241
2006	274.0	0.7586	0.7586
1977	226.0	0.7931	0.7931
1994	217.0	0.8276	0.8276
2002	207.0	0.8621	0.8621

2001	125.0	0.8966	0.8966
2004	114.0	0.9310	0.9310
2000	103.0	0.9655	0.9655

1

Program PeakFq U. S. GEOLOGICAL SURVEY

Seq.001.005

Ver. 5.2 Annual peak flow frequency analysis

Run Date / Time

11/01/2007 following Bulletin 17-B Guidelines

03/16/2012 10:09

Station - 12323750 Silver Bow Creek at Warm Springs MT

```
       10000.0
+----+------------+------+--------+-----+---------+---------+-----+--------+------+-
------+----+----+-----+
                |    |            |      |        |     |         |         |     |
     |      |    |    |    |     |
                |    |            |      |        |     |         |         |     |
     |      |    |    |    |     |
                |    |            |      |        |     |         |         |     |
     |      |    |    |    |     |
                |    | *****  NOTICE  *****  NOTICE  ******       |         |     |
     |      |    |    |    |     |
 A              |    | * PRELIMINARY MACHINE COMPUTATION. *       |         |     |
     |      |    |    |    |     |
 N              |    | *  USER IS RESPONSIBLE FOR ASSESS- *       |         |     |
     |      |    |    |    |     |
 N              |    | *     MENT AND INTERPRETATION.     *       |         |     |
     |      |    |    |    |     |
 U              |    | ************************************       |         |     |
     |      |    |    |    |     |
 A              |    |            |      |        |     |         |         |     |
     |      |    |    |    |     |
 L      3160.0
+----+------------+------+--------+-----+---------+---------+-----+--------+------+-
------+----+----+-----+
                |    |         PLOT SYMBOL KEY          |         |         |     |
     |      |    |    |    |     |
 P              |    |   *  17B FINAL FREQUENCY CURVE   |         |         |     |
     |      |    |    |    |      *
 E              |    |   O  OBSERVED (SYSTEMATIC) PEAKS |         |         |     |
     |      |    |    |    |      #
 A              |    |   $  HISTORICALLY ADJUSTED PEAKS |         |         |     |
     |      |    |    |     *
 K              |    |   #  SYSTEMATIC-RECORD FREQ CURVE|         |         |     |
     |      |    |     *    |     |
                |    |   WHEN POINTS COINCIDE, ONLY THE |         |         |     |
     |      |       *    |    |     |
 M              |    |   TOPMOST SYMBOL SHOWS.          |         |         |     |
     |      |     * #    |    |     |
 A              |    |            |      |        |     |         |         |     |
     |   O  * *O    |    |    |     |
```

```
 G             |    |             |      |         |     |          |         |     |
    O      #       |    |    |     |
 N      1000.0
+----+------------+------+--------+-----+---------+---------+-----+----O---*------+-
------+----+----+-----+
 I             |    |            |      |        |     |         |         |     |
    |      |    |    |    |    |
 T             |    |            |      |        |     |         |         |     | O
    |      |    |    |    |    |
 U             |    |            |      |        |     |         |         |     *
    |      |    |    |    |    |
 D             |    |            |      |        |     |         |         * O O |
    |      |    |    |    |    |
 E             |    |            |      |        |     |         |     O O O     |
    |      |    |    |    |    |
 S             |    |            |      |        |     |         |   **    |     |
    |      |    |    |    |    |
               |    |            |      |        |     |        O*O O      |     |
    |      |    |    |    |    |
               |    |            |      |        |     |      *O |         |     |
    |      |    |    |    |    |
               |    |            |      |        |     |    *O   |         |     |
    |      |    |    |    |    |
 /      316.0
+----+------------+------+--------+-----O-*-O-----+---------+-----+--------+------+-
------+----+----+-----+
 L             |    |            |      |        | O  O*         |         |     |
    |      |    |    |    |    |
 O             |    |            |      |        *     |         |         |     |
    |      |    |    |    |    |
 G             |    |            |      |      O O     |         |         |     |
    |      |    |    |    |    |
               |    |            |      |   O    |     |         |         |     |
    |      |    |    |    |    |
 S             |    |            |      *        |     |         |         |     |
    |      |    |    |    |    |
 C             |    |            |      |        |     |         |         |     |
    |      |    |    |    |    |
 A             |    |            |      |        |     |         |         |     |
    |      |    |    |    |    |
 L             |    |          * *      |O       |     |         |         |     |
    |      |    |    |    |    |
 E             |    |          # |  O   |        |     |         |         |     |
    |      |    |    |    |    |
 /      100.0
+----+----*-*--O--+------+--------+-----+---------+---------+-----+--------+------+-
------+----+----+-----+
               |    |    #       |      |        |     |         |         |     |
    |      |    |    |    |    |
               |    *            |      |        |     |         |         |     |
    |      |    |    |    |    |
               |    #            |      |        |     |         |         |     |
    |      |    |    |    |    |
               *    |            |      |        |     |         |         |     |
    |      |    |    |    |    |
               #    |            |      |        |     |         |         |     |
    |      |    |    |    |    |
               |    |            |      |        |     |         |         |     |
    |      |    |    |    |    |
               |    |            |      |        |     |         |         |     |
    |      |    |    |    |    |
               |    |            |      |        |     |         |         |     |
    |      |    |    |    |    |
```

```
                |    |            |      |        |     |         |         |     |
     |      |       |    |    |     |
          31.6
+----+------------+------+--------+-----+---------+---------+-----+--------+------+-
------+----+----+-----+

             99.5 99.0         95.0   90.0     80.0  70.0      50.0      30.0  20.0
   10.0    5.0     2.0  1.0  0.5   0.2
                                    ANNUAL EXCEEDANCE PROBABILITY, PERCENT   (NORMAL
SCALE)
1


 End PeakFQ analysis.
   Stations processed :       1
   Number of errors   :       0
   Stations skipped   :       0
   Station years      :      28


Data records may have been ignored for the stations listed below.
(Card type must be Y, Z, N, H, I, 2, 3, 4,  or *.)
(2, 4, and * records are ignored.)

 For the station below, the following records were ignored:

 FINISHED PROCESSING STATION:  12323750       USGS Silver Bow Creek at Warm Spri


 For the station below, the following records were ignored:

 FINISHED PROCESSING STATION:
```

```
                         12323800 CFR at Galen Road.PRT
1
  Program PeakFq           U. S. GEOLOGICAL SURVEY             Seq.000.000
  Ver. 5.2            Annual peak flow frequency analysis      Run Date / Time
  11/01/2007          following Bulletin 17-B Guidelines       03/15/2012 14:05

                         --- PROCESSING OPTIONS ---

                      Plot option         = Graphics & Printer
                      Basin char output   = None
                      Print option        = Yes
                      Debug print         = No
                      Input peaks listing = Long
                      Input peaks format  = WATSTORE peak file

                      Input files used:
                         peaks (ascii)  -
C:\USERS\PMCCARTH\DESKTOP\PEAKFQWIN_TESTFILES\CLARK FORK RIVER AT GALEN
                         specifications - PKFQWPSF.TMP

                      Output file(s):
                         main - C:\USERS\PMCCARTH\DESKTOP\PEAKFQWIN_TESTFILES\CLARK
FORK RIVER AT GALEN.PRT

1


  Program PeakFq           U. S. GEOLOGICAL SURVEY             Seq.001.001
  Ver. 5.2            Annual peak flow frequency analysis      Run Date / Time
  11/01/2007          following Bulletin 17-B Guidelines       03/15/2012 14:05

                 Station - 12323800  Clark Fork near Galen MT


                     I N P U T   D A T A   S U M M A R Y

               Number of peaks in record           =       23
               Peaks not used in analysis          =        0
               Systematic peaks in analysis        =       23
               Historic peaks in analysis          =        0
               Years of historic record            =        0
               Generalized skew                    =   -0.070
                    Standard error                 =    0.640
                    Mean Square error              =    0.410
               Skew option                         =   WEIGHTED
               Gage base discharge                 =      0.0
               User supplied high outlier threshold =   --
               User supplied low outlier criterion  =      224.0
               Plotting position parameter         =     0.00


  *********  NOTICE  --  Preliminary machine computations.        *********
  *********  User responsible for assessment and interpretation.  *********

    WCF134I-NO SYSTEMATIC PEAKS WERE BELOW GAGE BASE.                   0.0
   *WCF191I-USER LOW-OUTLIER CRITERION SUPERSEDES 17B.       224.0    113.3
    WCF198I-LOW OUTLIERS BELOW FLOOD BASE WERE DROPPED.        4       224.0
    WCF163I-NO HIGH OUTLIERS OR HISTORIC PEAKS EXCEEDED HHBASE.      1835.1
1


  Program PeakFq           U. S. GEOLOGICAL SURVEY             Seq.001.002
  Ver. 5.2            Annual peak flow frequency analysis      Run Date / Time
```

Station - 12323800 Clark Fork near Galen MT

ANNUAL FREQUENCY CURVE PARAMETERS -- LOG-PEARSON TYPE III

	FLOOD BASE		LOGARITHMIC		
	DISCHARGE	EXCEEDANCE PROBABILITY	MEAN	STANDARD DEVIATION	SKEW
SYSTEMATIC RECORD	0.0	1.0000	2.7456	0.2824	-0.755
BULL.17B ESTIMATE	224.0	0.8261	2.7947	0.2077	-0.255

ANNUAL FREQUENCY CURVE -- DISCHARGES AT SELECTED EXCEEDANCE PROBABILITIES

ANNUAL EXCEEDANCE PROBABILITY	BULL.17B ESTIMATE	SYSTEMATIC RECORD	'EXPECTED PROBABILITY' ESTIMATE	95-PCT CONFIDENCE LIMITS FOR BULL. 17B ESTIMATES LOWER	UPPER
0.9950	--	66.3	--	--	--
0.9900	--	86.6	--	--	--
0.9500	--	169.3	--	--	--
0.9000	--	233.7	--	--	--
0.8000	419.7	334.2	412.3	335.2	499.1
0.6667	516.1	452.8	512.3	427.2	608.1
0.5000	636.1	603.7	636.1	537.7	754.6
0.4292	692.2	674.0	694.0	587.0	827.4
0.2000	936.8	971.6	951.4	787.2	1176.0
0.1000	1134.0	1194.0	1167.0	935.5	1487.0
0.0400	1379.0	1444.0	1451.0	1109.0	1902.0
0.0200	1558.0	1608.0	1670.0	1231.0	2223.0
0.0100	1733.0	1755.0	1897.0	1347.0	2549.0
0.0050	1906.0	1886.0	2134.0	1459.0	2883.0
0.0020	2132.0	2039.0	2466.0	1602.0	3335.0

1

Program PeakFq U. S. GEOLOGICAL SURVEY Seq.001.003
Ver. 5.2 Annual peak flow frequency analysis Run Date / Time
11/01/2007 following Bulletin 17-B Guidelines 03/15/2012 14:05

Station - 12323800 Clark Fork near Galen MT

I N P U T D A T A L I S T I N G

WATER YEAR	DISCHARGE	CODES	WATER YEAR	DISCHARGE	CODES
1989	737.0		2001	224.0	
1990	374.0		2002	324.0	
1991	795.0		2003	912.0	
1992	150.0		2004	213.0	
1993	581.0		2005	571.0	
1994	428.0		2006	528.0	
1995	1120.0		2007	605.0	
1996	926.0		2008	787.0	
1997	1240.0		2009	955.0	
1998	545.0		2010	1020.0	

1999	610.0	2011	1410.0
2000	145.0		

Explanation of peak discharge qualification codes

PeakFQ CODE	NWIS CODE	DEFINITION
D	3	Dam failure, non-recurrent flow anomaly
G	8	Discharge greater than stated value
X	3+8	Both of the above
L	4	Discharge less than stated value
K	6 OR C	Known effect of regulation or urbanization
H	7	Historic peak

- Minus-flagged discharge -- Not used in computation
  -8888.0 -- No discharge value given
- Minus-flagged water year -- Historic peak used in computation

1

Program PeakFq U. S. GEOLOGICAL SURVEY Seq.001.004
Ver. 5.2 Annual peak flow frequency analysis Run Date / Time
11/01/2007 following Bulletin 17-B Guidelines 03/15/2012 14:05

Station - 12323800 Clark Fork near Galen MT

EMPIRICAL FREQUENCY CURVES -- WEIBULL PLOTTING POSITIONS

WATER YEAR	RANKED DISCHARGE	SYSTEMATIC RECORD	BULL.17B ESTIMATE
2011	1410.0	0.0417	0.0417
1997	1240.0	0.0833	0.0833
1995	1120.0	0.1250	0.1250
2010	1020.0	0.1667	0.1667
2009	955.0	0.2083	0.2083
1996	926.0	0.2500	0.2500
2003	912.0	0.2917	0.2917
1991	795.0	0.3333	0.3333
2008	787.0	0.3750	0.3750
1989	737.0	0.4167	0.4167
1999	610.0	0.4583	0.4583
2007	605.0	0.5000	0.5000
1993	581.0	0.5417	0.5417
2005	571.0	0.5833	0.5833
1998	545.0	0.6250	0.6250
2006	528.0	0.6667	0.6667
1994	428.0	0.7083	0.7083
1990	374.0	0.7500	0.7500
2002	324.0	0.7917	0.7917
2001	224.0	0.8333	0.8333
2004	213.0	0.8750	0.8750
1992	150.0	0.9167	0.9167
2000	145.0	0.9583	0.9583

1

```
                                12323800 CFR at Galen Road.PRT
                                Program PeakFq           U. S. GEOLOGICAL SURVEY
   Seq.001.005
                                Ver. 5.2            Annual peak flow frequency analysis
   Run Date / Time
                                11/01/2007          following Bulletin 17-B Guidelines
   03/15/2012 14:05
```

Station - 12323800 Clark Fork near Galen MT

```
       10000.0
+----+------------+------+--------+-----+---------+---------+-----+--------+------+-
------+----+----+-----+
               |    |            |      |        |     |         |         |     |
     |      |       |    |    |
               |    |            |      |        |     |         |         |     |
     |      |       |    |    |
               |    |            |      |        |     |         |         |     |
     |      |       |    |    |
               |    | *****  NOTICE  *****  NOTICE  ******       |         |     |
     |      |       |    |    |
 A             |    | * PRELIMINARY MACHINE COMPUTATION. *       |         |     |
     |      |       |    |    |
 N             |    | *  USER IS RESPONSIBLE FOR ASSESS- *       |         |     |
     |      |       |    |    |
 N             |    | *     MENT AND INTERPRETATION.     *       |         |     |
     |      |       |    |    |
 U             |    | ************************************       |         |     |
     |      |       |    |    |
 A             |    |            |      |        |     |         |         |     |
     |      |       |    |    |
 L      3160.0
+----+------------+------+--------+-----+---------+---------+-----+--------+------+-
------+----+----+-----+
               |    |         PLOT SYMBOL KEY          |         |         |     |
     |      |       |    |    |
 P             |    |   *  17B FINAL FREQUENCY CURVE   |         |         |     |
     |      |       |    |    |
 E             |    |   O  OBSERVED (SYSTEMATIC) PEAKS |         |         |     |
     |      |       |    |    |     *
 A             |    |   $  HISTORICALLY ADJUSTED PEAKS |         |         |     |
     |      |       |    |    *     #
 K             |    |   #  SYSTEMATIC-RECORD FREQ CURVE|         |         |     |
     |      |       |    *    |    |
               |    |   WHEN POINTS COINCIDE, ONLY THE |         |         |     |
     |      |     * *    |    |    |
 M             |    |   TOPMOST SYMBOL SHOWS.          |         |         |     |
     |      # *     |    |    |    |
 A             |    |            |      |        |     |         |         |     |
    # O    *       |    |    |    |
 G             |    |            |      |        |     |         |         |     |
  O  *         |    |    |    |    |
 N      1000.0
+----+------------+------+--------+-----+---------+---------+-----O--O-----+------+-
------+----+----+-----+
 I             |    |            |      |        |     |         |         |O O  *
```

```
     |      |       |    |    |    |
 T          |    |          |    |        |    |         |    O O *    |
     |      |       |    |    |    |
 U          |    |          |    |        |    |         |   **   |    |
     |      |       |    |    |    |
 D          |    |          |    |        |    |        * O     |    |
     |      |       |    |    |    |
 E          |    |          |    |        |    |   O*O*O |        |    |
     |      |       |    |    |    |
 S          |    |          |    |        |    * *  #   |        |    |
     |      |       |    |    |    |
            |    |          |    |        |   O# #      |        |    |
     |      |       |    |    |    |
            |    |          |    |        *    |        |        |    |
     |      |       |    |    |    |
            |    |          |    |        |  O  |        |        |    |
     |      |       |    |    |    |
 /       316.0
+----+-----------+------+--------O-----+---------+---------+-----+--------+------+-
------+----+----+-----+
 L          |    |          |    |        |    |        |        |    |
     |      |       |    |    |    |
 O          |    |          |    |        |    |        |        |    |
     |      |       |    |    |    |
 G          |    |          |    #  O  O  |    |        |        |    |
     |      |       |    |    |    |
            |    |          |    |        |    |        |        |    |
     |      |       |    |    |    |
 S          |    |          #    |        |    |        |        |    |
     |      |       |    |    |    |
 C          |    |        # |    O |        |    |        |        |    |
     |      |       |    |    |    |
 A          |    |        O |    |        |    |        |        |    |
     |      |       |    |    |    |
 L          |    |      #   |    |        |    |        |        |    |
     |      |       |    |    |    |
 E          |    |    #     |    |        |    |        |        |    |
     |      |       |    |    |    |
 /       100.0
+----+-----------+------+--------+-----+---------+---------+-----+--------+------+-
------+----+----+-----+
            |    #     |    |    |        |    |        |        |    |
     |      |       |    |    |    |
            |    |          |    |        |    |        |        |    |
     |      |       |    |    |    |
            |    |          |    |        |    |        |        |    |
     |      |       |    |    |    |
           #    |          |    |        |    |        |        |    |
     |      |       |    |    |    |
            |    |          |    |        |    |        |        |    |
     |      |       |    |    |    |
            |    |          |    |        |    |        |        |    |
     |      |       |    |    |    |
            |    |          |    |        |    |        |        |    |
     |      |       |    |    |    |
            |    |          |    |        |    |        |        |    |
     |      |       |    |    |    |
            |    |          |    |        |    |        |        |    |
     |      |       |    |    |    |
            |    |          |    |        |    |        |        |    |
     |      |       |    |    |    |
         31.6
+----+-----------+------+--------+-----+---------+---------+-----+--------+------+-
------+----+----+-----+
```

```
                          12323800 CFR at Galen Road.PRT
             99.5 99.0         95.0   90.0     80.0  70.0      50.0      30.0  20.0
   10.0    5.0     2.0  1.0  0.5   0.2
                                   ANNUAL EXCEEDANCE PROBABILITY, PERCENT   (NORMAL
SCALE)
1



 End PeakFQ analysis.
   Stations processed :       1
   Number of errors   :       0
   Stations skipped   :       0
   Station years      :      23


Data records may have been ignored for the stations listed below.
(Card type must be Y, Z, N, H, I, 2, 3, 4,  or *.)
(2, 4, and * records are ignored.)

 For the station below, the following records were ignored:

 FINISHED PROCESSING STATION:  12323800       USGS Clark Fork near Galen MT


 For the station below, the following records were ignored:

 FINISHED PROCESSING STATION:
```

```
                         12324200 CFR at Deer Lodge.PRT
1
  Program PeakFq           U. S. GEOLOGICAL SURVEY            Seq.000.000
  Ver. 5.2            Annual peak flow frequency analysis      Run Date / Time
  11/01/2007          following Bulletin 17-B Guidelines       03/16/2012 10:06

                         --- PROCESSING OPTIONS ---

                      Plot option         = Line printer
                      Basin char output   = None
                      Print option        = Yes
                      Debug print         = No
                      Input peaks listing = Long
                      Input peaks format  = WATSTORE peak file

                      Input files used:
                         peaks (ascii)  -
C:\USERS\PMCCARTH\DESKTOP\PEAKFQWIN_TESTFILES\12324200.CI
                         specifications - PKFQWPSF.TMP

                      Output file(s):
                         main -
C:\USERS\PMCCARTH\DESKTOP\PEAKFQWIN_TESTFILES\12324200.PRT

1


  Program PeakFq           U. S. GEOLOGICAL SURVEY            Seq.001.001
  Ver. 5.2            Annual peak flow frequency analysis      Run Date / Time
  11/01/2007          following Bulletin 17-B Guidelines       03/16/2012 10:06

               Station - 12324200  Clark Fork at Deer Lodge MT


                    I N P U T   D A T A   S U M M A R Y

               Number of peaks in record           =       33
               Peaks not used in analysis          =        0
               Systematic peaks in analysis        =       33
               Historic peaks in analysis          =        0
               Years of historic record            =        0
               Generalized skew                    =    0.000
                    Standard error                 =    0.640
                    Mean Square error              =    0.410
               Skew option                         =   WEIGHTED
               Gage base discharge                 =      0.0
               User supplied high outlier threshold =   --
               User supplied low outlier criterion  =   --
               Plotting position parameter         =     0.00


  *********  NOTICE  --  Preliminary machine computations.        *********
  *********  User responsible for assessment and interpretation.  *********

    WCF134I-NO SYSTEMATIC PEAKS WERE BELOW GAGE BASE.                  0.0
    WCF195I-NO LOW OUTLIERS WERE DETECTED BELOW CRITERION.           166.8
    WCF163I-NO HIGH OUTLIERS OR HISTORIC PEAKS EXCEEDED HHBASE.     4583.5
1


  Program PeakFq           U. S. GEOLOGICAL SURVEY            Seq.001.002
  Ver. 5.2            Annual peak flow frequency analysis      Run Date / Time
  11/01/2007          following Bulletin 17-B Guidelines       03/16/2012 10:06
```

12324200 CFR at Deer Lodge.PRT

Station - 12324200 Clark Fork at Deer Lodge MT

ANNUAL FREQUENCY CURVE PARAMETERS -- LOG-PEARSON TYPE III

	FLOOD BASE		LOGARITHMIC		
	DISCHARGE	EXCEEDANCE PROBABILITY	MEAN	STANDARD DEVIATION	SKEW
SYSTEMATIC RECORD	0.0	1.0000	2.9418	0.2763	-0.297
BULL.17B ESTIMATE	0.0	1.0000	2.9418	0.2763	-0.207

ANNUAL FREQUENCY CURVE -- DISCHARGES AT SELECTED EXCEEDANCE PROBABILITIES

ANNUAL EXCEEDANCE PROBABILITY	BULL.17B ESTIMATE	SYSTEMATIC RECORD	'EXPECTED PROBABILITY' ESTIMATE	95-PCT CONFIDENCE LIMITS FOR BULL. 17B ESTIMATES LOWER	UPPER
0.9950	150.1	142.4	128.6	91.1	211.7
0.9900	180.8	173.6	160.6	114.6	248.2
0.9500	296.2	291.9	280.9	209.7	380.4
0.9000	382.0	380.3	369.8	284.7	476.5
0.8000	515.8	517.7	507.5	405.2	626.6
0.6667	677.2	682.8	672.8	551.5	813.1
0.5000	893.9	902.4	893.9	742.7	1078.0
0.4292	1000.0	1009.0	1003.0	833.6	1215.0
0.2000	1502.0	1504.0	1524.0	1235.0	1916.0
0.1000	1946.0	1932.0	2000.0	1565.0	2597.0
0.0400	2542.0	2490.0	2666.0	1984.0	3580.0
0.0200	3006.0	2913.0	3209.0	2296.0	4390.0
0.0100	3484.0	3340.0	3794.0	2609.0	5258.0
0.0050	3978.0	3772.0	4425.0	2924.0	6187.0
0.0020	4654.0	4349.0	5340.0	3344.0	7508.0

1

Program PeakFq
Ver. 5.2
11/01/2007

U. S. GEOLOGICAL SURVEY
Annual peak flow frequency analysis
following Bulletin 17-B Guidelines

Seq.001.003
Run Date / Time
03/16/2012 10:06

Station - 12324200 Clark Fork at Deer Lodge MT

I N P U T D A T A L I S T I N G

WATER YEAR	DISCHARGE	CODES	WATER YEAR	DISCHARGE	CODES
1979	697.0		1996	1400.0	
1980	1710.0		1997	2020.0	
1981	2500.0		1998	1200.0	
1982	1450.0		1999	819.0	
1983	1190.0		2000	263.0	
1984	1730.0		2001	310.0	
1985	492.0		2002	461.0	
1986	2090.0		2003	1060.0	
1987	463.0		2004	286.0	
1988	409.0		2005	848.0	
1989	1430.0		2006	654.0	

1990	507.0	2007	1130.0
1991	1020.0	2008	1020.0
1992	367.0	2009	1180.0
1993	613.0	2010	1540.0
1994	462.0	2011	1970.0
1995	1240.0		

Explanation of peak discharge qualification codes

PeakFQ CODE	NWIS CODE	DEFINITION
D	3	Dam failure, non-recurrent flow anomaly
G	8	Discharge greater than stated value
X	3+8	Both of the above
L	4	Discharge less than stated value
K	6 OR C	Known effect of regulation or urbanization
H	7	Historic peak

- Minus-flagged discharge -- Not used in computation
  -8888.0 -- No discharge value given
- Minus-flagged water year -- Historic peak used in computation

1

Program PeakFq U. S. GEOLOGICAL SURVEY Seq.001.004
Ver. 5.2 Annual peak flow frequency analysis Run Date / Time
11/01/2007 following Bulletin 17-B Guidelines 03/16/2012 10:06

Station - 12324200 Clark Fork at Deer Lodge MT

EMPIRICAL FREQUENCY CURVES -- WEIBULL PLOTTING POSITIONS

WATER YEAR	RANKED DISCHARGE	SYSTEMATIC RECORD	BULL.17B ESTIMATE
1981	2500.0	0.0294	0.0294
1986	2090.0	0.0588	0.0588
1997	2020.0	0.0882	0.0882
2011	1970.0	0.1176	0.1176
1984	1730.0	0.1471	0.1471
1980	1710.0	0.1765	0.1765
2010	1540.0	0.2059	0.2059
1982	1450.0	0.2353	0.2353
1989	1430.0	0.2647	0.2647
1996	1400.0	0.2941	0.2941
1995	1240.0	0.3235	0.3235
1998	1200.0	0.3529	0.3529
1983	1190.0	0.3824	0.3824
2009	1180.0	0.4118	0.4118
2007	1130.0	0.4412	0.4412
2003	1060.0	0.4706	0.4706
1991	1020.0	0.5000	0.5000
2008	1020.0	0.5294	0.5294
2005	848.0	0.5588	0.5588
1999	819.0	0.5882	0.5882
1979	697.0	0.6176	0.6176
2006	654.0	0.6471	0.6471

1993	613.0	0.6765	0.6765
1990	507.0	0.7059	0.7059
1985	492.0	0.7353	0.7353
1987	463.0	0.7647	0.7647
1994	462.0	0.7941	0.7941
2002	461.0	0.8235	0.8235
1988	409.0	0.8529	0.8529
1992	367.0	0.8824	0.8824
2001	310.0	0.9118	0.9118
2004	286.0	0.9412	0.9412
2000	263.0	0.9706	0.9706

1

Program PeakFq U. S. GEOLOGICAL SURVEY

Seq.001.005

Ver. 5.2 Annual peak flow frequency analysis

Run Date / Time

11/01/2007 following Bulletin 17-B Guidelines

03/16/2012 10:06

Station - 12324200 Clark Fork at Deer Lodge MT

```
       10000.0
+----+------------+------+--------+-----+---------+---------+-----+--------+------+-
------+----+----+-----+
               |    |            |      |        |     |         |         |     |
     |      |       |    |    |     |
               |    |            |      |        |     |         |         |     |
     |      |       |    |    |     |
               |    |            |      |        |     |         |         |     |
     |      |       |    |    |     |
               |    | *****  NOTICE  *****  NOTICE  ******       |         |     |
     |      |       |    |    |     |
 A             |    | * PRELIMINARY MACHINE COMPUTATION. *       |         |     |
     |      |       |    |    |     |
 N             |    | *  USER IS RESPONSIBLE FOR ASSESS- *       |         |     |
     |      |       |    |    |     |
 N             |    | *     MENT AND INTERPRETATION.     *       |         |     |
     |      |       |    |    |     *
 U             |    | ************************************       |         |     |
     |      |       |    |    *     |
 A             |    |            |      |        |     |         |         |     |
     |      |       |    *    |     |
 L      3160.0
+----+------------+------+--------+-----+---------+---------+-----+--------+------+-
------*----#----+-----+
               |    |         PLOT SYMBOL KEY          |         |         |     |
     |      |     * #    |    |     |
 P             |    |   *  17B FINAL FREQUENCY CURVE   |         |         |     |
     |      * *  O   |    |    |     |
 E             |    |   O  OBSERVED (SYSTEMATIC) PEAKS |         |         |     |
     |      #        |    |    |     |
 A             |    |   $  HISTORICALLY ADJUSTED PEAKS |         |         |     |
   O *O   O |       |    |    |     |
```

```
 K             |    |   #  SYSTEMATIC-RECORD FREQ CURVE|         |         |     | O
O    |      |       |    |     |
               |    |   WHEN POINTS COINCIDE, ONLY THE |         |         |     *
     |      |       |    |     |
 M             |    |   TOPMOST SYMBOL SHOWS.          |         |         |OO O |
     |      |       |    |     |
 A             |    |          |     |        |     |         |     OO O*     |
     |      |       |    |    |    |
 G             |    |          |     |        |     |         |O OO     |     |
     |      |       |    |    |     |
 N      1000.0
+----+------------+------+--------+-----+--------OO---**----+-----+--------+------+-
------+----+----+-----+
 I             |    |          |     |        |     |      O  *         |     |
     |      |       |    |    |     |
 T             |    |          |     |        |     |    *O*  |         |     |
     |      |       |    |    |     |
 U             |    |          |     |        |     | * O     |         |     |
     |      |       |    |    |     |
 D             |    |          |     |        |     *O O      |         |     |
     |      |       |    |    |     |
 E             |    |          |     |        |     |         |         |     |
     |      |       |    |    |     |
 S             |    |          |     |        *   O O         |         |     |
     |      |       |    |    |     |
               |    |          |     |      O O O   |         |         |     |
     |      |       |    |    |     |
               |    |          |     *    O   |     |         |         |     |
     |      |       |    |    |     |
               |    |          |     | O      |     |         |         |     |
     |      |       |    |    |     |
 /      316.0
+----+------------+-----O+--------+-----+---------+---------+-----+--------+------+-
------+----+----+-----+
 L             |    |         * * O    |        |     |         |         |     |
     |      |       |    |    |     |
 O             |    |      O   |     |        |     |         |         |     |
     |      |       |    |    |     |
 G             |    |    * *   |     |        |     |         |         |     |
     |      |       |    |    |     |
               |    |          |     |        |     |         |         |     |
     |      |       |    |    |     |
 S             |    *          |     |        |     |         |         |     |
     |      |       |    |    |     |
 C           *    |    |    |     |        |     |         |         |     |
     |      |       |    |    |     |
 A            #    |          |     |        |     |         |         |     |
     |      |       |    |    |     |
 L             |    |          |     |        |     |         |         |     |
     |      |       |    |    |     |
 E             |    |          |     |        |     |         |         |     |
     |      |       |    |    |     |
 /      100.0
+----+------------+------+--------+-----+---------+---------+-----+--------+------+-
------+----+----+-----+
               |    |          |     |        |     |         |         |     |
     |      |       |    |    |     |
               |    |          |     |        |     |         |         |     |
     |      |       |    |    |     |
               |    |          |     |        |     |         |         |     |
     |      |       |    |    |     |
               |    |          |     |        |     |         |         |     |
     |      |       |    |    |     |
               |    |          |     |        |     |         |         |     |
     |      |       |    |    |     |
```

```
                |    |            |      |         |     |          |          |     |
     |      |    |    |    |     |
                |    |            |      |         |     |          |          |     |
     |      |    |    |    |     |
                |    |            |      |         |     |          |          |     |
     |      |    |    |    |     |
                |    |            |      |         |     |          |          |     |
     |      |    |    |    |     |
                |    |            |      |         |     |          |          |     |
     |      |    |    |    |     |
          31.6
+----+------------+------+--------+-----+---------+---------+-----+--------+------+-
------+----+----+-----+

             99.5 99.0         95.0   90.0     80.0  70.0      50.0      30.0  20.0
   10.0    5.0     2.0  1.0  0.5   0.2
                                   ANNUAL EXCEEDANCE PROBABILITY, PERCENT   (NORMAL
SCALE)
1
```

```
 End PeakFQ analysis.
   Stations processed :       1
   Number of errors   :       0
   Stations skipped   :       0
   Station years      :      33
```

Data records may have been ignored for the stations listed below.
(Card type must be Y, Z, N, H, I, 2, 3, 4, or *.)
(2, 4, and * records are ignored.)

For the station below, the following records were ignored:

FINISHED PROCESSING STATION: 12324200 USGS Clark Fork at Deer Lodge MT

For the station below, the following records were ignored:

FINISHED PROCESSING STATION:

Appendix E

Hydraulics

DRAFT

Manning’s n Estimate

CLARK FORK RIVER OU - PHASES 5+6

DETERMINATION OF MANNING'S n FOR RIVER CHANNEL AND FLOODPLAIN

Q_{2YR} = 727 cfs

S_o = 0.0016 ft/ft

Hd_{CH} = 3.29

R_{CH} = 3.13

Hd = 2.99

R 2.85

D_{84} = 2.9 in

D_{50} = 1.8 in

D_{16} = 1.1 in

- ANDERSON (1970)

$$n = 0.0395 \left(D_{50}\right)^{1/6}$$

$$n = 0.0395 \left(1.8\,in \frac{1\,ft}{12\,in}\right)^{1/6} = \underline{\underline{0.029}}$$

- LIMERINOS (1970)

$$n = \frac{0.113\, d^{1/6}}{1.16 + 2.00 \log\left(\frac{d}{D_{84}}\right)}$$

D_{84} = 2.9 in = 0.074 m

d = 3.29 ft = 1.0 m

$$n = \frac{0.113\,(1.0)^{1/6}}{1.16 + 2\log\left(\frac{1.0}{0.074}\right)} = \underline{\underline{0.033}}$$

- STRICKLER (1923)

$$n = a\,(D_{90})^{1/6}$$

$a = 0.0385 \rightarrow 0.041$

$$n = 0.0395\left(3\,\text{in}\left(\frac{1\,\text{ft}}{12\,\text{in}}\right)\right)^{1/6} = 0.031$$

$$n = 0.041\,\left(3\left(1/12\right)\right)^{1/6} = \underline{\underline{0.032}}$$

- JARRETT (1984)

$$n = 0.39\,S^{0.38}\,R^{-0.16}$$

$$n = 0.39\,(0.0016)^{0.38}\,(3.13)^{-0.16} = \underline{\underline{0.028}}$$

- MINNESOTA TECH RELEASE 3 1989

$$n = \underline{\underline{0.028}}$$

- CHOW 1959

$$n = \underline{\underline{0.038}}$$

$$\boxed{\text{AVE} = 0.0313}$$

(ALC No 15114-01 3/4

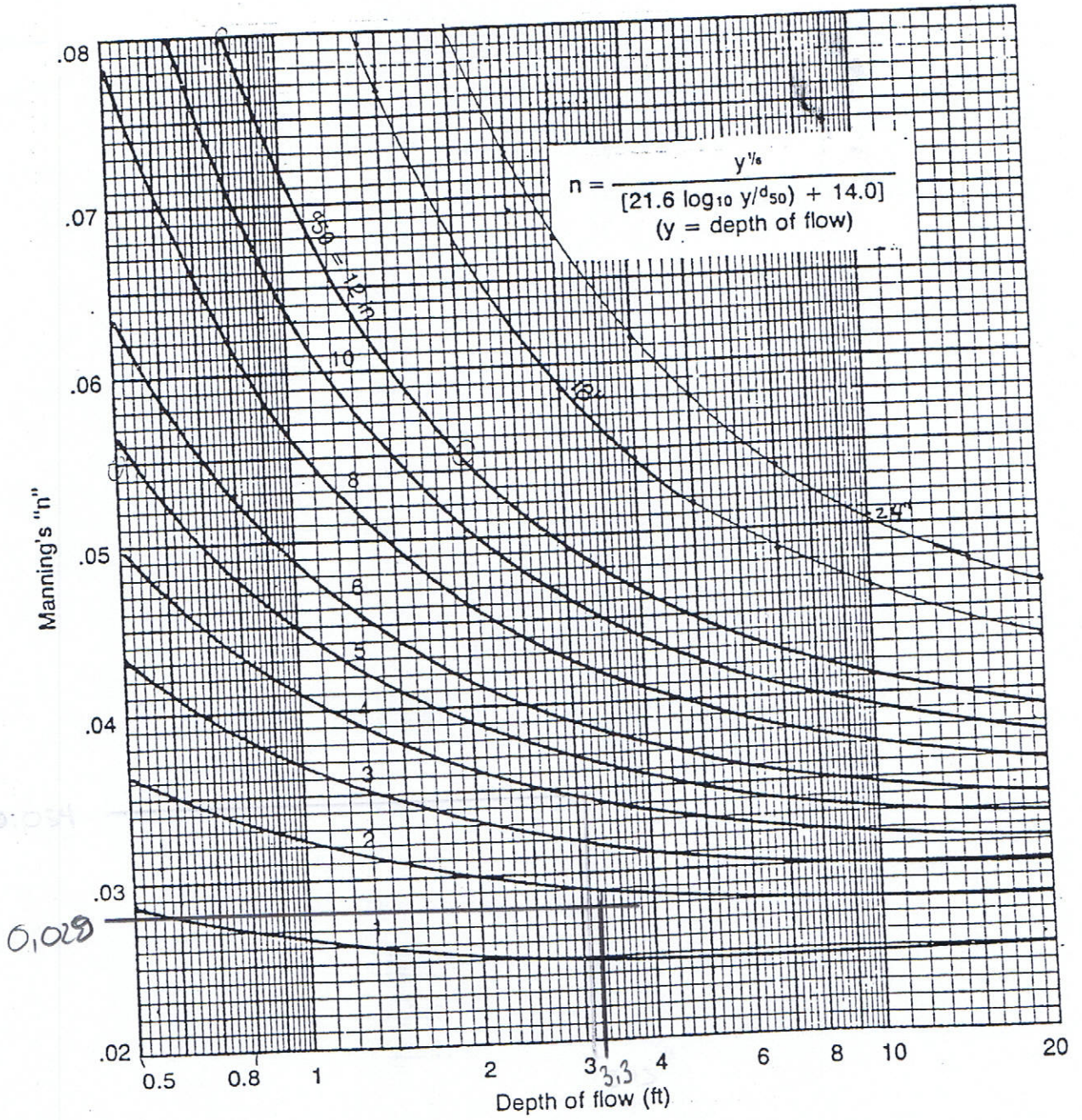


Figure 5-2. Values of n for riprap-lined channels D50 size vs. depth of flow (d)

U.S. DEPT OF AGRICULTURE
LOOSE RIPRAP PROTECTION
MINNESOTA TECHNICAL RELEASE 3
JULY 1989

Show

Manning's n Values

Reference tables for Manning's n values for Channels, Closed Conduits Flowing Partially Full, and Corrugated Metal Pipes.

Manning's n for Channels (Chow, 1959).

Type of Channel and Description	Minimum	Normal	Maximum
Natural streams - minor streams (top width at floodstage < 100 ft)			
1. Main Channels			
a. clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. same as above, but more stones and weeds	0.030	0.035	0.040
c. clean, winding, some pools and shoals	0.033	0.040	0.045
d. same as above, but some weeds and stones	0.035	0.045	0.050
e. same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
f. same as "d" with more stones	0.045	0.050	0.060
g. sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
2. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
a. bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
b. bottom: cobbles with large boulders	0.040	0.050	0.070
3. Floodplains			
a. Pasture, no brush			
1.short grass	0.025	0.030	0.035
2. high grass	0.030	0.035	0.050
b. Cultivated areas			
1. no crop	0.020	0.030	0.040
2. mature row crops	0.025	0.035	0.045
3. mature field crops	0.030	0.040	0.050
c. Brush			
1. scattered brush, heavy weeds	0.035	0.050	0.070
2. light brush and trees, in winter	0.035	0.050	0.060
3. light brush and trees, in summer	0.040	0.060	0.080
4. medium to dense brush, in winter	0.045	0.070	0.110
5. medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. dense willows, summer, straight	0.110	0.150	0.200

2-Year Event

HEC-RAS Plan: CFR Design Flow River: CFR_CL Reach: CFR Profile: 2yr

Reach	River Sta	Profile	Q Total	Min Ch El Sta	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Top Width	Vel Chnl	Q Channel	Froude # Chl	Hydr Depth C	Hydr Radius C	Top W Act Chan	Shear Chan
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft)	(ft/s)	(cfs)		(ft)	(ft)	(ft)	(lb/sq ft)
CFR	23282.1	2yr	754.00	1218.78	4709.25	4715.36		4715.51	0.001022	65.78	3.06	754.00	0.28	3.74	3.54	65.78	0.23
CFR	23228	2yr	754.00	48.44	4709.77	4715.35	4712.49	4715.45	0.000636	79.14	2.49	754.00	0.22	3.83	3.69	79.14	0.15
CFR	23192		Bridge														
CFR	23156	2yr	754.00	66.62	4709.20	4715.31		4715.40	0.000462	77.41	2.28	754.00	0.19	4.26	4.13	77.41	0.12
CFR	23100.0	2yr	754.00	1762.76	4710.58	4715.10		4715.33	0.001954	58.76	3.91	754.00	0.38	3.32	3.14	58.10	0.38
CFR	22956.3	2yr	754.00	1995.88	4709.50	4714.87		4715.09	0.001451	75.50	3.79	751.32	0.34	3.91	3.75	50.64	0.34
CFR	22606.0	2yr	754.00	2266.54	4710.59	4714.33		4714.54	0.001681	79.99	3.62	753.91	0.35	3.28	3.13	63.58	0.33
CFR	22349.9	2yr	754.00	2334.50	4708.62	4713.92		4714.14	0.001461	140.93	3.72	749.59	0.33	3.87	3.62	52.12	0.33
CFR	22047.4	2yr	754.00	2111.87	4707.88	4713.54		4713.72	0.001230	446.18	3.55	718.68	0.30	4.24	3.83	47.79	0.29
CFR	21661.8	2yr	754.00	2612.14	4707.98	4713.07		4713.25	0.001217	347.08	3.58	710.60	0.30	4.31	3.91	46.06	0.30
CFR	21288.1	2yr	754.00	2686.46	4709.10	4712.21		4712.54	0.003392	78.88	4.58	753.88	0.49	2.77	2.63	59.37	0.56
CFR	20885.9	2yr	754.00	2523.84	4706.91	4711.51		4711.69	0.001307	70.42	3.44	753.96	0.31	3.73	3.49	58.84	0.29
CFR	20452.2	2yr	754.00	2497.18	4704.59	4711.03		4711.19	0.001005	69.95	3.28	751.29	0.28	4.31	3.98	53.09	0.25
CFR	20152.9	2yr	754.00	1944.66	4706.09	4710.47		4710.75	0.002277	130.89	4.25	737.87	0.41	3.34	3.17	52.01	0.45
CFR	19673.0	2yr	754.00	1999.41	4704.02	4709.94		4710.06	0.000890	184.85	2.77	737.97	0.26	3.56	3.37	74.80	0.19
CFR	19289.8	2yr	754.00	1501.03	4704.64	4709.24		4709.52	0.002340	126.64	4.27	748.82	0.41	3.31	3.13	52.93	0.46
CFR	18852.7	2yr	754.00	1448.54	4702.78	4708.73		4708.89	0.000880	58.08	3.20	753.99	0.26	4.57	4.22	51.57	0.23
CFR	18469.6	2yr	754.00	1430.10	4705.00	4708.24		4708.42	0.001768	290.65	3.45	739.70	0.36	2.90	2.80	74.04	0.31
CFR	18351.3	2yr	754.00	1611.47	4703.40	4708.07		4708.22	0.001599	344.45	3.15	735.05	0.33	2.85	2.63	81.94	0.26
CFR	18290.2	2yr	754.00	1712.05	4702.42	4707.97		4708.13	0.001169	303.81	3.28	736.16	0.29	3.89	3.55	57.68	0.26
CFR	18044.8	2yr	754.00	1955.43	4702.07	4707.66		4707.84	0.001176	178.49	3.44	749.90	0.30	4.04	3.79	53.93	0.28
CFR	17872.7	2yr	754.00	2131.20	4703.15	4707.57		4707.65	0.000777	397.97	2.27	738.19	0.23	2.95	2.77	110.10	0.13
CFR	17595.7	2yr	754.00	2265.13	4703.15	4707.27		4707.39	0.001086	227.16	2.86	749.01	0.28	3.18	3.04	82.31	0.21
CFR	17396.7	2yr	754.00	2319.37	4702.89	4706.97		4707.14	0.001500	120.71	3.25	752.49	0.33	3.02	2.89	76.83	0.27
CFR	16918.1	2yr	754.00	2185.89	4701.82	4706.05		4706.30	0.002017	79.09	4.04	751.13	0.39	3.26	3.21	57.03	0.40
CFR	16612.2	2yr	754.00	1592.47	4701.15	4705.32		4705.61	0.002523	55.86	4.30	754.00	0.43	3.14	2.98	55.86	0.47
CFR	16264.4	2yr	754.00	1409.21	4700.10	4704.76		4704.93	0.001412	181.34	3.47	681.49	0.32	3.60	3.34	54.61	0.29
CFR	15947.2	2yr	754.00	1275.10	4700.27	4703.84		4704.22	0.003710	51.41	4.96	754.00	0.51	2.99	2.77	50.93	0.64
CFR	15566.1	2yr	754.00	1394.03	4698.28	4702.74		4703.06	0.002495	48.73	4.56	753.99	0.42	3.62	3.29	45.71	0.51
CFR	15091.5	2yr	754.00	1249.55	4695.42	4702.49		4702.58	0.000434	64.12	2.42	753.99	0.19	5.09	4.72	61.15	0.13
CFR	14604.7	2yr	754.00	1046.67	4697.51	4701.83		4702.12	0.002796	105.69	4.37	753.31	0.45	2.95	2.83	58.52	0.49
CFR	14218.6	2yr	754.00	1201.02	4695.79	4700.89		4701.18	0.002135	47.19	4.33	754.00	0.40	3.69	3.42	47.19	0.46
CFR	13905.5	2yr	754.00	1325.86	4694.55	4700.40		4700.62	0.001419	83.88	3.82	732.89	0.33	4.11	3.84	46.79	0.34
CFR	13422.4	2yr	754.00	803.40	4694.12	4699.75		4699.95	0.001334	54.09	3.58	754.00	0.32	3.89	3.67	54.09	0.31
CFR	13012.6	2yr	754.00	936.60	4695.50	4699.16		4699.33	0.001703	85.57	3.36	753.80	0.35	2.93	2.77	76.66	0.29
CFR	12583.6	2yr	754.00	1497.41	4694.36	4698.16		4698.42	0.002690	72.23	4.10	753.40	0.44	2.71	2.65	67.66	0.45
CFR	12145.0	2yr	754.00	1709.00	4690.77	4697.72		4697.83	0.000707	101.50	2.60	748.08	0.24	3.79	3.65	75.78	0.16
CFR	11609.7	2yr	754.00	1268.31	4692.95	4696.97		4697.22	0.002034	58.07	3.96	754.00	0.39	3.28	3.11	58.07	0.39
CFR	11181.9	2yr	754.00	1011.45	4691.31	4695.80		4696.08	0.003573	77.41	4.24	754.00	0.49	2.30	2.25	77.41	0.50
CFR	10736.1	2yr	754.00	969.42	4690.24	4695.13		4695.25	0.001047	315.87	2.78	717.89	0.28	3.12	3.01	82.80	0.20
CFR	10137.7	2yr	754.00	576.61	4690.47	4694.19		4694.40	0.002020	121.67	3.64	752.91	0.38	2.82	2.75	73.26	0.35
CFR	9823.3	2yr	754.00	367.58	4689.60	4693.30		4693.60	0.003205	157.09	4.40	748.95	0.48	2.67	2.59	63.79	0.52
CFR	9326.1	2yr	754.00	1083.94	4687.73	4692.28		4692.49	0.001569	102.26	3.67	751.83	0.34	3.58	3.36	57.15	0.33
CFR	9106.3	2yr	754.00	1055.26	4689.06	4691.79		4692.03	0.003000	496.67	3.95	734.95	0.45	2.38	2.31	78.12	0.43
CFR	8951.0	2yr	754.00	937.37	4688.01	4691.61		4691.68	0.001309	703.08	2.25	753.91	0.29	1.91	1.85	175.40	0.15
CFR	8661.2	2yr	754.00	738.60	4686.90	4690.96		4691.19	0.002097	773.17	3.91	752.06	0.38	3.20	2.97	60.22	0.39
CFR	8221.4	2yr	754.00	345.72	4685.71	4690.14		4690.36	0.001695	303.57	3.76	754.00	0.35	3.52	3.29	56.98	0.35
CFR	7755.8	2yr	754.00	420.10	4685.03	4689.51	4687.40	4689.68	0.001238	274.91	3.30	753.50	0.31	3.64	3.43	62.71	0.27
CFR	7700		Inl Struct														
CFR	7614.0	2yr	754.00	398.08	4685.44	4689.45		4689.62	0.001386	500.58	3.29	742.78	0.32	3.25	3.13	69.47	0.27
CFR	7214.1	2yr	754.00	704.44	4685.33	4688.88		4689.05	0.001472	859.69	3.29	741.60	0.33	3.07	3.00	73.46	0.28
CFR	6630.6	2yr	754.00	389.47	4683.67	4687.86		4688.07	0.001898	582.97	3.68	752.59	0.37	3.00	2.93	68.15	0.35
CFR	6329.6	2yr	754.00	251.60	4683.98	4687.31	4685.90	4687.49	0.001899	386.57	3.44	754.00	0.37	2.73	2.64	80.23	0.31
CFR	6165		Inl Struct														
CFR	6070.3	2yr	754.00	545.45	4682.94	4687.30		4687.39	0.000709	420.13	2.39	753.97	0.23	3.35	3.21	94.01	0.14
CFR	5559.7	2yr	754.00	1069.26	4681.52	4686.83		4686.97	0.000929	232.15	2.99	753.60	0.27	3.88	3.67	64.93	0.21
CFR	5088.6	2yr	754.00	1226.65	4681.41	4686.15		4686.37	0.001827	244.27	3.84	728.76	0.37	3.42	3.21	55.46	0.37
CFR	4683.6	2yr	754.00	875.36	4682.02	4685.64		4685.77	0.001126	1015.44	2.86	753.39	0.29	3.11	2.97	84.58	0.21
CFR	4235.7	2yr	754.00	265.33	4680.81	4684.86		4685.08	0.002172	302.76	3.75	754.00	0.39	2.84	2.72	70.78	0.37
CFR	3783.9	2yr	754.00	239.20	4680.74	4684.06		4684.20	0.001661	143.42	3.11	732.10	0.34	2.56	2.52	92.02	0.26
CFR	3487.5	2yr	754.00	427.08	4679.19	4683.55		4683.73	0.001510	94.88	3.51	731.93	0.33	3.44	3.23	60.57	0.30

HEC-RAS Plan: CFR Design Flow River: CFR_CL Reach: CFR Profile: 2yr (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El Sta	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Top Width	Vel Chnl	Q Channel	Froude # Chl	Hydr Depth C	Hydr Radius C	Top W Act Chan	Shear Chan
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft)	(ft/s)	(cfs)		(ft)	(ft)	(ft)	(lb/sq ft)
CFR	3028.0	2yr	754.00	507.11	4679.26	4682.65		4682.86	0.002428	183.90	3.71	750.68	0.41	2.55	2.47	79.43	0.37
CFR	2786.0	2yr	754.00	396.69	4678.24	4682.29		4682.42	0.001287	90.39	2.88	754.00	0.30	2.90	2.71	90.39	0.22
CFR	2645.3	2yr	754.00	196.42	4678.17	4682.14		4682.25	0.001040	207.62	2.80	672.14	0.28	3.21	3.06	74.72	0.20
CFR	2244.1	2yr	754.00	86.79	4677.95	4681.28		4681.57	0.003034	93.05	4.32	752.01	0.46	2.74	2.62	63.70	0.50
CFR	1921.5	2yr	754.00	531.55	4676.06	4680.66		4680.86	0.001557	71.53	3.59	753.93	0.34	3.45	3.28	60.84	0.32
CFR	1558.4	2yr	754.00	759.92	4675.85	4680.22		4680.37	0.001102	68.34	3.10	753.94	0.29	3.59	3.41	67.74	0.23
CFR	1224.6	2yr	754.00	786.25	4675.55	4679.70		4679.91	0.001781	68.48	3.63	754.00	0.36	3.14	3.01	66.22	0.33
CFR	835.5	2yr	754.00	448.01	4675.27	4679.00		4679.18	0.001928	94.85	3.44	754.00	0.37	2.70	2.61	81.37	0.31
CFR	682.5	2yr	754.00	281.66	4673.19	4678.74		4678.94	0.001310	66.20	3.55	752.72	0.32	3.80	3.67	55.80	0.30
CFR	529	2yr	754.00	40.62	4673.72	4678.50	4676.40	4678.72	0.001547	55.81	3.73	754.00	0.34	3.63	3.48	55.81	0.34
CFR	496		Bridge														
CFR	463	2yr	754.00	31.70	4673.23	4678.43		4678.61	0.001306	61.88	3.40	754.00	0.32	3.58	3.44	61.88	0.28
CFR	368.0	2yr	754.00	202.50	4674.07	4678.27		4678.46	0.001882	274.30	3.60	721.44	0.37	2.97	2.86	67.34	0.34
CFR	139.6	2yr	754.00	382.40	4672.96	4677.85	4675.83	4678.07	0.001600	263.77	3.69	754.00	0.34	3.58	3.34	57.00	0.33

HEC-RAS Plan: CFR Design Flow River: CFR_CL Reach: CFR Profile: 2yr

Reach	River Sta	Profile	Q Total	Q Left	Q Right	Hydr Depth L	Hydr Depth R	Shear LOB	Shear ROB	Shear Total	Shear Chan	Vel Left	Vel Right
			(cfs)	(cfs)	(cfs)	(ft)	(ft)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(ft/s)	(ft/s)
CFR	23282.1	2yr	754.00							0.23	0.23		
CFR	23228	2yr	754.00							0.15	0.15		
CFR	23192		Bridge										
CFR	23156	2yr	754.00							0.12	0.12		
CFR	23100.0	2yr	754.00		0.00		0.03		0.00	0.38	0.38		0.10
CFR	22956.3	2yr	754.00		2.68		0.27		0.02	0.24	0.34		0.40
CFR	22606.0	2yr	754.00	0.09		0.04		0.00		0.26	0.33	0.15	
CFR	22349.9	2yr	754.00	1.90	2.51	0.42	0.13	0.04	0.01	0.14	0.33	0.32	0.26
CFR	22047.4	2yr	754.00	34.44	0.88	0.32	0.16	0.02	0.01	0.06	0.29	0.29	0.26
CFR	21661.8	2yr	754.00	43.38	0.01	0.42	0.04	0.03	0.00	0.07	0.30	0.34	0.17
CFR	21288.1	2yr	754.00	0.12		0.05		0.01		0.43	0.56	0.13	
CFR	20885.9	2yr	754.00		0.04		0.04		0.00	0.24	0.29		0.10
CFR	20452.2	2yr	754.00	2.71		0.39		0.02		0.20	0.25	0.42	
CFR	20152.9	2yr	754.00	3.30	12.83	0.20	0.45	0.03	0.06	0.21	0.45	0.41	0.72
CFR	19673.0	2yr	754.00	1.81	14.22	0.27	0.54	0.01	0.03	0.09	0.19	0.31	0.30
CFR	19289.8	2yr	754.00		5.18		0.25		0.04	0.22	0.46		0.28
CFR	18852.7	2yr	754.00		0.01		0.03		0.00	0.21	0.23		0.04
CFR	18469.6	2yr	754.00	9.66	4.64	0.16	0.75	0.02	0.08	0.10	0.31	0.31	0.82
CFR	18351.3	2yr	754.00	18.95		0.20		0.02		0.08	0.26	0.36	
CFR	18290.2	2yr	754.00	17.70	0.14	0.21	0.12	0.02	0.01	0.07	0.26	0.37	0.20
CFR	18044.8	2yr	754.00	4.10		0.19		0.01		0.10	0.28	0.18	
CFR	17872.7	2yr	754.00	14.15	1.67	0.27	0.22	0.01	0.01	0.05	0.13	0.20	0.30
CFR	17595.7	2yr	754.00	4.69	0.30	0.19	0.11	0.01	0.01	0.08	0.21	0.18	0.31
CFR	17396.7	2yr	754.00	1.51		0.17		0.02		0.18	0.27	0.20	
CFR	16918.1	2yr	754.00	1.27	1.60	0.25	1.69	0.03	0.11	0.30	0.40	0.26	0.41
CFR	16612.2	2yr	754.00							0.47	0.47		
CFR	16264.4	2yr	754.00	71.97	0.55	0.81	0.24	0.07	0.02	0.14	0.29	0.81	0.14
CFR	15947.2	2yr	754.00		0.00		0.01			0.64	0.64		0.02
CFR	15566.1	2yr	754.00	0.01		0.03		0.01		0.48	0.51	0.13	
CFR	15091.5	2yr	754.00	0.01		0.05		0.00		0.12	0.13	0.07	
CFR	14604.7	2yr	754.00		0.69		0.11		0.02	0.29	0.49		0.13
CFR	14218.6	2yr	754.00							0.46	0.46		
CFR	13905.5	2yr	754.00	21.11		0.74		0.07		0.22	0.34	0.77	
CFR	13422.4	2yr	754.00							0.31	0.31		
CFR	13012.6	2yr	754.00		0.20		0.10		0.01	0.27	0.29		0.23
CFR	12583.6	2yr	754.00		0.60		0.35		0.06	0.42	0.45		0.37
CFR	12145.0	2yr	754.00	5.88	0.03	0.54	0.48	0.02	0.01	0.13	0.16	0.43	0.22
CFR	11609.7	2yr	754.00							0.39	0.39		
CFR	11181.9	2yr	754.00							0.50	0.50		
CFR	10736.1	2yr	754.00	0.19	35.93	0.11	0.51	0.01	0.03	0.08	0.20	0.19	0.31
CFR	10137.7	2yr	754.00		1.10		0.11		0.01	0.22	0.35		0.20
CFR	9823.3	2yr	754.00		5.05		0.19		0.04	0.24	0.52		0.29
CFR	9326.1	2yr	754.00	2.17		0.43		0.04		0.29	0.33	0.56	
CFR	9106.3	2yr	754.00	19.05		0.38		0.07		0.28	0.43	0.86	

HEC-RAS Plan: CFR Design Flow River: CFR_CL Reach: CFR Profile: 2yr (Continued)

Reach	River Sta	Profile	Q Total	Q Left	Q Right	Hydr Depth L	Hydr Depth R	Shear LOB	Shear ROB	Shear Total	Shear Chan	Vel Left	Vel Right
			(cfs)	(cfs)	(cfs)	(ft)	(ft)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(ft/s)	(ft/s)
CFR	8951.0	2yr	754.00	0.10		0.05		0.00		0.14	0.15	0.13	
CFR	8661.2	2yr	754.00	1.94		0.23		0.03		0.31	0.39	0.45	
CFR	8221.4	2yr	754.00							0.35	0.35		
CFR	7755.8	2yr	754.00		0.50		0.08		0.01	0.14	0.27		0.11
CFR	7700		Inl Struct										
CFR	7614.0	2yr	754.00		11.22		0.28		0.02	0.13	0.27		0.41
CFR	7214.1	2yr	754.00	12.40		0.52		0.05		0.19	0.28	0.53	
CFR	6630.6	2yr	754.00		1.41		0.14		0.02	0.28	0.35		0.52
CFR	6329.6	2yr	754.00		0.00		0.01		0.00	0.29	0.31		0.06
CFR	6165		Inl Struct										
CFR	6070.3	2yr	754.00		0.03		0.03		0.00	0.13	0.14		0.11
CFR	5559.7	2yr	754.00	0.40		0.14		0.01		0.16	0.21	0.12	
CFR	5088.6	2yr	754.00	25.23	0.01	0.36	0.03	0.04	0.00	0.13	0.37	0.45	0.16
CFR	4683.6	2yr	754.00	0.31	0.30	0.13	0.09	0.01	0.01	0.16	0.21	0.13	0.29
CFR	4235.7	2yr	754.00							0.37	0.37		
CFR	3783.9	2yr	754.00		21.90		0.47		0.05	0.19	0.26		1.04
CFR	3487.5	2yr	754.00		22.07		0.54		0.05	0.21	0.30		1.19
CFR	3028.0	2yr	754.00	3.31	0.01	0.17	0.04	0.03	0.01	0.24	0.37	0.38	0.24
CFR	2786.0	2yr	754.00							0.22	0.22		
CFR	2645.3	2yr	754.00	81.86		1.28		0.08		0.15	0.20	1.00	
CFR	2244.1	2yr	754.00		1.99		0.17		0.03	0.35	0.50		0.41
CFR	1921.5	2yr	754.00		0.07		0.03		0.00	0.27	0.32		0.18
CFR	1558.4	2yr	754.00		0.06		0.23		0.01	0.23	0.23		0.45
CFR	1224.6	2yr	754.00	0.00		0.01				0.32	0.33	0.03	
CFR	835.5	2yr	754.00	0.00		0.04		0.00		0.31	0.31	0.12	
CFR	682.5	2yr	754.00	0.28	1.01	0.16	0.25	0.01	0.02	0.26	0.30	0.45	0.61
CFR	529	2yr	754.00							0.34	0.34		
CFR	496		Bridge										
CFR	463	2yr	754.00							0.28	0.28		
CFR	368.0	2yr	754.00		32.56		1.39		0.14	0.31	0.34		2.12
CFR	139.6	2yr	754.00							0.33	0.33		

10-Year Event

HEC-RAS Plan: CFR Design Flow River: CFR_CL Reach: CFR Profile: 10yr

Reach	River Sta	Profile	Q Total	Min Ch El Sta	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Top Width	Vel Chnl	Q Channel	Froude # Chl	Hydr Depth C	Hydr Radius C	Top W Act Chan	Shear Chan
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft)	(ft/s)	(cfs)		(ft)	(ft)	(ft)	(lb/sq ft)
CFR	23282.1	10yr	1508.00	1218.78	4709.25	4716.59		4716.92	0.001707	266.78	4.56	1506.21	0.37	4.66	4.37	70.98	0.47
CFR	23228	10yr	1508.00	48.44	4709.77	4716.60	4713.45	4716.81	0.001143	93.61	3.66	1508.00	0.31	4.40	4.25	93.61	0.30
CFR	23192		Bridge														
CFR	23156	10yr	1508.00	66.62	4709.20	4716.52		4716.71	0.000919	88.80	3.51	1508.00	0.28	4.84	4.70	88.80	0.27
CFR	23100.0	10yr	1508.00	1762.76	4710.58	4716.01	4714.46	4716.58	0.003584	159.26	6.08	1498.77	0.53	4.09	3.86	60.27	0.86
CFR	22956.3	10yr	1508.00	1995.88	4709.50	4715.91		4716.16	0.001585	838.41	4.58	1148.90	0.36	4.91	4.65	51.10	0.46
CFR	22606.0	10yr	1508.00	2266.54	4710.59	4715.37		4715.59	0.001603	1081.66	4.25	1165.19	0.36	4.31	4.12	63.64	0.41
CFR	22349.9	10yr	1508.00	2334.50	4708.62	4714.87	4712.85	4715.16	0.001844	1322.53	4.78	1202.45	0.38	4.80	4.43	52.38	0.51
CFR	22047.4	10yr	1508.00	2111.87	4707.88	4714.59		4714.72	0.001041	1584.80	3.66	934.97	0.29	5.03	4.56	50.82	0.30
CFR	21661.8	10yr	1508.00	2612.14	4707.98	4714.24		4714.36	0.000926	1757.94	3.60	915.76	0.27	5.34	4.86	47.62	0.28
CFR	21288.1	10yr	1508.00	2686.46	4709.10	4713.55		4713.86	0.002470	931.14	4.97	1219.50	0.44	4.00	3.77	61.33	0.58
CFR	20885.9	10yr	1508.00	2523.84	4706.91	4712.88		4713.13	0.001461	962.47	4.31	1309.89	0.35	4.81	4.51	63.22	0.41
CFR	20452.2	10yr	1508.00	2497.18	4704.59	4712.25	4709.35	4712.52	0.001437	807.41	4.50	1330.99	0.35	5.27	4.88	56.15	0.44
CFR	20152.9	10yr	1508.00	1944.66	4706.09	4711.76	4710.18	4712.03	0.001923	978.70	4.76	1146.64	0.39	4.55	4.26	52.90	0.51
CFR	19673.0	10yr	1508.00	1999.41	4704.02	4711.26		4711.41	0.000900	693.72	3.42	1250.55	0.27	4.88	4.59	74.96	0.26
CFR	19289.8	10yr	1508.00	1501.03	4704.64	4710.67		4710.93	0.001918	702.33	4.56	1194.05	0.39	4.22	4.00	62.14	0.48
CFR	18852.7	10yr	1508.00	1448.54	4702.78	4709.74	4707.04	4710.11	0.001847	570.58	4.99	1449.99	0.39	5.09	4.71	57.16	0.54
CFR	18469.6	10yr	1508.00	1430.10	4705.00	4709.35		4709.49	0.001248	1403.98	3.58	1062.04	0.32	3.98	3.85	74.49	0.30
CFR	18351.3	10yr	1508.00	1611.47	4703.40	4709.27		4709.35	0.000856	1501.61	2.81	946.94	0.25	3.82	3.54	88.35	0.19
CFR	18290.2	10yr	1508.00	1712.05	4702.42	4709.22		4709.30	0.000716	1651.55	2.80	858.11	0.24	4.36	4.04	70.22	0.18
CFR	18044.8	10yr	1508.00	1955.43	4702.07	4708.85		4709.06	0.001295	1229.73	4.19	1191.21	0.33	5.04	4.73	56.42	0.38
CFR	17872.7	10yr	1508.00	2131.20	4703.15	4708.79		4708.84	0.000662	1642.25	2.12	1096.55	0.22	2.95	2.83	175.01	0.12
CFR	17595.7	10yr	1508.00	2265.13	4703.15	4708.57		4708.67	0.000755	1393.87	2.98	1103.13	0.25	4.46	4.26	82.93	0.20
CFR	17396.7	10yr	1508.00	2319.37	4702.89	4708.39		4708.51	0.000931	1421.21	3.26	1117.02	0.28	4.35	4.17	78.63	0.24
CFR	16918.1	10yr	1508.00	2185.89	4701.82	4707.60	4705.48	4707.92	0.001764	807.37	4.82	1332.65	0.39	4.72	4.64	58.56	0.51
CFR	16612.2	10yr	1508.00	1592.47	4701.15	4706.72	4704.97	4707.22	0.002971	463.60	5.71	1466.32	0.49	4.27	4.05	60.04	0.75
CFR	16264.4	10yr	1508.00	1409.21	4700.10	4706.34		4706.51	0.001153	644.97	3.82	1107.07	0.31	4.83	4.51	59.89	0.32
CFR	15947.2	10yr	1508.00	1275.10	4700.27	4705.52	4703.85	4705.95	0.002753	534.47	5.57	1346.58	0.47	4.45	4.13	54.35	0.71
CFR	15566.1	10yr	1508.00	1394.03	4698.28	4704.39		4704.92	0.002793	135.59	5.92	1456.07	0.47	4.98	4.48	49.32	0.78
CFR	15091.5	10yr	1508.00	1249.55	4695.42	4704.07		4704.24	0.000673	500.83	3.41	1416.56	0.24	6.13	5.68	67.83	0.24
CFR	14604.7	10yr	1508.00	1046.67	4697.51	4703.39		4703.70	0.002136	535.71	4.83	1302.59	0.41	4.23	4.03	63.73	0.54
CFR	14218.6	10yr	1508.00	1201.02	4695.79	4702.50	4700.34	4702.89	0.002159	584.55	5.26	1345.59	0.42	4.90	4.54	52.21	0.61
CFR	13905.5	10yr	1508.00	1325.86	4694.55	4702.12		4702.35	0.001240	683.68	4.37	1191.06	0.32	5.68	5.21	48.03	0.40
CFR	13422.4	10yr	1508.00	803.40	4694.12	4701.23	4698.68	4701.57	0.002167	588.62	4.82	1451.33	0.42	4.17	3.97	72.22	0.54
CFR	13012.6	10yr	1508.00	936.60	4695.50	4700.69		4700.87	0.001255	809.39	3.72	1280.77	0.31	4.36	4.06	78.90	0.32
CFR	12583.6	10yr	1508.00	1497.41	4694.36	4699.77		4700.14	0.002387	307.96	4.93	1477.36	0.44	3.91	3.82	76.56	0.57
CFR	12145.0	10yr	1508.00	1709.00	4690.77	4699.36		4699.54	0.000772	258.53	3.46	1421.82	0.26	5.43	5.23	75.78	0.25
CFR	11609.7	10yr	1508.00	1268.31	4692.95	4698.42		4698.82	0.002707	118.17	5.10	1478.64	0.46	3.82	3.66	75.94	0.62
CFR	11181.9	10yr	1508.00	1011.45	4691.31	4696.86		4697.37	0.004256	80.70	5.77	1508.00	0.56	3.24	3.13	80.70	0.83
CFR	10736.1	10yr	1508.00	969.42	4690.24	4696.35		4696.48	0.000951	578.56	3.28	1180.66	0.28	4.28	4.13	84.18	0.25
CFR	10137.7	10yr	1508.00	576.61	4690.47	4695.41		4695.70	0.002017	364.29	4.53	1352.11	0.40	3.97	3.83	75.09	0.48
CFR	9823.3	10yr	1508.00	367.58	4689.60	4694.61		4694.98	0.002702	286.28	5.20	1320.27	0.46	3.95	3.78	64.16	0.64
CFR	9326.1	10yr	1508.00	1083.94	4687.73	4693.42		4693.79	0.002163	1061.95	5.06	1370.10	0.42	4.57	4.28	59.30	0.58
CFR	9106.3	10yr	1508.00	1055.26	4689.06	4693.05		4693.29	0.002121	1254.25	4.31	1234.84	0.40	3.52	3.41	81.48	0.45
CFR	8951.0	10yr	1508.00	937.37	4688.01	4692.99		4693.06	0.000750	1740.02	2.33	1391.61	0.24	3.06	2.97	195.10	0.14
CFR	8661.2	10yr	1508.00	738.60	4686.90	4692.36		4692.70	0.002062	1859.20	4.91	1362.51	0.41	4.55	4.23	60.98	0.55
CFR	8221.4	10yr	1508.00	345.72	4685.71	4691.49		4691.79	0.002024	1843.89	4.67	1326.79	0.40	4.25	3.99	66.87	0.50
CFR	7755.8	10yr	1508.00	420.10	4685.03	4690.75	4688.42	4690.96	0.001500	1252.16	4.02	1258.75	0.35	4.21	3.98	74.52	0.37
CFR	7700		Inl Struct														
CFR	7614.0	10yr	1508.00	398.08	4685.44	4690.74		4690.92	0.001217	1269.87	3.81	1201.60	0.31	4.53	4.30	69.63	0.33
CFR	7214.1	10yr	1508.00	704.44	4685.33	4690.02		4690.33	0.001901	1773.77	4.57	1414.06	0.39	4.19	4.05	73.80	0.48
CFR	6630.6	10yr	1508.00	389.47	4683.67	4689.03		4689.27	0.001729	1401.03	4.33	1229.65	0.37	4.15	4.01	68.33	0.43
CFR	6329.6	10yr	1508.00	251.60	4683.98	4688.61	4686.77	4688.80	0.001457	1321.20	3.84	1247.65	0.34	3.98	3.80	81.81	0.35
CFR	6165		Inl Struct														
CFR	6070.3	10yr	1508.00	545.45	4682.94	4688.60		4688.73	0.000828	1422.40	3.04	1346.68	0.26	4.27	4.09	103.73	0.21
CFR	5559.7	10yr	1508.00	1069.26	4681.52	4687.92		4688.17	0.001429	1150.57	4.25	1378.85	0.34	4.75	4.50	68.18	0.40
CFR	5088.6	10yr	1508.00	1226.65	4681.41	4687.31		4687.50	0.001471	1569.30	4.19	1063.86	0.34	4.58	4.30	55.46	0.39
CFR	4683.6	10yr	1508.00	875.36	4682.02	4686.89		4687.02	0.000939	2654.82	3.27	1205.90	0.28	4.35	4.16	84.58	0.24
CFR	4235.7	10yr	1508.00	265.33	4680.81	4685.96	4684.30	4686.34	0.002775	1448.81	5.08	1431.21	0.46	3.74	3.57	75.48	0.62
CFR	3783.9	10yr	1508.00	239.20	4680.74	4685.17		4685.37	0.001617	1286.86	3.77	1289.22	0.36	3.48	3.43	98.14	0.35
CFR	3487.5	10yr	1508.00	427.08	4679.19	4684.63		4684.87	0.001695	1110.51	4.43	1215.00	0.37	4.49	4.20	61.15	0.44

HEC-RAS Plan: CFR Design Flow River: CFR_CL Reach: CFR Profile: 10yr (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El Sta	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Top Width	Vel Chnl	Q Channel	Froude # Chl	Hydr Depth C	Hydr Radius C	Top W Act Chan	Shear Chan
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft)	(ft/s)	(cfs)		(ft)	(ft)	(ft)	(lb/sq ft)
CFR	3028.0	10yr	1508.00	507.11	4679.26	4683.89		4684.11	0.001762	1322.97	4.12	1241.68	0.37	3.79	3.67	79.43	0.40
CFR	2786.0	10yr	1508.00	396.69	4678.24	4683.49		4683.69	0.001712	1098.03	3.70	1440.95	0.36	3.37	3.19	115.58	0.34
CFR	2645.3	10yr	1508.00	196.42	4678.17	4683.31		4683.48	0.001212	1013.33	3.62	1196.71	0.31	4.20	4.01	78.55	0.30
CFR	2244.1	10yr	1508.00	86.79	4677.95	4682.58		4682.83	0.002335	844.54	4.54	1200.49	0.42	3.59	3.44	73.72	0.50
CFR	1921.5	10yr	1508.00	531.55	4676.06	4682.13		4682.30	0.001241	761.24	3.74	1152.58	0.32	4.33	4.12	71.15	0.32
CFR	1558.4	10yr	1508.00	759.92	4675.85	4681.63		4681.85	0.001190	573.88	3.99	1355.58	0.32	4.94	4.69	68.85	0.35
CFR	1224.6	10yr	1508.00	786.25	4675.55	4681.32		4681.47	0.001036	680.76	3.51	1127.72	0.29	4.51	4.30	71.12	0.28
CFR	835.5	10yr	1508.00	448.01	4675.27	4680.84		4681.05	0.001200	1267.23	3.74	1411.08	0.32	4.36	4.23	86.68	0.32
CFR	682.5	10yr	1508.00	281.66	4673.19	4680.63		4680.87	0.001059	958.54	4.18	1325.82	0.31	5.69	5.49	55.80	0.36
CFR	529	10yr	1508.00	40.62	4673.72	4680.28	4677.64	4680.65	0.001851	64.77	4.88	1508.00	0.39	4.77	4.55	64.77	0.53
CFR	496		Bridge														
CFR	463	10yr	1508.00	31.70	4673.23	4680.21		4680.52	0.001518	70.75	4.44	1508.00	0.36	4.80	4.59	70.75	0.43
CFR	368.0	10yr	1508.00	202.50	4674.07	4680.17		4680.36	0.001166	860.91	3.72	1259.90	0.31	4.49	4.29	75.31	0.31
CFR	139.6	10yr	1508.00	382.40	4672.96	4679.72	4676.97	4680.03	0.001603	1060.56	4.55	1462.80	0.36	4.88	4.56	65.96	0.46

HEC-RAS Plan: CFR Design Flow River: CFR_CL Reach: CFR Profile: 10yr

Reach	River Sta	Profile	Q Total	Q Left	Q Right	Hydr Depth L	Hydr Depth R	Shear LOB	Shear ROB	Shear Total	Shear Chan	Vel Left	Vel Right
			(cfs)	(cfs)	(cfs)	(ft)	(ft)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(ft/s)	(ft/s)
CFR	23282.1	10yr	1508.00	0.58	1.20	0.14	0.09	0.01	0.01	0.35	0.47	0.27	1.24
CFR	23228	10yr	1508.00							0.30	0.30		
CFR	23192		Bridge										
CFR	23156	10yr	1508.00							0.27	0.27		
CFR	23100.0	10yr	1508.00	0.11	9.12	0.02	0.18	0.01	0.04	0.36	0.86	0.21	0.65
CFR	22956.3	10yr	1508.00	236.26	122.84	0.62	0.42	0.06	0.04	0.08	0.46	1.22	0.61
CFR	22606.0	10yr	1508.00	284.81	58.00	0.64	0.28	0.06	0.03	0.07	0.41	0.75	0.49
CFR	22349.9	10yr	1508.00	72.69	232.86	0.34	0.47	0.04	0.05	0.07	0.51	0.36	0.73
CFR	22047.4	10yr	1508.00	367.02	206.01	1.12	0.47	0.07	0.03	0.06	0.30	0.52	0.52
CFR	21661.8	10yr	1508.00	424.77	167.47	0.92	0.41	0.05	0.02	0.05	0.28	0.43	0.81
CFR	21288.1	10yr	1508.00	288.50		0.61		0.09		0.13	0.58	0.56	
CFR	20885.9	10yr	1508.00	83.16	114.95	0.34	0.48	0.03	0.04	0.06	0.41	0.49	0.59
CFR	20452.2	10yr	1508.00	58.87	118.14	0.33	0.44	0.03	0.04	0.07	0.44	0.68	0.55
CFR	20152.9	10yr	1508.00	160.28	201.08	0.59	0.40	0.07	0.05	0.08	0.51	0.91	0.80
CFR	19673.0	10yr	1508.00	98.99	158.46	0.53	1.15	0.03	0.06	0.07	0.26	0.55	0.49
CFR	19289.8	10yr	1508.00	22.14	291.81	0.29	0.89	0.03	0.11	0.13	0.48	0.85	0.60
CFR	18852.7	10yr	1508.00		58.01		0.35		0.04	0.10	0.54		0.34
CFR	18469.6	10yr	1508.00	344.05	101.91	0.75	0.37	0.06	0.03	0.06	0.30	0.73	0.50
CFR	18351.3	10yr	1508.00	477.82	83.25	0.89	0.42	0.05	0.02	0.05	0.19	0.70	0.43
CFR	18290.2	10yr	1508.00	555.47	94.42	0.92	0.53	0.04	0.02	0.04	0.18	0.64	0.48
CFR	18044.8	10yr	1508.00	312.96	3.83	0.73	0.58	0.06	0.05	0.07	0.38	0.43	0.06
CFR	17872.7	10yr	1508.00	365.01	46.44	0.88	0.83	0.04	0.03	0.05	0.12	0.35	0.59
CFR	17595.7	10yr	1508.00	377.43	27.45	0.85	1.11	0.04	0.05	0.05	0.20	0.37	1.25
CFR	17396.7	10yr	1508.00	390.77	0.21	0.77	0.45	0.04	0.02	0.06	0.24	0.39	0.60
CFR	16918.1	10yr	1508.00	120.70	54.65	0.49	0.85	0.05	0.09	0.10	0.51	0.43	0.37
CFR	16612.2	10yr	1508.00	2.04	39.64	0.16	0.34	0.03	0.06	0.15	0.75	0.40	0.31
CFR	16264.4	10yr	1508.00	333.05	67.88	1.19	0.81	0.09	0.06	0.10	0.32	0.95	0.30
CFR	15947.2	10yr	1508.00	30.23	131.19	0.25	0.93	0.04	0.16	0.18	0.71	0.62	0.50
CFR	15566.1	10yr	1508.00	51.93		0.47		0.08		0.35	0.78	1.29	
CFR	15091.5	10yr	1508.00	76.53	14.91	0.70	0.41	0.03	0.02	0.05	0.24	0.62	0.14
CFR	14604.7	10yr	1508.00	1.36	204.04	0.44	1.00	0.06	0.13	0.18	0.54	0.07	0.48
CFR	14218.6	10yr	1508.00	101.83	60.58	0.40	0.66	0.05	0.09	0.12	0.61	0.71	0.52
CFR	13905.5	10yr	1508.00	316.94	0.00	0.64	0.01	0.05	0.00	0.08	0.40	0.78	0.04
CFR	13422.4	10yr	1508.00	34.26	22.41	0.32	0.21	0.04	0.03	0.10	0.54	1.10	0.26
CFR	13012.6	10yr	1508.00	62.64	164.59	0.32	0.57	0.02	0.04	0.07	0.32	0.71	0.67
CFR	12583.6	10yr	1508.00	9.24	21.40	0.17	0.44	0.03	0.06	0.18	0.57	0.40	0.51
CFR	12145.0	10yr	1508.00	85.89	0.29	0.62	1.55	0.03	0.02	0.10	0.25	0.76	0.34
CFR	11609.7	10yr	1508.00	0.02	29.34	0.02	1.08	0.00	0.18	0.45	0.62	0.10	0.81
CFR	11181.9	10yr	1508.00							0.83	0.83		
CFR	10736.1	10yr	1508.00	67.20	260.14	0.82	1.21	0.05	0.07	0.09	0.25	0.71	0.57
CFR	10137.7	10yr	1508.00		155.89		0.88		0.11	0.19	0.48		0.61
CFR	9823.3	10yr	1508.00		187.73		1.06		0.18	0.28	0.64		0.80
CFR	9326.1	10yr	1508.00	137.90		0.58		0.08		0.17	0.58	0.83	
CFR	9106.3	10yr	1508.00	273.16		0.75		0.10		0.17	0.45	1.01	

HEC-RAS Plan: CFR Design Flow River: CFR_CL Reach: CFR Profile: 10yr (Continued)

Reach	River Sta	Profile	Q Total	Q Left	Q Right	Hydr Depth L	Hydr Depth R	Shear LOB	Shear ROB	Shear Total	Shear Chan	Vel Left	Vel Right
			(cfs)	(cfs)	(cfs)	(ft)	(ft)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(ft/s)	(ft/s)
CFR	8951.0	10yr	1508.00	93.32	23.07	0.67	0.65	0.03	0.03	0.07	0.14	0.52	0.88
CFR	8661.2	10yr	1508.00	108.28	37.21	0.88	0.81	0.11	0.10	0.25	0.55	1.04	1.68
CFR	8221.4	10yr	1508.00	12.99	168.22	0.46	0.66	0.06	0.08	0.15	0.50	0.67	0.85
CFR	7755.8	10yr	1508.00		249.25		0.97		0.09	0.13	0.37		0.56
CFR	7700		Inl Struct										
CFR	7614.0	10yr	1508.00	0.00	306.40	0.04	1.02	0.00	0.08	0.12	0.33	0.09	0.87
CFR	7214.1	10yr	1508.00	93.94		0.59		0.07		0.16	0.48	0.56	
CFR	6630.6	10yr	1508.00	0.19	278.17	0.16	0.68	0.02	0.07	0.14	0.43	0.30	1.41
CFR	6329.6	10yr	1508.00		260.35		0.68		0.06	0.13	0.35		1.47
CFR	6165		Inl Struct										
CFR	6070.3	10yr	1508.00		161.32		0.62		0.03	0.08	0.21		0.88
CFR	5559.7	10yr	1508.00	128.81	0.33	0.65	0.24	0.06	0.02	0.10	0.40	0.42	0.61
CFR	5088.6	10yr	1508.00	311.09	133.06	0.94	0.48	0.09	0.04	0.09	0.39	0.55	0.99
CFR	4683.6	10yr	1508.00	40.62	261.48	0.52	0.53	0.03	0.03	0.05	0.24	0.29	0.87
CFR	4235.7	10yr	1508.00		76.79		0.24		0.04	0.15	0.62		0.96
CFR	3783.9	10yr	1508.00		218.78		0.52		0.05	0.13	0.35		1.40
CFR	3487.5	10yr	1508.00	149.55	143.46	0.64	0.64	0.07	0.07	0.11	0.44	0.78	1.44
CFR	3028.0	10yr	1508.00	232.08	34.24	0.72	1.01	0.08	0.11	0.13	0.40	0.83	1.78
CFR	2786.0	10yr	1508.00	59.91	7.14	0.46	0.39	0.05	0.04	0.16	0.34	0.67	0.93
CFR	2645.3	10yr	1508.00	237.99	73.30	2.04	0.33	0.15	0.02	0.10	0.30	1.37	0.72
CFR	2244.1	10yr	1508.00		307.52		0.50		0.07	0.11	0.50		0.79
CFR	1921.5	10yr	1508.00	65.01	290.41	0.68	0.57	0.05	0.04	0.07	0.32	0.67	1.05
CFR	1558.4	10yr	1508.00	146.98	5.44	0.60	0.36	0.04	0.03	0.09	0.35	0.61	0.72
CFR	1224.6	10yr	1508.00	281.64	98.63	0.89	0.58	0.06	0.04	0.08	0.28	0.74	0.95
CFR	835.5	10yr	1508.00	75.04	21.88	0.60	1.05	0.04	0.08	0.12	0.32	0.61	1.50
CFR	682.5	10yr	1508.00	67.07	115.11	1.18	0.66	0.08	0.04	0.13	0.36	1.54	1.20
CFR	529	10yr	1508.00							0.53	0.53		
CFR	496		Bridge										
CFR	463	10yr	1508.00							0.43	0.43		
CFR	368.0	10yr	1508.00	1.11	246.98	0.32	1.04	0.02	0.08	0.14	0.31	0.16	1.48
CFR	139.6	10yr	1508.00	3.23	41.97	0.30	0.71	0.03	0.07	0.21	0.46	0.18	1.36

100-Year Event

HEC-RAS Plan: CFR Design Flow River: CFR_CL Reach: CFR Profile: 100yr

Reach	River Sta	Profile	Q Total	Min Ch El Sta	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Top Width	Vel Chnl	Q Channel	Froude # Chl	Hydr Depth C	Hydr Radius C	Top W Act Chan	Shear Chan
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft)	(ft/s)	(cfs)		(ft)	(ft)	(ft)	(lb/sq ft)
CFR	23282.1	100yr	2539.00	1218.78	4709.25	4717.74		4718.22	0.001888	1294.31	5.55	2286.54	0.41	5.80	5.45	70.98	0.64
CFR	23228	100yr	2539.00	48.44	4709.77	4717.72	4714.57	4718.09	0.001627	100.30	4.88	2539.00	0.38	5.19	5.01	100.30	0.51
CFR	23192		Bridge														
CFR	23156	100yr	2539.00	66.62	4709.20	4717.58		4717.94	0.001512	99.37	4.80	2539.00	0.37	5.33	5.17	99.37	0.49
CFR	23100.0	100yr	2539.00	1762.76	4710.58	4715.88	4715.71	4717.62	0.011269	102.21	10.59	2530.71	0.93	3.98	3.76	60.01	2.64
CFR	22956.3	100yr	2539.00	1995.88	4709.50	4716.46		4716.67	0.001646	1102.27	4.91	1370.87	0.38	5.31	5.01	52.61	0.52
CFR	22606.0	100yr	2539.00	2266.54	4710.59	4715.89		4716.10	0.001687	1599.95	4.70	1445.52	0.38	4.83	4.62	63.64	0.49
CFR	22349.9	100yr	2539.00	2334.50	4708.62	4715.43		4715.67	0.001841	1831.76	5.11	1435.60	0.39	5.35	4.91	52.52	0.56
CFR	22047.4	100yr	2539.00	2111.87	4707.88	4715.15		4715.26	0.001035	2007.36	3.92	1111.20	0.29	5.58	5.06	50.82	0.33
CFR	21661.8	100yr	2539.00	2612.14	4707.98	4714.86		4714.94	0.000773	2418.88	3.54	1005.57	0.26	5.96	5.42	47.62	0.26
CFR	21288.1	100yr	2539.00	2686.46	4709.10	4714.15		4714.49	0.002906	1502.05	5.78	1634.51	0.48	4.44	4.19	63.65	0.76
CFR	20885.9	100yr	2539.00	2523.84	4706.91	4713.52		4713.73	0.001431	1510.27	4.63	1597.62	0.35	5.45	5.11	63.22	0.46
CFR	20452.2	100yr	2539.00	2497.18	4704.59	4712.91		4713.17	0.001517	1694.92	5.01	1668.83	0.36	5.94	5.49	56.15	0.52
CFR	20152.9	100yr	2539.00	1944.66	4706.09	4712.60		4712.74	0.001230	1486.81	4.26	1215.01	0.32	5.39	5.05	52.90	0.39
CFR	19673.0	100yr	2539.00	1999.41	4704.02	4712.06		4712.24	0.001040	1063.68	4.07	1732.24	0.30	5.68	5.35	74.96	0.35
CFR	19289.8	100yr	2539.00	1501.03	4704.64	4711.63		4711.80	0.001380	1098.82	4.43	1423.46	0.34	5.17	4.91	62.14	0.42
CFR	18852.7	100yr	2539.00	1448.54	4702.78	4710.17	4708.35	4710.88	0.003475	744.84	7.13	2253.83	0.54	5.42	5.02	58.33	1.09
CFR	18469.6	100yr	2539.00	1430.10	4705.00	4710.04		4710.13	0.000933	2030.33	3.45	1200.36	0.28	4.68	4.52	74.49	0.26
CFR	18351.3	100yr	2539.00	1611.47	4703.40	4709.97		4710.03	0.000676	2140.74	2.79	1115.26	0.23	4.52	4.19	88.35	0.18
CFR	18290.2	100yr	2539.00	1712.05	4702.42	4709.94		4709.99	0.000570	2204.51	2.74	978.90	0.22	5.00	4.64	71.37	0.17
CFR	18044.8	100yr	2539.00	1955.43	4702.07	4709.58		4709.78	0.001345	1953.12	4.67	1521.13	0.34	5.77	5.42	56.42	0.45
CFR	17872.7	100yr	2539.00	2131.20	4703.15	4709.52		4709.57	0.000589	2201.49	2.32	1492.09	0.21	3.68	3.53	175.01	0.13
CFR	17595.7	100yr	2539.00	2265.13	4703.15	4709.33		4709.42	0.000732	2000.15	3.26	1411.65	0.25	5.22	4.99	82.93	0.23
CFR	17396.7	100yr	2539.00	2319.37	4702.89	4709.18		4709.28	0.000806	2116.74	3.40	1374.90	0.26	5.15	4.93	78.63	0.25
CFR	16918.1	100yr	2539.00	2185.89	4701.82	4708.58		4708.82	0.001420	2048.44	4.90	1634.89	0.36	5.70	5.59	58.56	0.50
CFR	16612.2	100yr	2539.00	1592.47	4701.15	4707.65	4707.18	4708.17	0.003210	1111.96	6.44	2024.26	0.52	4.81	4.57	65.45	0.91
CFR	16264.4	100yr	2539.00	1409.21	4700.10	4707.19		4707.39	0.001334	1029.10	4.58	1557.98	0.34	5.68	5.29	59.89	0.44
CFR	15947.2	100yr	2539.00	1275.10	4700.27	4706.62		4706.90	0.001874	1423.62	5.32	1604.63	0.40	5.55	5.14	54.35	0.60
CFR	15566.1	100yr	2539.00	1394.03	4698.28	4705.46	4703.89	4706.09	0.003009	776.71	6.98	2085.52	0.50	6.04	5.41	49.50	1.02
CFR	15091.5	100yr	2539.00	1249.55	4695.42	4705.06		4705.29	0.000837	1053.93	4.20	2031.01	0.28	7.12	6.60	67.83	0.35
CFR	14604.7	100yr	2539.00	1046.67	4697.51	4704.13		4704.61	0.002923	731.36	6.29	1991.34	0.50	4.97	4.73	63.73	0.86
CFR	14218.6	100yr	2539.00	1201.02	4695.79	4703.26		4703.64	0.002253	944.32	5.91	1744.90	0.44	5.66	5.24	52.21	0.74
CFR	13905.5	100yr	2539.00	1325.86	4694.55	4702.90		4703.10	0.001225	1169.34	4.73	1467.09	0.33	6.46	5.92	48.03	0.45
CFR	13422.4	100yr	2539.00	803.40	4694.12	4701.90	4699.94	4702.29	0.002530	1062.31	5.63	1975.19	0.46	4.69	4.47	74.75	0.71
CFR	13012.6	100yr	2539.00	936.60	4695.50	4701.49		4701.62	0.000982	1456.48	3.67	1493.70	0.28	5.16	4.77	78.96	0.29
CFR	12583.6	100yr	2539.00	1497.41	4694.36	4700.98		4701.15	0.001293	1615.93	4.14	1635.25	0.33	4.76	4.66	82.97	0.38
CFR	12145.0	100yr	2539.00	1709.00	4690.77	4700.62		4700.79	0.000678	1512.64	3.72	1887.84	0.25	6.69	6.45	75.78	0.27
CFR	11609.7	100yr	2539.00	1268.31	4692.95	4699.69	4697.83	4700.16	0.002382	610.76	5.80	2241.11	0.45	5.09	4.88	75.94	0.73
CFR	11181.9	100yr	2539.00	1011.45	4691.31	4697.68	4696.73	4698.60	0.005873	163.10	7.71	2533.69	0.68	3.97	3.80	82.84	1.39
CFR	10736.1	100yr	2539.00	969.42	4690.24	4697.39		4697.53	0.000922	1008.90	3.73	1670.41	0.28	5.32	5.13	84.18	0.30
CFR	10137.7	100yr	2539.00	576.61	4690.47	4696.45		4696.79	0.002014	621.69	5.25	1976.87	0.41	4.99	4.77	75.43	0.60
CFR	9823.3	100yr	2539.00	367.58	4689.60	4695.56		4696.04	0.002975	354.75	6.25	1970.30	0.50	4.88	4.62	64.63	0.86
CFR	9326.1	100yr	2539.00	1083.94	4687.73	4694.28		4694.70	0.002484	2016.49	5.92	1911.23	0.46	5.21	4.88	62.01	0.76
CFR	9106.3	100yr	2539.00	1055.26	4689.06	4694.06		4694.24	0.001483	1726.97	4.18	1547.76	0.35	4.40	4.26	84.09	0.39
CFR	8951.0	100yr	2539.00	937.37	4688.01	4693.98		4694.07	0.000643	2045.10	2.58	2049.25	0.23	4.00	3.88	198.50	0.16
CFR	8661.2	100yr	2539.00	738.60	4686.90	4693.23		4693.70	0.002522	2178.75	6.10	2016.58	0.46	5.43	5.04	60.98	0.79
CFR	8221.4	100yr	2539.00	345.72	4685.71	4692.44		4692.72	0.001800	2027.20	5.03	1749.75	0.39	5.20	4.87	66.87	0.55
CFR	7755.8	100yr	2539.00	420.10	4685.03	4691.74	4690.40	4691.96	0.001450	1673.59	4.48	1739.74	0.35	5.09	4.81	76.21	0.44
CFR	7700		Inl Struct														
CFR	7614.0	100yr	2539.00	398.08	4685.44	4691.74		4691.92	0.001150	1759.78	4.21	1621.18	0.32	5.53	5.22	69.66	0.37
CFR	7214.1	100yr	2539.00	704.44	4685.33	4690.78		4691.26	0.002632	2142.22	5.97	2181.24	0.47	4.95	4.73	73.90	0.78
CFR	6630.6	100yr	2539.00	389.47	4683.67	4689.88		4690.09	0.001499	1874.61	4.51	1544.07	0.36	4.95	4.75	69.08	0.44
CFR	6329.6	100yr	2539.00	251.60	4683.98	4689.49	4688.16	4689.69	0.001385	2013.59	4.25	1691.29	0.34	4.85	4.61	81.97	0.40
CFR	6165		Inl Struct														
CFR	6070.3	100yr	2539.00	545.45	4682.94	4689.49		4689.63	0.000900	1996.54	3.45	1860.83	0.28	4.85	4.66	111.13	0.26
CFR	5559.7	100yr	2539.00	1069.26	4681.52	4688.53		4688.93	0.002132	1492.63	5.63	2060.82	0.43	5.37	5.08	68.18	0.68
CFR	5088.6	100yr	2539.00	1226.65	4681.41	4687.91		4688.09	0.001519	2053.18	4.61	1325.49	0.36	5.18	4.86	55.46	0.46
CFR	4683.6	100yr	2539.00	875.36	4682.02	4687.46		4687.60	0.000975	2810.80	3.62	1511.57	0.29	4.93	4.72	84.58	0.29
CFR	4235.7	100yr	2539.00	265.33	4680.81	4686.64		4686.96	0.002529	2276.09	5.37	1789.61	0.45	4.37	4.16	76.30	0.66
CFR	3783.9	100yr	2539.00	239.20	4680.74	4685.88		4686.09	0.001616	1829.97	4.24	1746.20	0.37	4.16	4.08	99.11	0.41
CFR	3487.5	100yr	2539.00	427.08	4679.19	4685.37		4685.61	0.001664	1741.68	4.86	1554.64	0.37	5.23	4.90	61.15	0.51

HEC-RAS Plan: CFR Design Flow River: CFR_CL Reach: CFR Profile: 100yr (Continued)

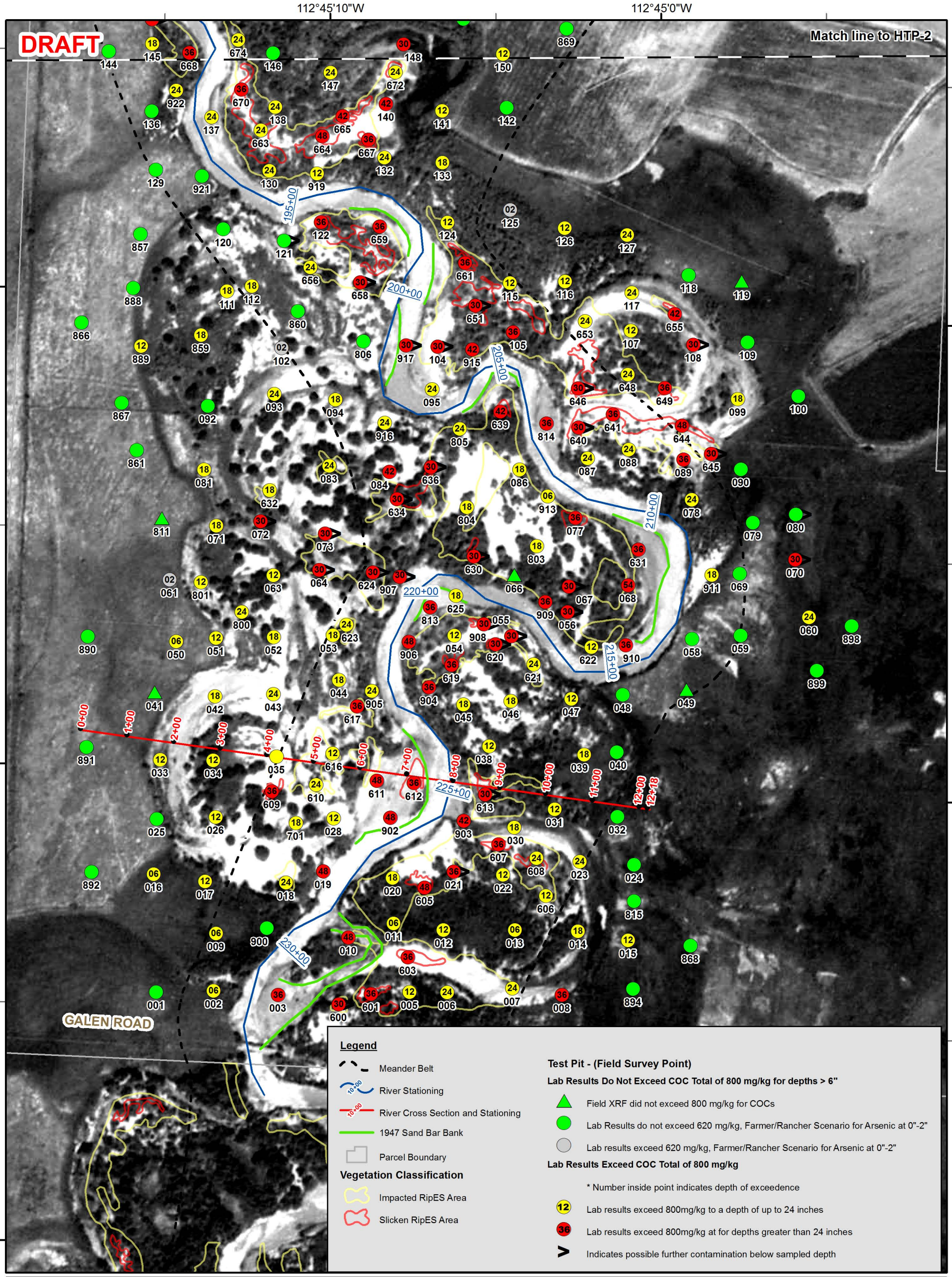
Reach	River Sta	Profile	Q Total	Min Ch El Sta	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Top Width	Vel Chnl	Q Channel	Froude # Chl	Hydr Depth C	Hydr Radius C	Top W Act Chan	Shear Chan
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft)	(ft/s)	(cfs)		(ft)	(ft)	(ft)	(lb/sq ft)
CFR	3028.0	100yr	2539.00	507.11	4679.26	4684.67		4684.90	0.001741	1700.68	4.64	1684.41	0.38	4.57	4.42	79.43	0.48
CFR	2786.0	100yr	2539.00	396.69	4678.24	4684.08		4684.41	0.002416	1752.50	4.90	2239.63	0.43	3.96	3.75	115.58	0.57
CFR	2645.3	100yr	2539.00	196.42	4678.17	4683.89		4684.10	0.001543	1795.27	4.46	1673.04	0.36	4.78	4.56	78.55	0.44
CFR	2244.1	100yr	2539.00	86.79	4677.95	4683.38		4683.52	0.001519	1636.47	4.12	1334.79	0.35	4.28	4.09	75.77	0.39
CFR	1921.5	100yr	2539.00	531.55	4676.06	4683.16		4683.24	0.000605	1691.58	3.01	1150.32	0.23	5.37	5.11	71.15	0.19
CFR	1558.4	100yr	2539.00	759.92	4675.85	4682.82		4682.98	0.000848	1385.89	3.89	1639.96	0.28	6.13	5.82	68.85	0.31
CFR	1224.6	100yr	2539.00	786.25	4675.55	4682.70		4682.76	0.000423	1616.28	2.68	1125.12	0.19	5.90	5.62	71.12	0.15
CFR	835.5	100yr	2539.00	448.01	4675.27	4682.37		4682.55	0.000835	1616.80	3.81	1941.94	0.28	5.88	5.71	86.68	0.30
CFR	682.5	100yr	2539.00	281.66	4673.19	4682.29		4682.43	0.000594	1285.80	3.71	1521.70	0.24	7.34	7.09	55.80	0.26
CFR	529	100yr	2539.00	40.62	4673.72	4681.59	4678.90	4682.21	0.002728	75.29	6.35	2539.00	0.49	5.31	5.06	75.29	0.86
CFR	496		Bridge														
CFR	463	100yr	2539.00	31.70	4673.23	4681.48		4682.02	0.002132	75.27	5.86	2539.00	0.43	5.76	5.39	75.27	0.72
CFR	368.0	100yr	2539.00	202.50	4674.07	4681.63		4681.79	0.000768	952.75	3.65	1635.83	0.26	5.96	5.69	75.31	0.27
CFR	139.6	100yr	2539.00	382.40	4672.96	4681.12	4678.26	4681.53	0.001601	1118.77	5.37	2224.86	0.38	6.28	5.87	65.96	0.59

HEC-RAS Plan: CFR Design Flow River: CFR_CL Reach: CFR Profile: 100yr

Reach	River Sta	Profile	Q Total	Q Left	Q Right	Hydr Depth L	Hydr Depth R	Shear LOB	Shear ROB	Shear Total	Shear Chan	Vel Left	Vel Right
			(cfs)	(cfs)	(cfs)	(ft)	(ft)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(ft/s)	(ft/s)
CFR	23282.1	100yr	2539.00	45.03	207.43	0.59	0.91	0.07	0.11	0.28	0.64	0.75	6.05
CFR	23228	100yr	2539.00							0.51	0.51		
CFR	23192		Bridge										
CFR	23156	100yr	2539.00							0.49	0.49		
CFR	23100.0	100yr	2539.00		8.29		0.16		0.11	1.63	2.64		1.23
CFR	22956.3	100yr	2539.00	690.69	477.44	1.09	0.76	0.11	0.08	0.11	0.52	1.82	0.90
CFR	22606.0	100yr	2539.00	772.36	321.12	1.14	0.51	0.12	0.05	0.10	0.49	1.11	0.73
CFR	22349.9	100yr	2539.00	332.24	771.16	0.81	0.80	0.09	0.09	0.11	0.56	0.57	0.91
CFR	22047.4	100yr	2539.00	710.82	716.98	1.63	0.92	0.11	0.06	0.09	0.33	0.66	0.75
CFR	21661.8	100yr	2539.00	898.23	635.21	1.44	0.74	0.07	0.04	0.06	0.26	0.53	1.02
CFR	21288.1	100yr	2539.00	904.24	0.25	0.90	0.05	0.16	0.01	0.19	0.76	0.79	0.33
CFR	20885.9	100yr	2539.00	473.22	468.16	0.67	1.01	0.06	0.09	0.09	0.46	0.74	0.94
CFR	20452.2	100yr	2539.00	321.77	548.40	0.55	0.84	0.05	0.08	0.08	0.52	0.65	0.89
CFR	20152.9	100yr	2539.00	518.61	805.37	1.09	1.00	0.08	0.08	0.09	0.39	0.93	0.87
CFR	19673.0	100yr	2539.00	445.03	361.73	0.92	1.48	0.06	0.10	0.09	0.35	0.82	0.62
CFR	19289.8	100yr	2539.00	299.90	815.64	0.58	1.68	0.05	0.14	0.13	0.42	1.24	0.78
CFR	18852.7	100yr	2539.00	0.00	285.17	0.01	0.66	0.00	0.14	0.22	1.09	0.08	0.67
CFR	18469.6	100yr	2539.00	876.14	462.50	1.29	0.93	0.08	0.05	0.08	0.26	0.90	0.72
CFR	18351.3	100yr	2539.00	1064.46	359.28	1.43	0.95	0.06	0.04	0.06	0.18	0.82	0.62
CFR	18290.2	100yr	2539.00	1254.73	305.37	1.58	0.90	0.06	0.03	0.05	0.17	0.80	0.57
CFR	18044.8	100yr	2539.00	1001.93	15.94	1.33	0.94	0.11	0.08	0.12	0.45	0.66	0.09
CFR	17872.7	100yr	2539.00	933.22	113.69	1.50	1.23	0.06	0.04	0.06	0.13	0.47	0.73
CFR	17595.7	100yr	2539.00	1065.58	61.77	1.44	1.71	0.07	0.08	0.08	0.23	0.51	1.63
CFR	17396.7	100yr	2539.00	1163.32	0.78	1.40	1.18	0.07	0.03	0.08	0.25	0.54	0.78
CFR	16918.1	100yr	2539.00	727.89	176.22	0.93	1.01	0.08	0.09	0.10	0.50	0.57	0.40
CFR	16612.2	100yr	2539.00	176.60	338.14	0.46	1.03	0.09	0.21	0.20	0.91	0.84	0.57
CFR	16264.4	100yr	2539.00	740.88	240.15	1.38	1.35	0.11	0.11	0.14	0.44	1.12	0.44
CFR	15947.2	100yr	2539.00	536.99	397.38	0.84	1.83	0.10	0.21	0.16	0.60	0.96	0.65
CFR	15566.1	100yr	2539.00	439.57	13.91	0.64	0.48	0.12	0.09	0.18	1.02	1.08	0.33
CFR	15091.5	100yr	2539.00	371.11	136.88	0.92	1.13	0.05	0.06	0.07	0.35	0.68	0.31
CFR	14604.7	100yr	2539.00	8.41	539.25	0.63	1.46	0.12	0.27	0.29	0.86	0.10	0.69
CFR	14218.6	100yr	2539.00	590.80	203.31	0.86	1.11	0.12	0.16	0.17	0.74	1.06	0.75
CFR	13905.5	100yr	2539.00	1012.67	59.24	1.23	0.42	0.09	0.03	0.09	0.45	1.00	0.48
CFR	13422.4	100yr	2539.00	277.71	286.09	0.48	0.78	0.08	0.12	0.15	0.71	1.42	0.63
CFR	13012.6	100yr	2539.00	499.33	545.96	0.92	1.01	0.06	0.06	0.08	0.29	1.26	0.78
CFR	12583.6	100yr	2539.00	767.74	136.01	0.94	0.77	0.08	0.06	0.09	0.38	0.85	0.45
CFR	12145.0	100yr	2539.00	642.09	9.07	0.91	0.34	0.04	0.01	0.05	0.27	0.64	0.31
CFR	11609.7	100yr	2539.00	140.58	157.30	0.54	0.89	0.08	0.13	0.19	0.73	0.96	0.67
CFR	11181.9	100yr	2539.00	0.04	5.27	0.06	0.13	0.02	0.05	0.75	1.39	0.29	0.53
CFR	10736.1	100yr	2539.00	228.65	639.93	1.01	1.61	0.06	0.09	0.10	0.30	0.76	0.64
CFR	10137.7	100yr	2539.00	7.20	554.93	0.23	1.37	0.03	0.17	0.22	0.60	0.72	0.89
CFR	9823.3	100yr	2539.00		568.70		1.92		0.36	0.47	0.86		1.25
CFR	9326.1	100yr	2539.00	627.53	0.24	1.31	0.04	0.20	0.01	0.27	0.76	1.47	0.15
CFR	9106.3	100yr	2539.00	874.27	116.97	1.69	0.47	0.16	0.04	0.15	0.39	1.36	1.17

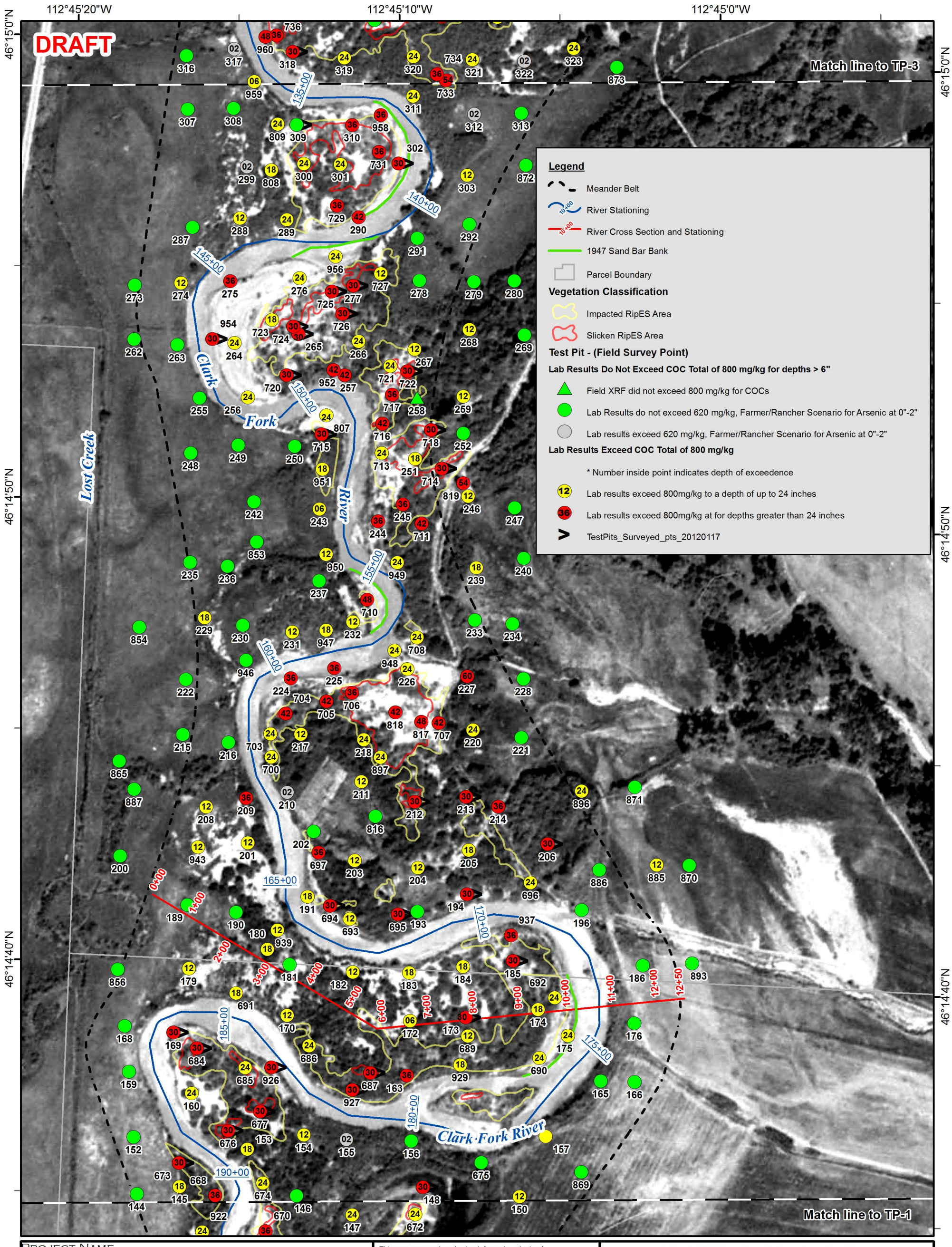
HEC-RAS Plan: CFR Design Flow River: CFR_CL Reach: CFR Profile: 100yr (Continued)

Reach	River Sta	Profile	Q Total	Q Left	Q Right	Hydr Depth L	Hydr Depth R	Shear LOB	Shear ROB	Shear Total	Shear Chan	Vel Left	Vel Right
			(cfs)	(cfs)	(cfs)	(ft)	(ft)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(ft/s)	(ft/s)
CFR	8951.0	100yr	2539.00	395.70	94.06	1.44	0.57	0.06	0.02	0.08	0.16	0.86	1.09
CFR	8661.2	100yr	2539.00	388.18	134.25	0.80	1.53	0.13	0.24	0.24	0.79	1.49	2.83
CFR	8221.4	100yr	2539.00	99.82	689.43	0.85	1.53	0.10	0.17	0.21	0.55	1.03	1.40
CFR	7755.8	100yr	2539.00	10.31	788.96	0.39	1.92	0.04	0.17	0.20	0.44	0.50	0.87
CFR	7700		Inl Struct										
CFR	7614.0	100yr	2539.00	20.04	897.78	0.41	1.81	0.03	0.13	0.14	0.37	0.47	1.25
CFR	7214.1	100yr	2539.00	357.76		1.23		0.20		0.31	0.78	0.89	
CFR	6630.6	100yr	2539.00	5.21	989.72	0.59	0.96	0.05	0.09	0.13	0.44	0.66	1.79
CFR	6329.6	100yr	2539.00	0.50	847.21	0.08	0.92	0.01	0.08	0.11	0.40	0.16	1.49
CFR	6165		Inl Struct										
CFR	6070.3	100yr	2539.00	0.05	678.12	0.05	1.07	0.00	0.06	0.10	0.26	0.11	1.33
CFR	5559.7	100yr	2539.00	474.63	3.54	1.23	0.57	0.16	0.07	0.23	0.68	0.79	1.32
CFR	5088.6	100yr	2539.00	704.58	508.93	1.44	1.01	0.14	0.10	0.14	0.46	0.75	1.66
CFR	4683.6	100yr	2539.00	142.15	885.28	0.97	1.04	0.06	0.06	0.08	0.29	0.45	1.36
CFR	4235.7	100yr	2539.00		749.39		0.64		0.10	0.16	0.66		1.62
CFR	3783.9	100yr	2539.00		792.80		0.93		0.09	0.15	0.41		1.70
CFR	3487.5	100yr	2539.00	520.71	463.65	1.24	1.15	0.13	0.12	0.17	0.51	1.17	1.99
CFR	3028.0	100yr	2539.00	773.49	81.10	1.44	0.72	0.16	0.08	0.20	0.48	1.32	2.23
CFR	2786.0	100yr	2539.00	259.53	39.84	0.97	0.18	0.15	0.03	0.20	0.57	1.19	1.20
CFR	2645.3	100yr	2539.00	375.19	490.77	2.23	0.73	0.21	0.07	0.14	0.44	1.65	1.35
CFR	2244.1	100yr	2539.00		1204.21		1.08		0.10	0.12	0.39		1.02
CFR	1921.5	100yr	2539.00	209.98	1178.70	1.62	1.25	0.06	0.05	0.06	0.19	0.84	1.21
CFR	1558.4	100yr	2539.00	757.84	141.20	1.75	0.90	0.09	0.05	0.11	0.31	1.05	1.15
CFR	1224.6	100yr	2539.00	868.01	545.87	1.98	1.60	0.05	0.04	0.06	0.15	0.85	1.20
CFR	835.5	100yr	2539.00	513.07	83.99	2.02	1.96	0.11	0.10	0.16	0.30	1.14	1.90
CFR	682.5	100yr	2539.00	256.62	760.67	1.12	1.99	0.04	0.07	0.08	0.26	1.11	1.64
CFR	529	100yr	2539.00							0.86	0.86		
CFR	496		Bridge										
CFR	463	100yr	2539.00							0.72	0.72		
CFR	368.0	100yr	2539.00	37.94	865.24	1.23	2.51	0.06	0.12	0.14	0.27	0.32	2.16
CFR	139.6	100yr	2539.00	58.06	256.08	1.70	2.11	0.17	0.21	0.35	0.59	0.56	2.79



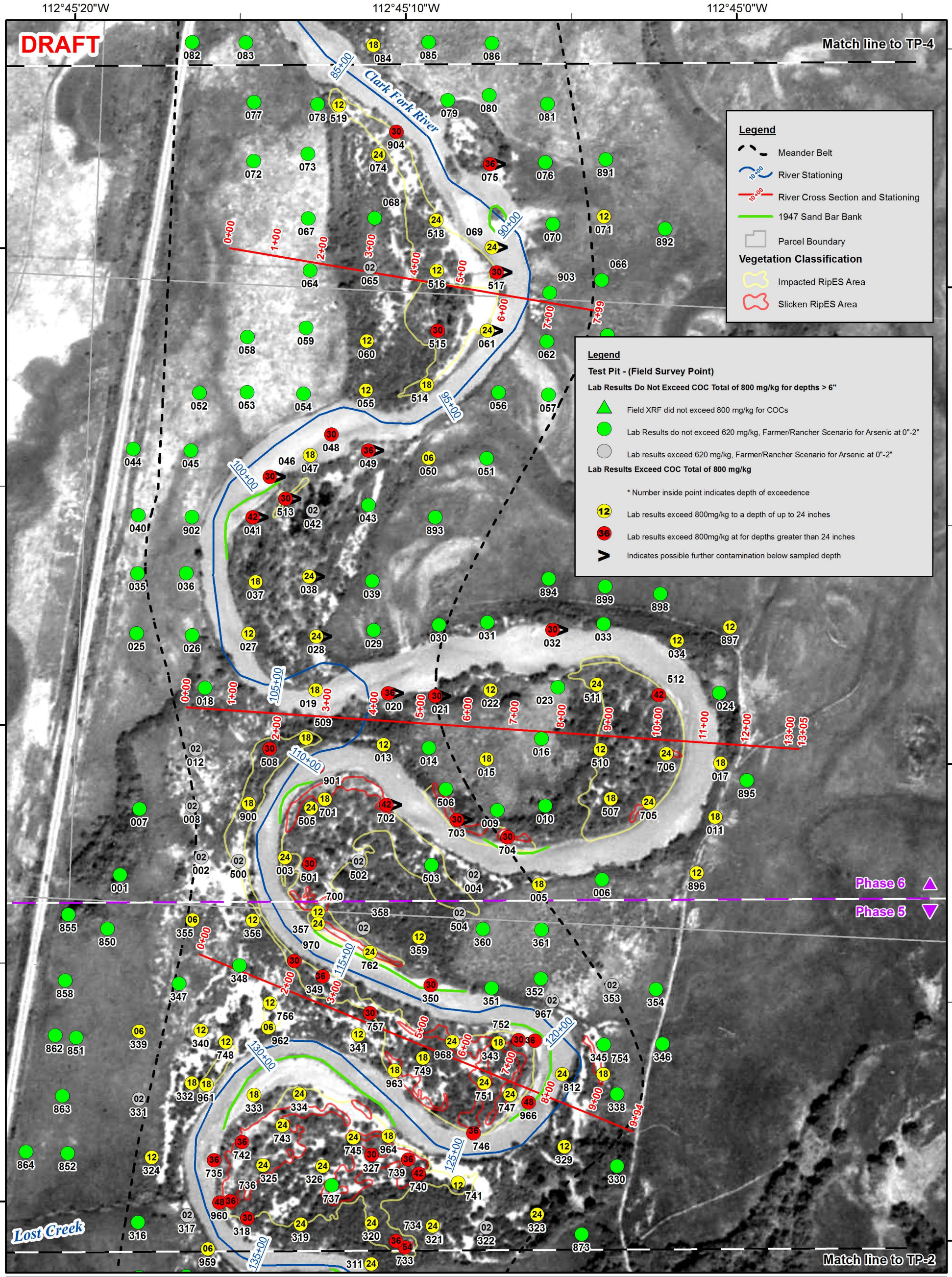
PROJECT NAME Clark Fork River Operable Unit Phases 5 & 6 Part 1, Floodplain Investigation	This map was produced using information obtained from several different sources that have not been independently verified. These sources have also not provided information on the precision and accuracy of the data. Information on this map is not a substitute for survey data.	Test Pit Depth of Contamination Results Map HTP-1 (1947 Aerial Image) DRAFT

TerraGraphics Environmental Engineering, Inc. www.TerraGraphics.com	FILE Montana\CFROU_Phase5\mxd\Results\DSR_DepthofContamination_HTP1_20120713	Map Projection: NAD83 UTM12N	Map Scale: 1:2,400 1 inch = 200 feet 0 50 100 200 Feet
	PRINT DATE July 13, 2012	PROJECT MANAGER M. Culpo / J. Mickey	
	PROJECT NUMBER 10074-3 MDEQ - CFR Investigation - TO #26	CARTOGRAPHER J. Mierzwinski / B. Bailey	



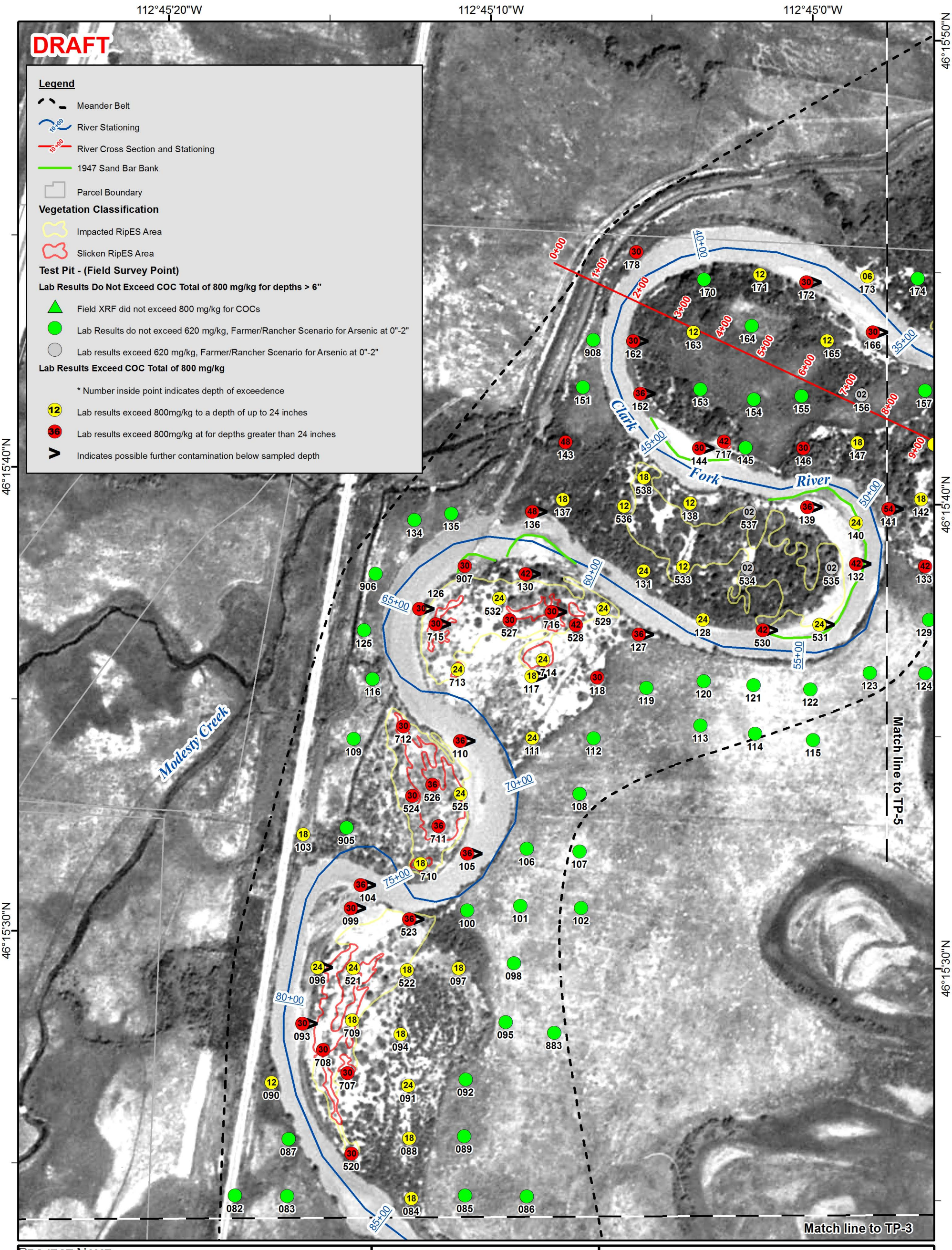
PROJECT NAME **Clark Fork River Operable Unit Phases 5 & 6 Part 1, Floodplain Investigation**	This map was produced using information obtained from several different sources that have not been independently verified. These sources have also not provided information on the precision and accuracy of the data. Information on this map is not a substitute for survey data.	**Test Pit Depth of Contamination Results Map HTP-2 (1947 Aerial Image)** **DRAFT**

TerraGraphics Environmental Engineering, Inc. www.TerraGraphics.com	FILE Montana\CFROU_Phase5\mxd\Results\DSR_DepthofContamination_HTP2_20120713	Map Projection: NAD83 UTM12N	Map Scale: **1:2,400** 1 inch = 200 feet 0 50 100 200 Feet
	PRINT DATE July 13, 2012	PROJECT MANAGER M. Culpo / J. Mickey	
	PROJECT NUMBER 10074-3 MDEQ - CFR Investigation - TO #26	CARTOGRAPHER J. Mierzwinski / B. Bailey	



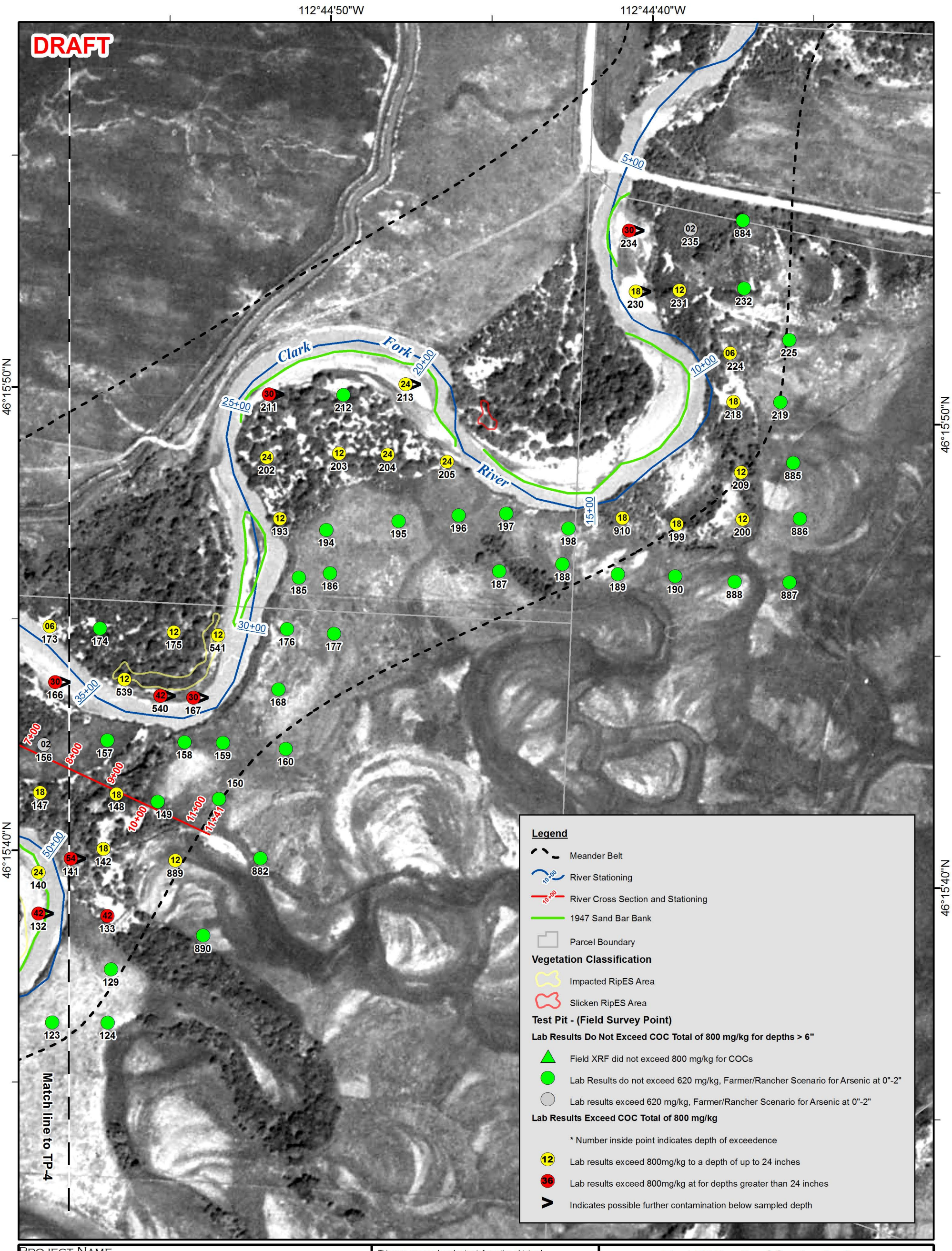
PROJECT NAME Clark Fork River Operable Unit Phases 5 & 6 Part 1, Floodplain Investigation	This map was produced using information obtained from several different sources that have not been independently verified. These sources have also not provided information on the precision and accuracy of the data. Information on this map is not a substitute for survey data.	Test Pit Depth of Contamination Results Map HTP-3 (1947 Aerial Image) DRAFT

TerraGraphics Environmental Engineering, Inc. www.TerraGraphics.com	FILE Montana\CFROU_Phase5\mxd\Results\DSR_DepthofContamination_HTP3_20120713	Map Projection: NAD83 UTM12N	Map Scale: 1:2,400 1 inch = 200 feet 0 50 100 200 Feet
	PRINT DATE July 13, 2012	PROJECT MANAGER M. Culpo / J. Mickey	
	PROJECT NUMBER 10074-3 MDEQ - CFR Investigation - TO #26	CARTOGRAPHER J. Mierzwinski / B. Bailey	



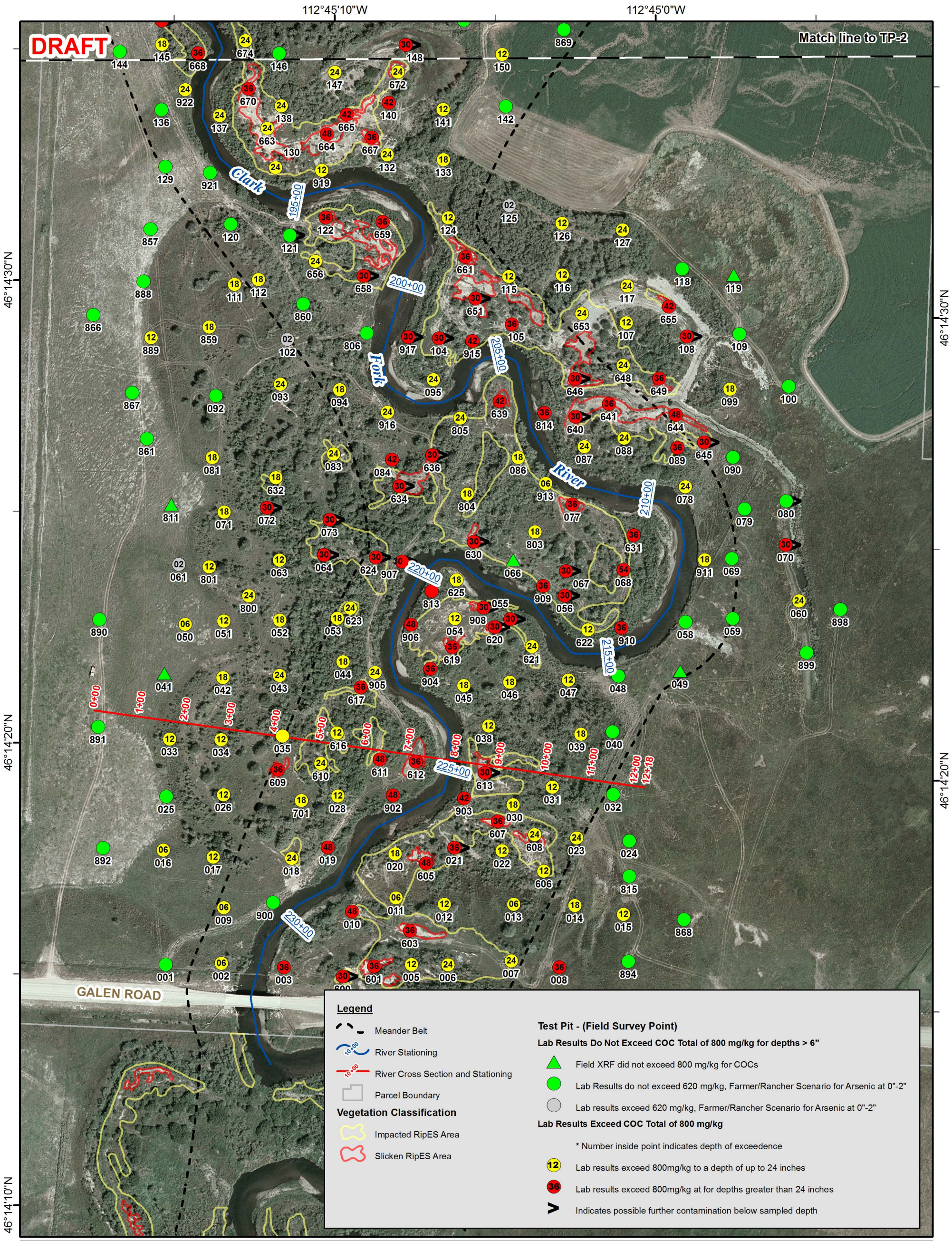
PROJECT NAME Clark Fork River Operable Unit Phases 5 & 6 Part 1, Floodplain Investigation	This map was produced using information obtained from several different sources that have not been independently verified. These sources have also not provided information on the precision and accuracy of the data. Information on this map is not a substitute for survey data.	Test Pit Depth of Contamination Results Map HTP-4 (1947 Aerial Image) DRAFT

TerraGraphics Environmental Engineering, Inc. www.TerraGraphics.com	FILE Montana\CFROU_Phase5\mxd\Results\DSR_DepthofContamination_HTP4_20120713	Map Projection: NAD83 UTM12N	Map Scale: 1:2,400 1 inch = 200 feet 0 50 100 200 Feet
	PRINT DATE July 13, 2012	PROJECT MANAGER M. Culpo / J. Mickey	
	PROJECT NUMBER 10074-3 MDEQ - CFR Investigation - TO #26	CARTOGRAPHER J. Mierzwinski / B. Bailey	



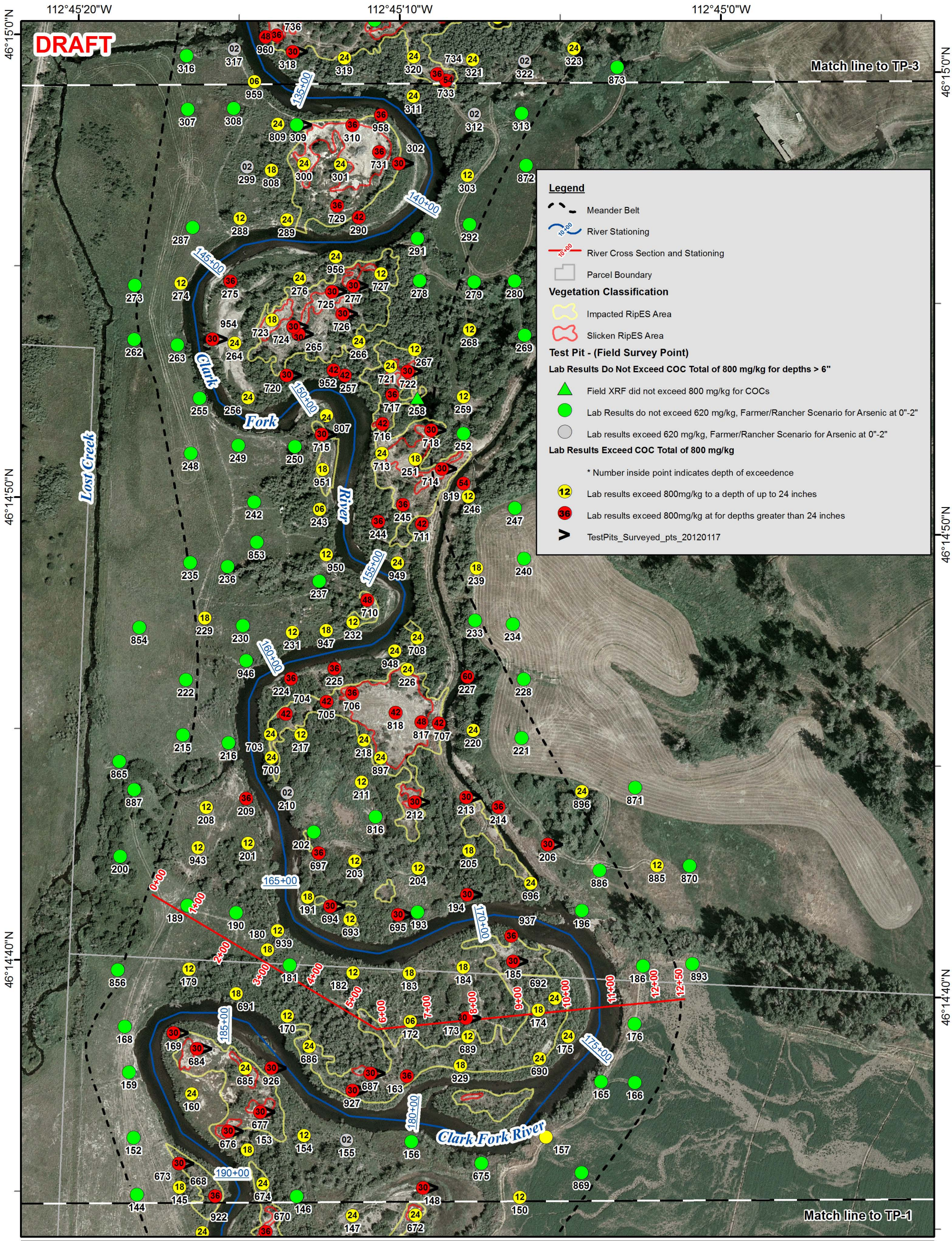
PROJECT NAME Clark Fork River Operable Unit Phases 5 & 6 Part 1, Floodplain Investigation	This map was produced using information obtained from several different sources that have not been independently verified. These sources have also not provided information on the precision and accuracy of the data. Information on this map is not a substitute for survey data.	Test Pit Depth of Contamination Results Map HTP-5 (1947 Aerial Image) DRAFT

TerraGraphics Environmental Engineering, Inc. www.TerraGraphics.com	FILE Montana\CFROU_Phase5\mxd\Results\DSR_DepthofContamination_HTP5_20120713	Map Projection: NAD83 UTM12N	Map Scale: 1:2,400 1 inch = 200 feet 0 50 100 200 Feet
	PRINT DATE July 13, 2012	PROJECT MANAGER M. Culpo / J. Mickey	
	PROJECT NUMBER 10074-3 MDEQ - CFR Investigation - TO #26	CARTOGRAPHER J. Mierzwinski / B. Bailey	



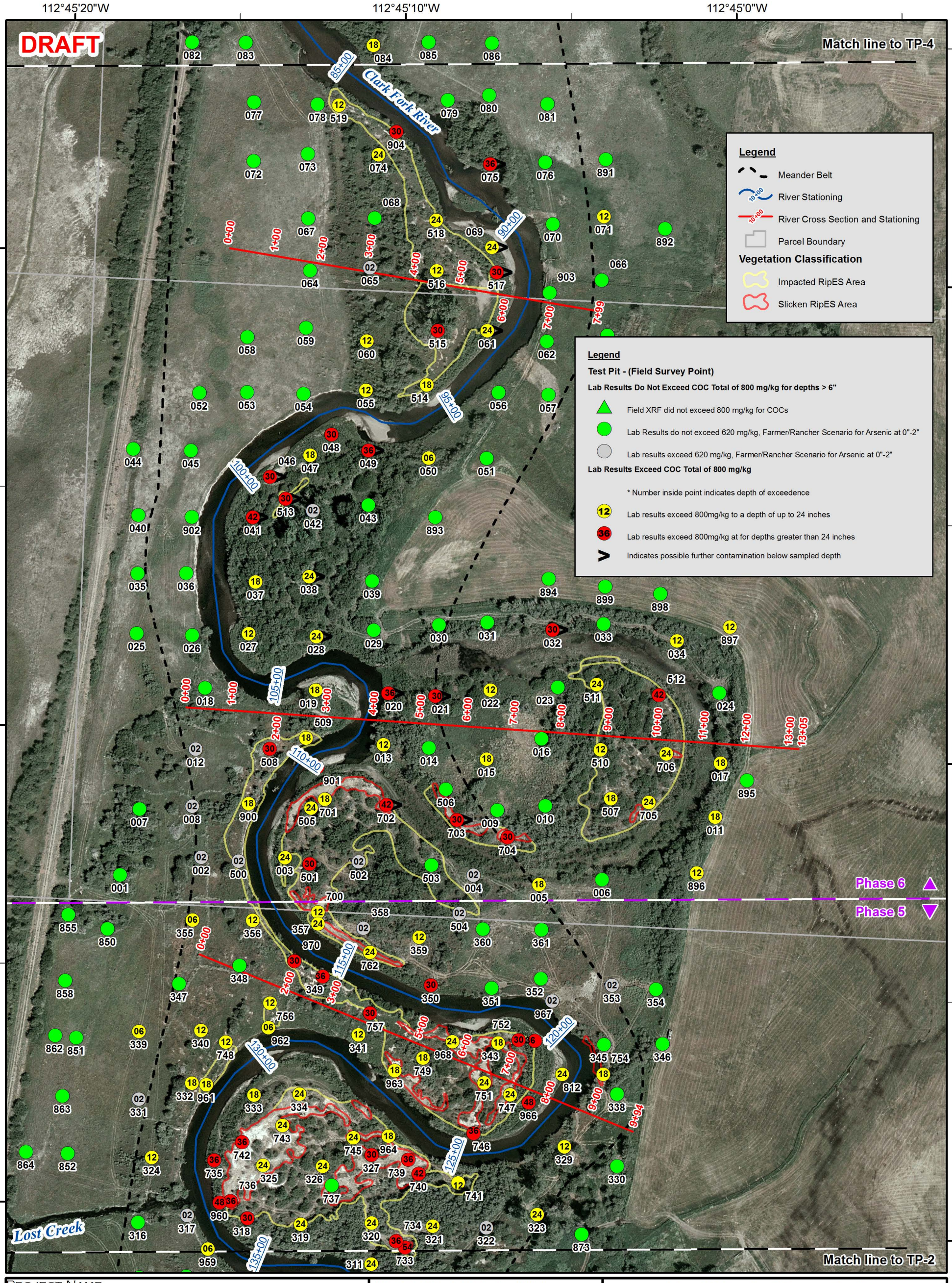
PROJECT NAME Clark Fork River Operable Unit Phases 5 & 6 Part 1, Floodplain Investigation	This map was produced using information obtained from several different sources that have not been independently verified. These sources have also not provided information on the precision and accuracy of the data. Information on this map is not a substitute for survey data.	Test Pit Depth of Contamination Results Map TP-1 (2011 Aerial Image) DRAFT

TerraGraphics Environmental Engineering, Inc. www.TerraGraphics.com	FILE Montana\CFROU_Phase5\mxd\Results\DSR_DepthofContamination_TP1_20120713	Map Projection: NAD83 UTM12N	Map Scale: 1:2,400 1 inch = 200 feet 0 50 100 200 Feet
	PRINT DATE July 13, 2012	PROJECT MANAGER M. Culpo / J. Mickey	
	PROJECT NUMBER 10074-3 MDEQ - CFR Investigation - TO #26	CARTOGRAPHER J. Mierzwinski / B. Bailey	



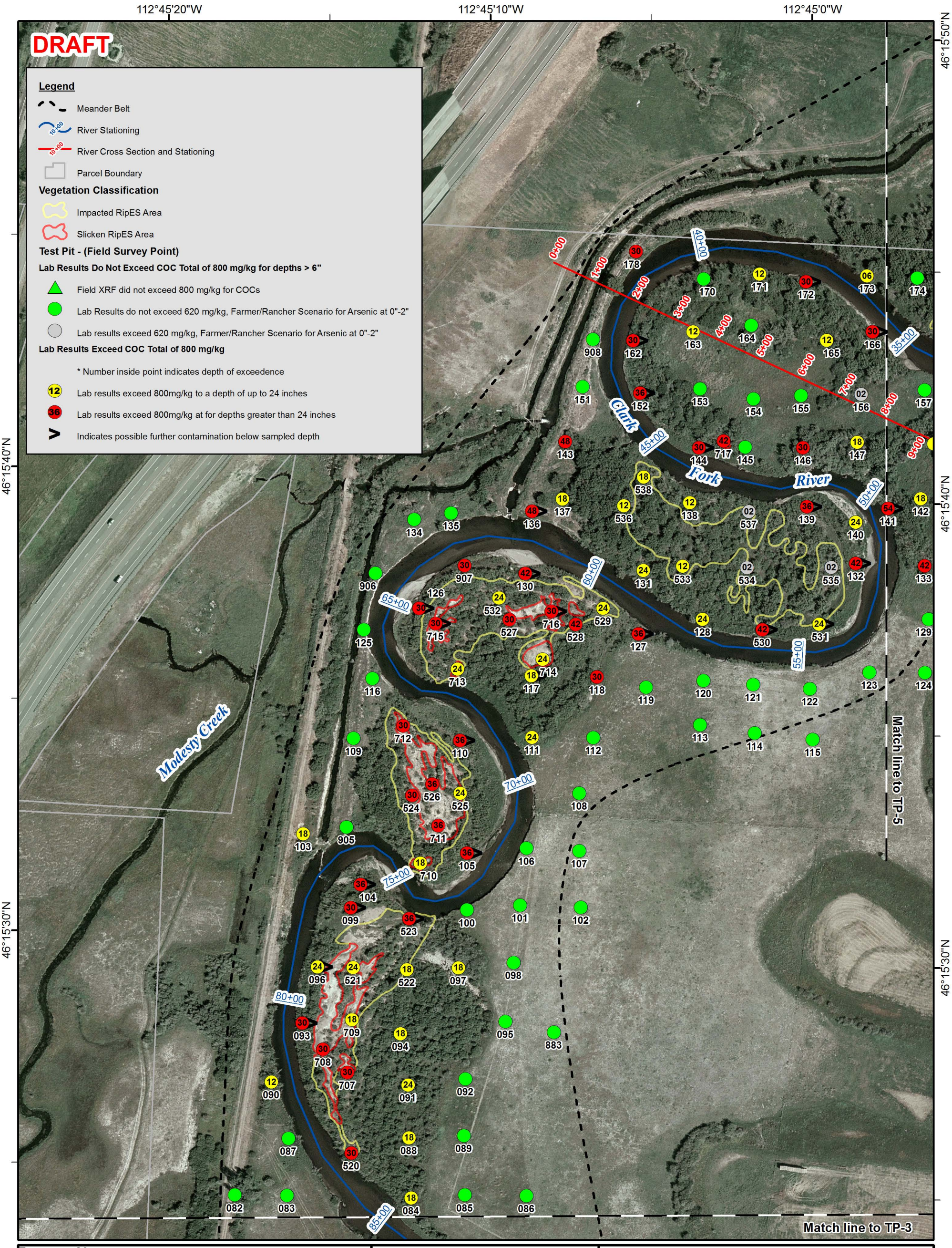
PROJECT NAME Clark Fork River Operable Unit Phases 5 & 6 Part 1, Floodplain Investigation	This map was produced using information obtained from several different sources that have not been independently verified. These sources have also not provided information on the precision and accuracy of the data. Information on this map is not a substitute for survey data.	Test Pit Depth of Contamination Results Map TP-2 (2011 Aerial Image) DRAFT

TerraGraphics Environmental Engineering, Inc. www.TerraGraphics.com	FILE Montana\CFROU_Phase5\mxd\Results\DSR_DepthofContamination_TP2_20120713	Map Projection: NAD83 UTM12N	Map Scale: 1:2,400 1 inch = 200 feet 0 50 100 200 Feet
	PRINT DATE July 13, 2012	PROJECT MANAGER M. Culpo / J. Mickey	
	PROJECT NUMBER 10074-3 MDEQ - CFR Investigation - TO #26	CARTOGRAPHER J. Mierzwinski / B. Bailey	



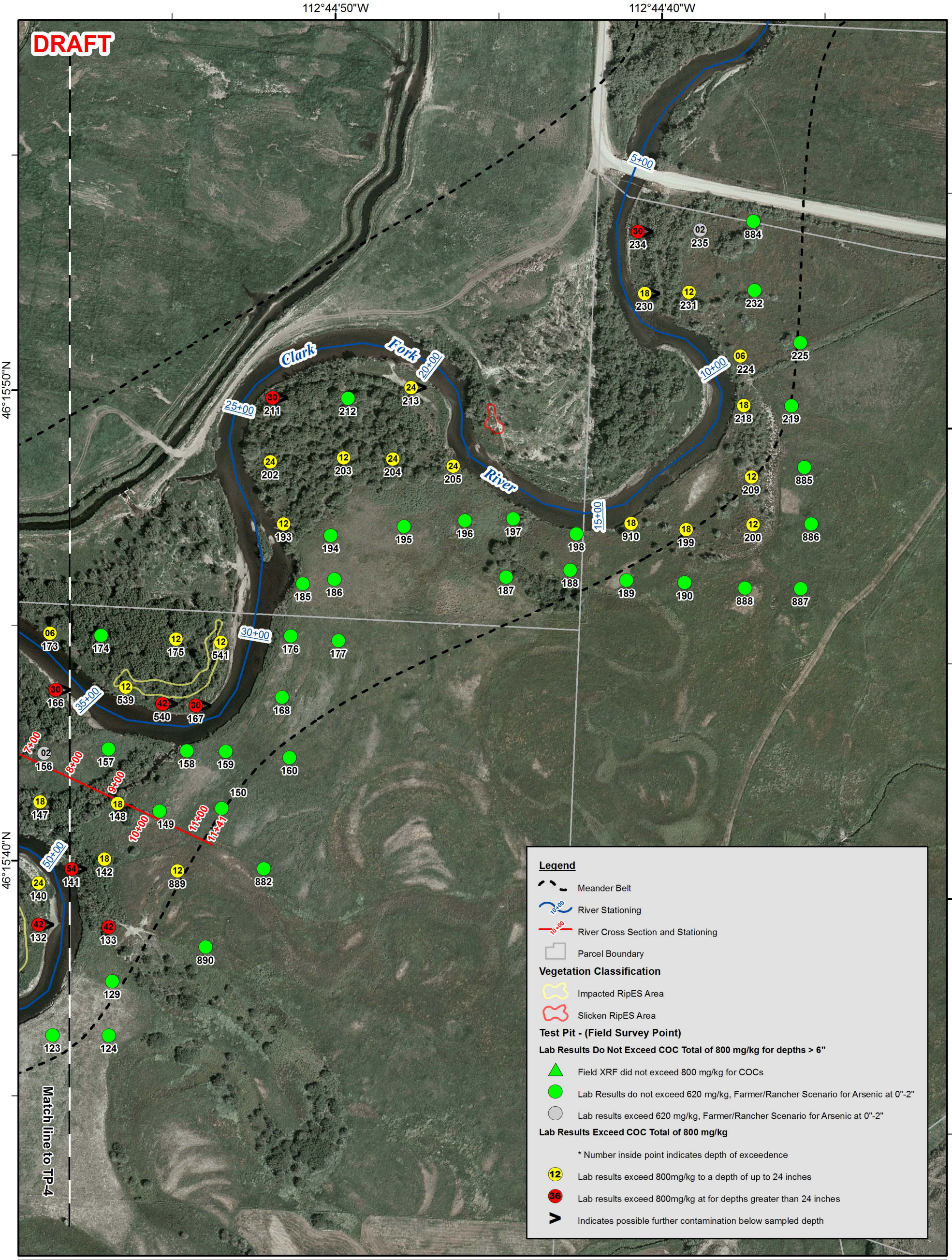
PROJECT NAME Clark Fork River Operable Unit Phases 5 & 6 Part 1, Floodplain Investigation	This map was produced using information obtained from several different sources that have not been independently verified. These sources have also not provided information on the precision and accuracy of the data. Information on this map is not a substitute for survey data.	Test Pit Depth of Contamination Results Map TP-3 (2011 Aerial Image) DRAFT

TerraGraphics Environmental Engineering, Inc. www.TerraGraphics.com	FILE Montana\CFROU_Phase5\mxd\Results\DSR_DepthofContamination_TP3_20120713	Map Projection: NAD83 UTM12N	Map Scale: 1:2,400 1 inch = 200 feet 0 50 100 200 Feet
	PRINT DATE July 13, 2012	PROJECT MANAGER M. Culpo / J. Mickey	
	PROJECT NUMBER 10074-3 MDEQ - CFR Investigation - TO #26	CARTOGRAPHER J. Mierzwinski / B. Bailey	



Project Name		
Clark Fork River Operable Unit Phases 5 & 6 Part 1, Floodplain Investigation	This map was produced using information obtained from several different sources that have not been independently verified. These sources have also not provided information on the precision and accuracy of the data. Information on this map is not a substitute for survey data.	Test Pit Depth of Contamination Results Map TP-4 (2011 Aerial Image) DRAFT

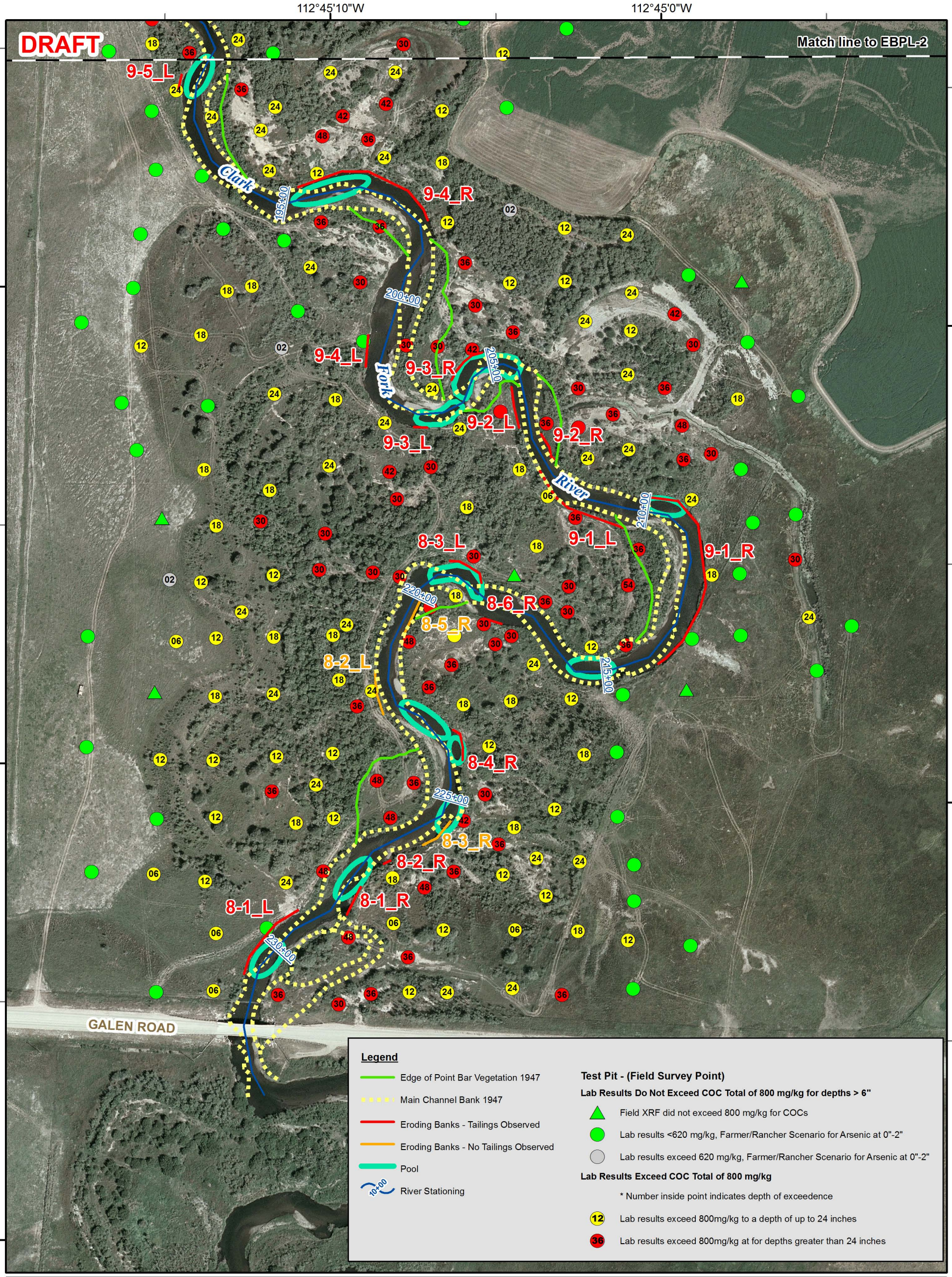
TerraGraphics Environmental Engineering, Inc. www.TerraGraphics.com	File Montana\CFROU_Phase5\mxd\Results\DSR_DepthofContamination_TP4_20120713	Map Projection: NAD83 UTM12N	Map Scale: 1:2,400 1 inch = 200 feet 0 50 100 200 Feet
	Print Date July 13, 2012	Project Manager M. Culpo / J. Mickey	
	Project Number 10074-3 MDEQ - CFR Investigation - TO #26	Cartographer J. Mierzwinski / B. Bailey	



PROJECT NAME Clark Fork River Operable Unit Phases 5 & 6 Part 1, Floodplain Investigation	This map was produced using information obtained from several different sources that have not been independently verified. These sources have also not provided information on the precision and accuracy of the data. Information on this map is not a substitute for survey data.	Test Pit Depth of Contamination Results Map TP-5 (2011 Aerial Image) DRAFT

TerraGraphics Environmental Engineering, Inc.
www.TerraGraphics.com

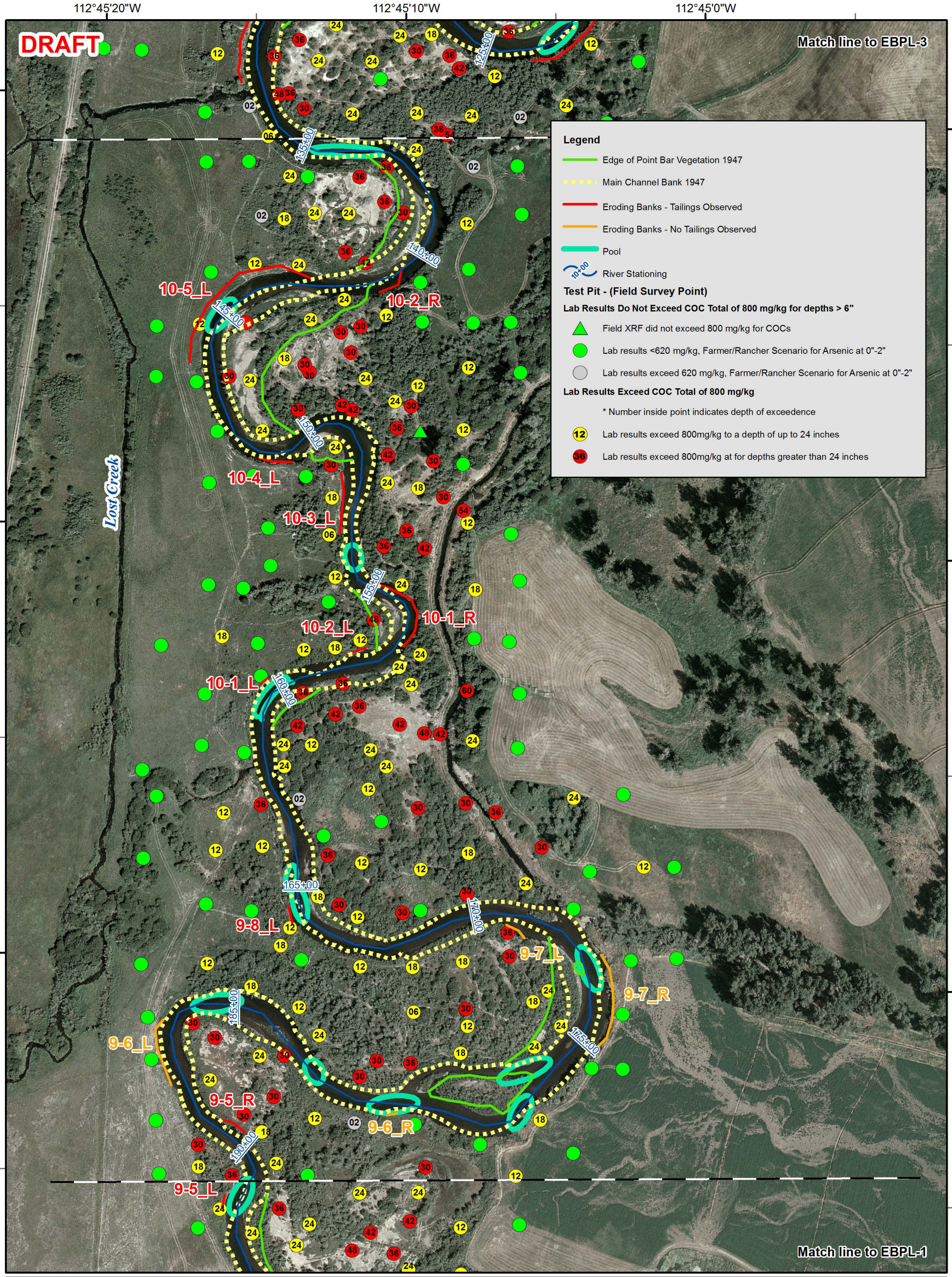
FILE Montana\CFROU_Phase5\mxd\Results\DSR_DepthofContamination_TP5_20120713	Map Projection: NAD83 UTM12N	Map Scale: 1:2,400 1 inch = 200 feet 0 50 100 200 Feet
PRINT DATE July 13, 2012	PROJECT MANAGER M. Culpo / J. Mickey	
PROJECT NUMBER 10074-3 MDEQ - CFR Investigation - TO #26	CARTOGRAPHER J. Mierzwinski / B. Bailey	



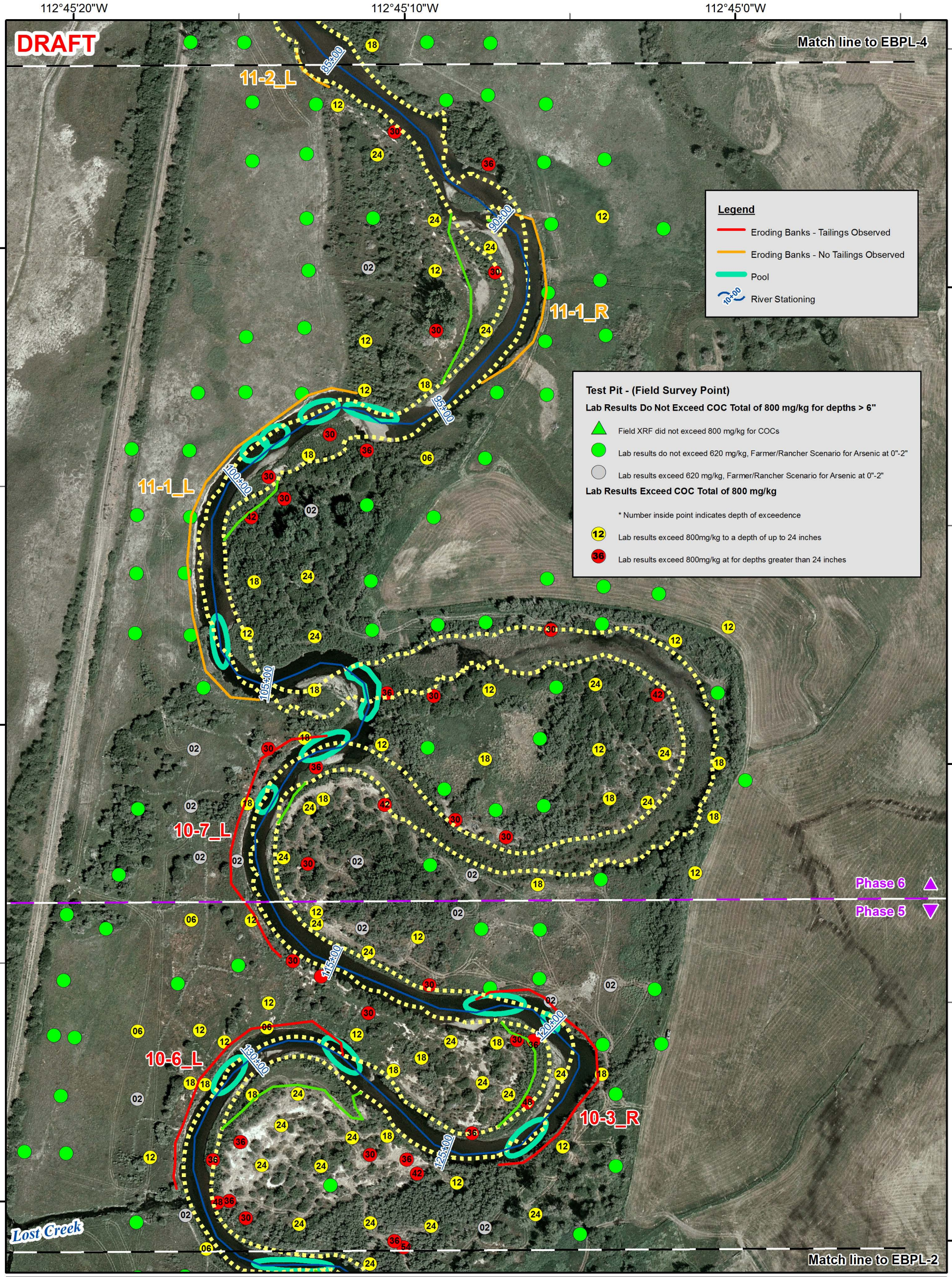
PROJECT NAME Clark Fork River Operable Unit Phase 5 & 6 Part 2, Geomorphic, Hydrologic & Hydraulic Investigation	This map was produced using information obtained from several different sources that have not been independently verified. These sources have also not provided information on the precision and accuracy of the data. Information on this map is not a substitute for survey data.	Eroding Banks and Pool Locations EBPL-1 DRAFT

TerraGraphics Environmental Engineering, Inc.
www.TerraGraphics.com

FILE Montana\CFROU_Phase5\mxd\EBPL1_20120720	Map Projection: NAD83 UTM12N	Map Scale: **1:2,400** 1 inch = 200 feet 0 50 100 200 Feet
PRINT DATE July 20, 2012	PROJECT MANAGER S. Firor	
PROJECT NUMBER 10074-3 MDEQ - CFR Investigation - TO #26	CARTOGRAPHER B. Bailey	



PROJECT NAME Clark Fork River Operable Unit Phase 5 & 6 Part 2, Geomorphic, Hydrologic & Hydraulic Investigation	This map was produced using information obtained from several different sources that have not been independently verified. These sources have also not provided information on the precision and accuracy of the data. Information on this map is not a substitute for survey data.	Eroding Banks and Pool Locations EBPL-2	DRAFT
TerraGraphics Environmental Engineering, Inc. www.TerraGraphics.com	FILE: Montana\CFROU_Phase5\mxd\EBPL2_20120720 PRINT DATE: July 20, 2012 PROJECT NUMBER: 10074-3 MDEQ - CFR Investigation - TO #26	Map Projection: NAD83 UTM12N PROJECT MANAGER: S. Firor CARTOGRAPHER: B. Bailey	Map Scale: 1:2,653 1 inch = 221 feet 0 50 100 200 Feet

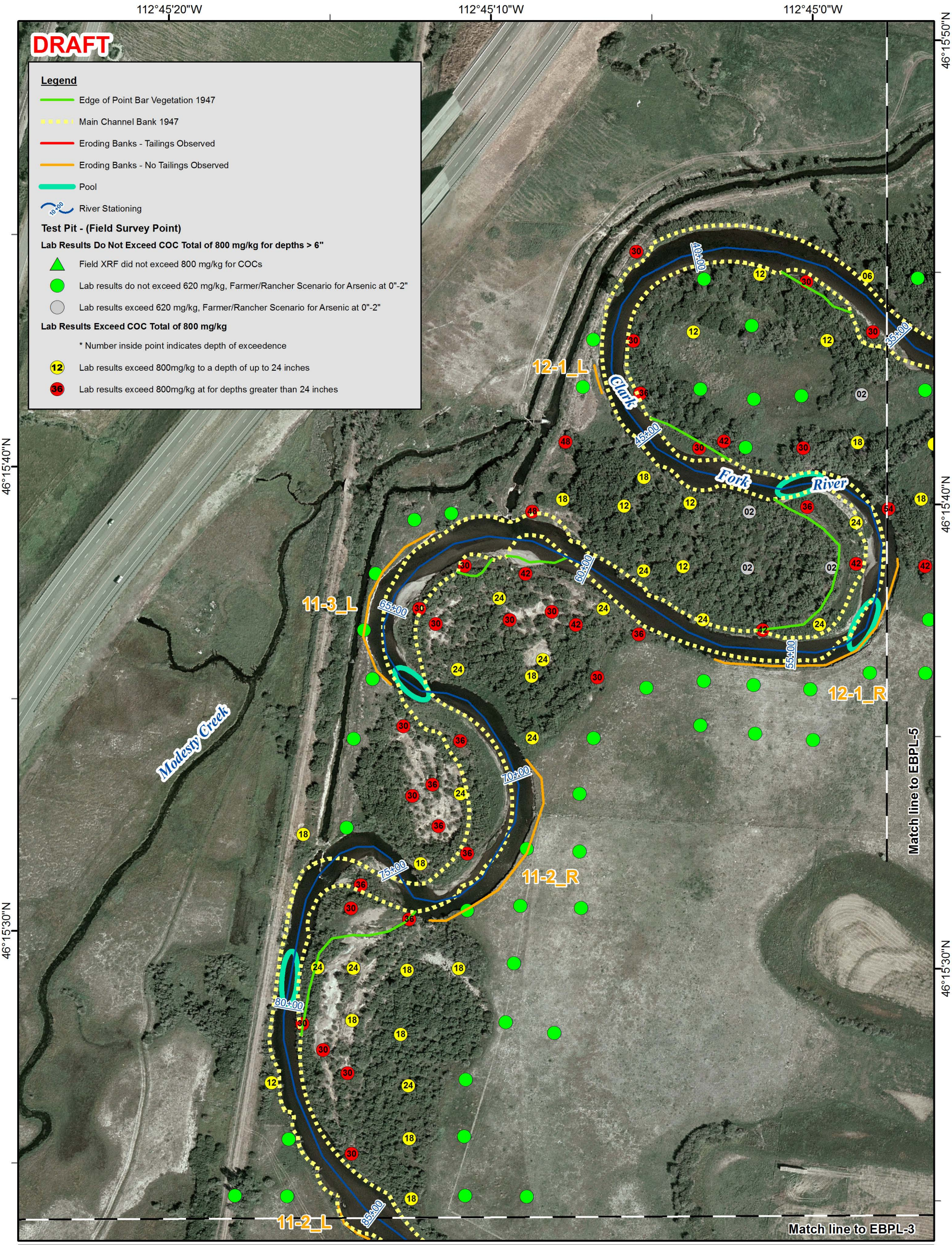


PROJECT NAME Clark Fork River Operable Unit Phase 5 & 6 Part 2, Geomorphic, Hydrologic & Hydraulic Investigation	This map was produced using information obtained from several different sources that have not been independently verified. These sources have also not provided information on the precision and accuracy of the data. Information on this map is not a substitute for survey data.	Eroding Banks and Pool Locations EBPL-3 DRAFT

TerraGraphics Environmental Engineering, Inc.
www.TerraGraphics.com

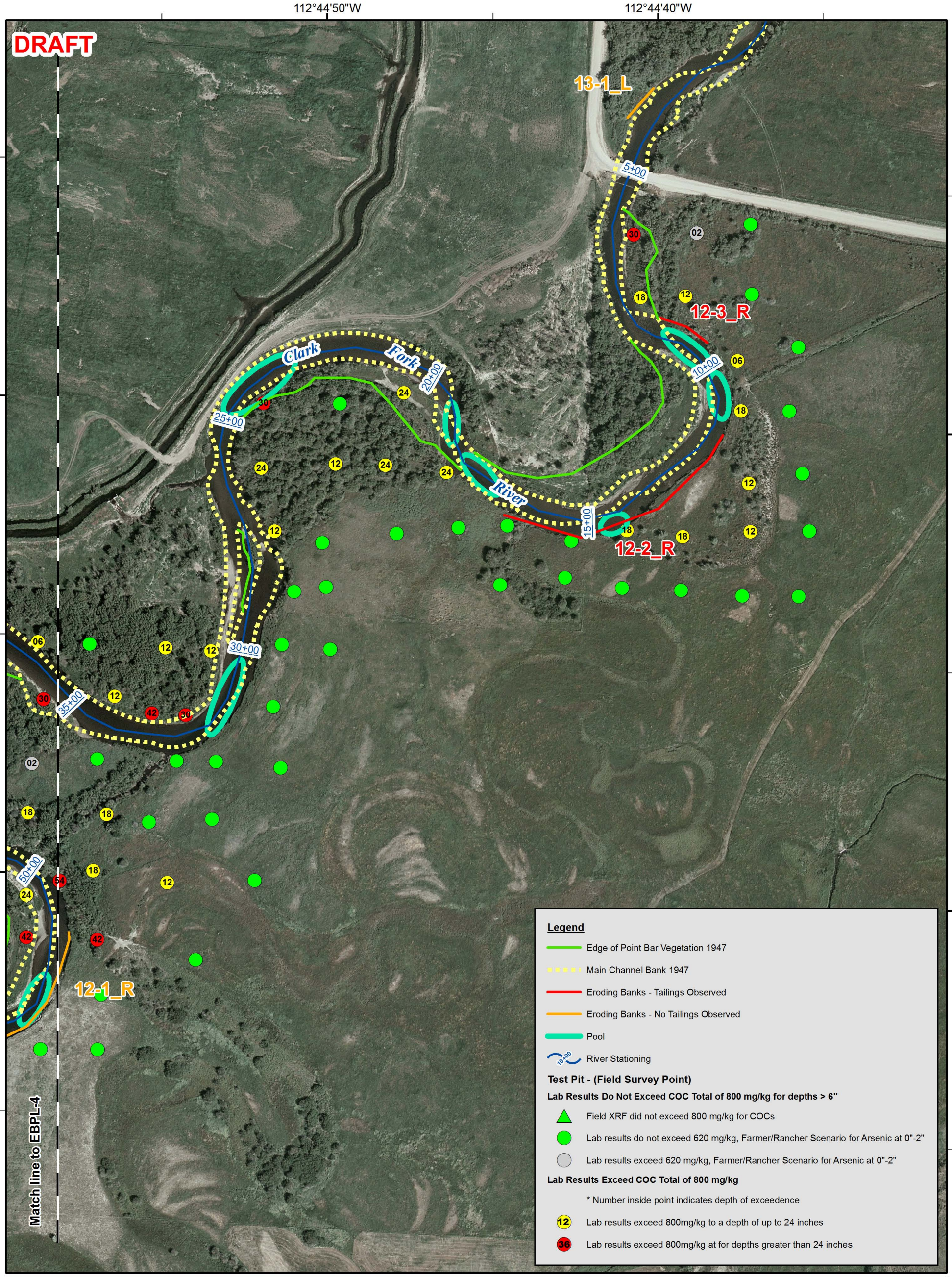
FILE	Montana\CFROU_Phase5\mxd\EBPL3_20110720	Map Projection:	NAD83 UTM12N
PRINT DATE	July 20, 2012	PROJECT MANAGER	S. Firor
PROJECT NUMBER	10074-3 MDEQ - CFR Investigation - TO #26	CARTOGRAPHER	B. Bailey

Map Scale: 1:2,400
1 inch = 200 feet
0 50 100 200 Feet



PROJECT NAME Clark Fork River Operable Unit Phase 5 & 6 Part 2, Geomorphic, Hydrologic & Hydraulic Investigation	This map was produced using information obtained from several different sources that have not been independently verified. These sources have also not provided information on the precision and accuracy of the data. Information on this map is not a substitute for survey data.	Eroding Banks and Pool Locations EBPL-4 DRAFT

TerraGraphics Environmental Engineering, Inc. www.TerraGraphics.com	FILE Montana\CFROU_Phase5\mxd\EBPL4_20110720	Map Projection: NAD83 UTM12N	Map Scale: **1:2,400** 1 inch = 200 feet 0 50 100 200 Feet
	PRINT DATE July 20, 2012	PROJECT MANAGER S. Firor	
	PROJECT NUMBER 10074-3 MDEQ - CFR Investigation - TO #26	CARTOGRAPHER B. Bailey	

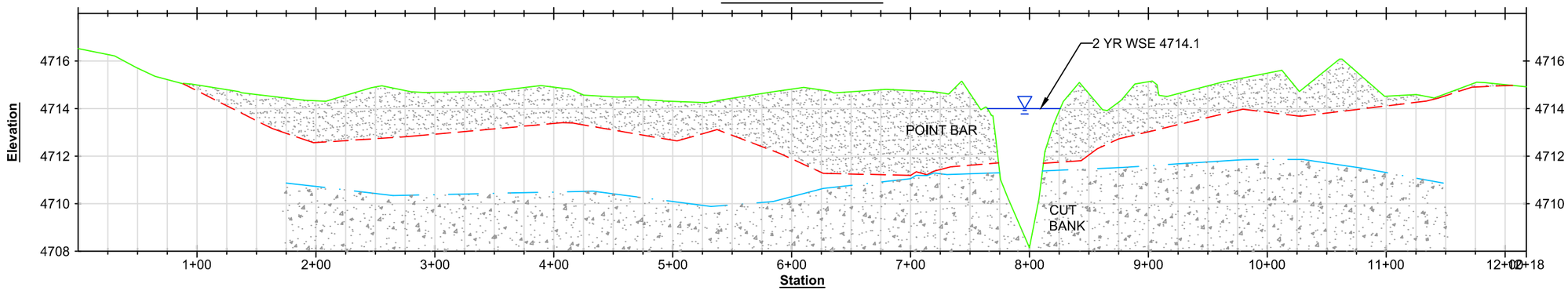


PROJECT NAME Clark Fork River Operable Unit Phase 5 & 6 Part 2, Geomorphic, Hydrologic & Hydraulic Investigation	This map was produced using information obtained from several different sources that have not been independently verified. These sources have also not provided information on the precision and accuracy of the data. Information on this map is not a substitute for survey data.	Eroding Banks and Pool Locations EBPL-5 DRAFT

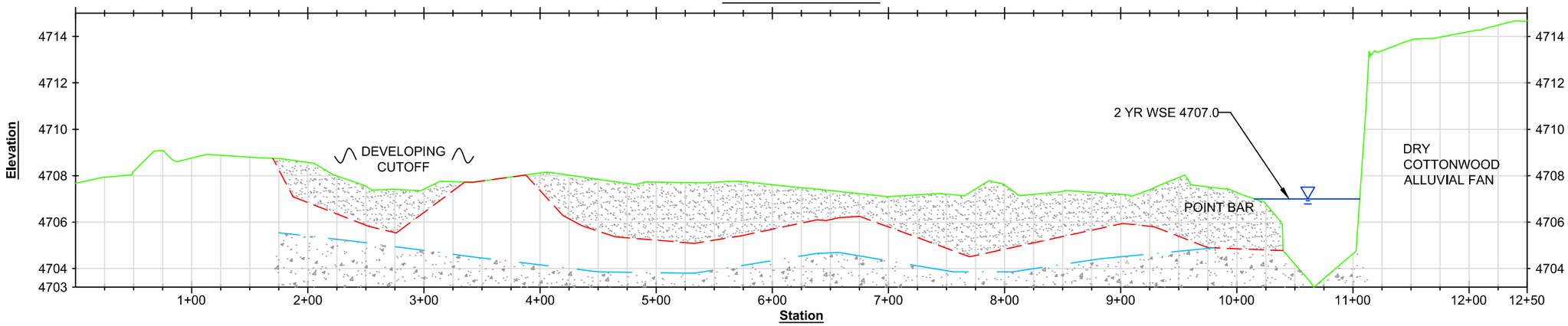
TerraGraphics Environmental Engineering, Inc.
www.TerraGraphics.com

FILE Montana\CFROU_Phase5\mxd\EBPL5_20110720	Map Projection: NAD83 UTM12N	Map Scale: 1:2,400 1 inch = 200 feet 0 50 100 200 Feet
PRINT DATE July 20, 2012	PROJECT MANAGER S. Firor	
PROJECT NUMBER 10074-3 MDEQ - CFR Investigation - TO #26	CARTOGRAPHER B. Bailey	

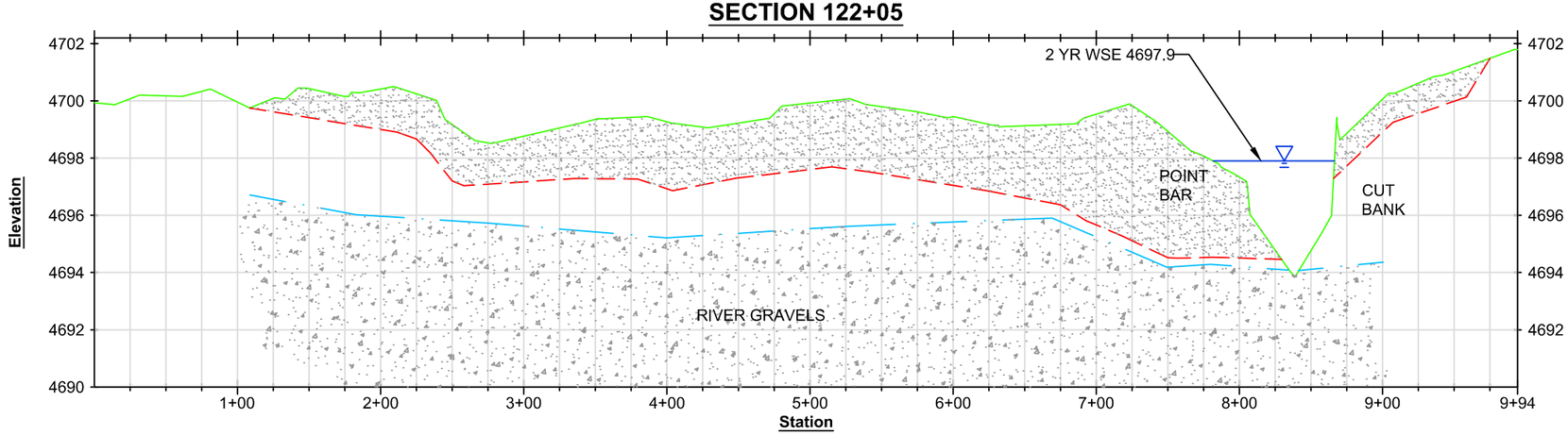
SECTION 224+65



SECTION 173+96



SECTION 122+05



LEGEND

- EXISTING GROUND LINE
- TOP OF RIVER GRAVELS LINE
- BOTTOM OF TAILINGS IMPACTED SOIL Σ C.O.C.s > 800 mg/kg
- WATER SURFACE ELEVATION

0 100 200
HORZ. SCALE: 1" = 100'

0 5 10
VERT. SCALE: 1" = 5'

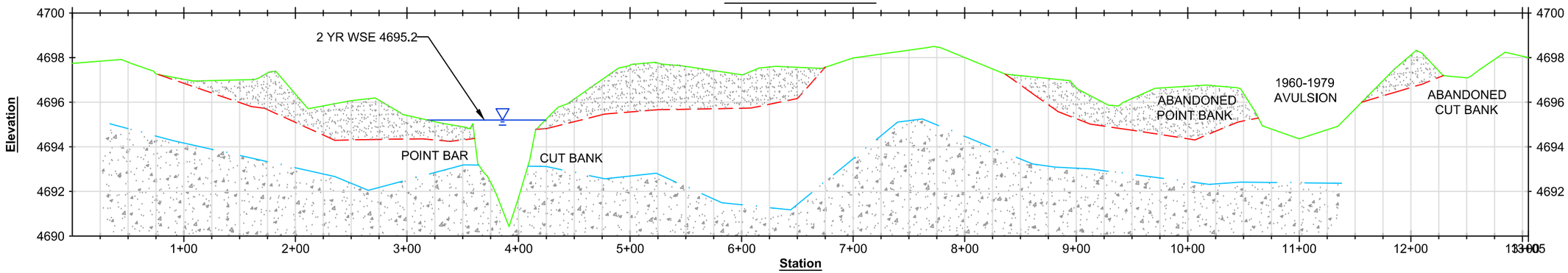
DRAFT

TerraGraphics Environmental Engineering, Inc.

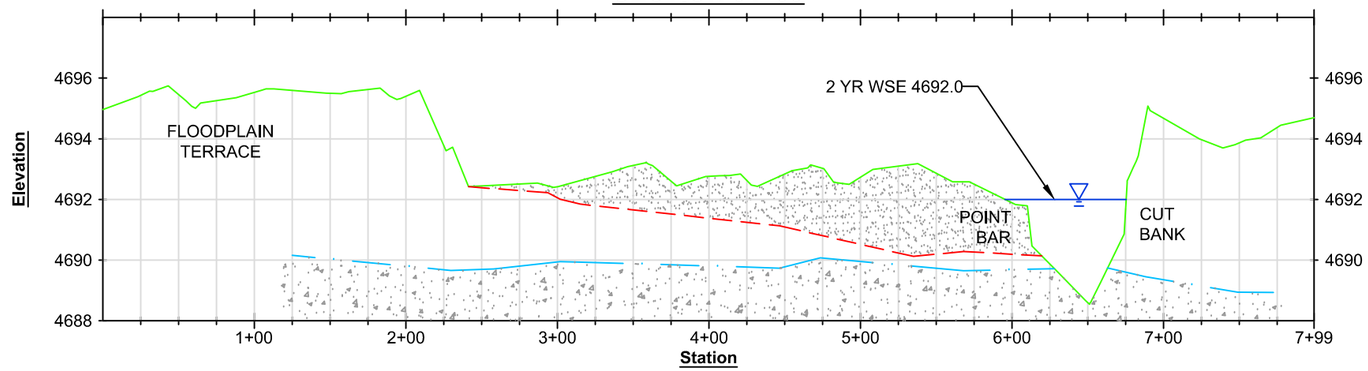
DRAWN: E. EARNEST	PROJECT NO.: 10074-4	CLARK FORK RIVER OPERABLE UNIT, PHASE 5 & 6	FLOODPLAIN CROSS SECTIONS
ENGINEER: M. CULPO	SCALE: HORZ. 1" = 100' VERT. 1" = 5'	GEOMORPHIC, HYDROLOGIC & HYDRAULIC INVESTIGATION	DRAWING: CS-1
CHECKED: XXXX	APPROVED: XXXX		DATE: 7/19/2012
DATE: XXXX	DATE: XXXX		SHEET: 1 OF 2
			COORDINATE SYSTEM:

T:\Clark Fork River Floodplain\TO 26 – 10074 – CFR Ph 5 and 6 Investigation\6) DRAWINGS – BOISE\d. Base & Existing Drawings\CFR_SECTIONS.dwg 7/19/2012

SECTION 108+15



SECTION 91+99



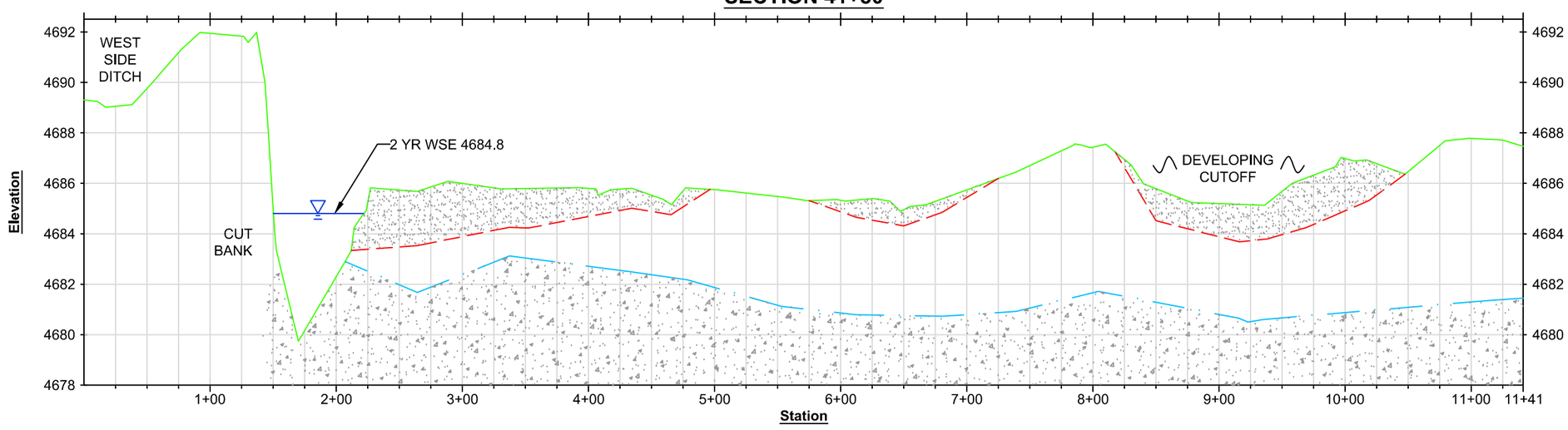
LEGEND

- EXISTING GROUND LINE
- TOP OF RIVER GRAVELS LINE
- BOTTOM O FTAILINGS IMPACTED SOIL Σ C.O.C.s > 800 mg/kg
- WATER SURFACE ELEVATION

0 100 200
HORZ. SCALE: 1" = 100'

0 5 10
VERT. SCALE: 1" = 5'

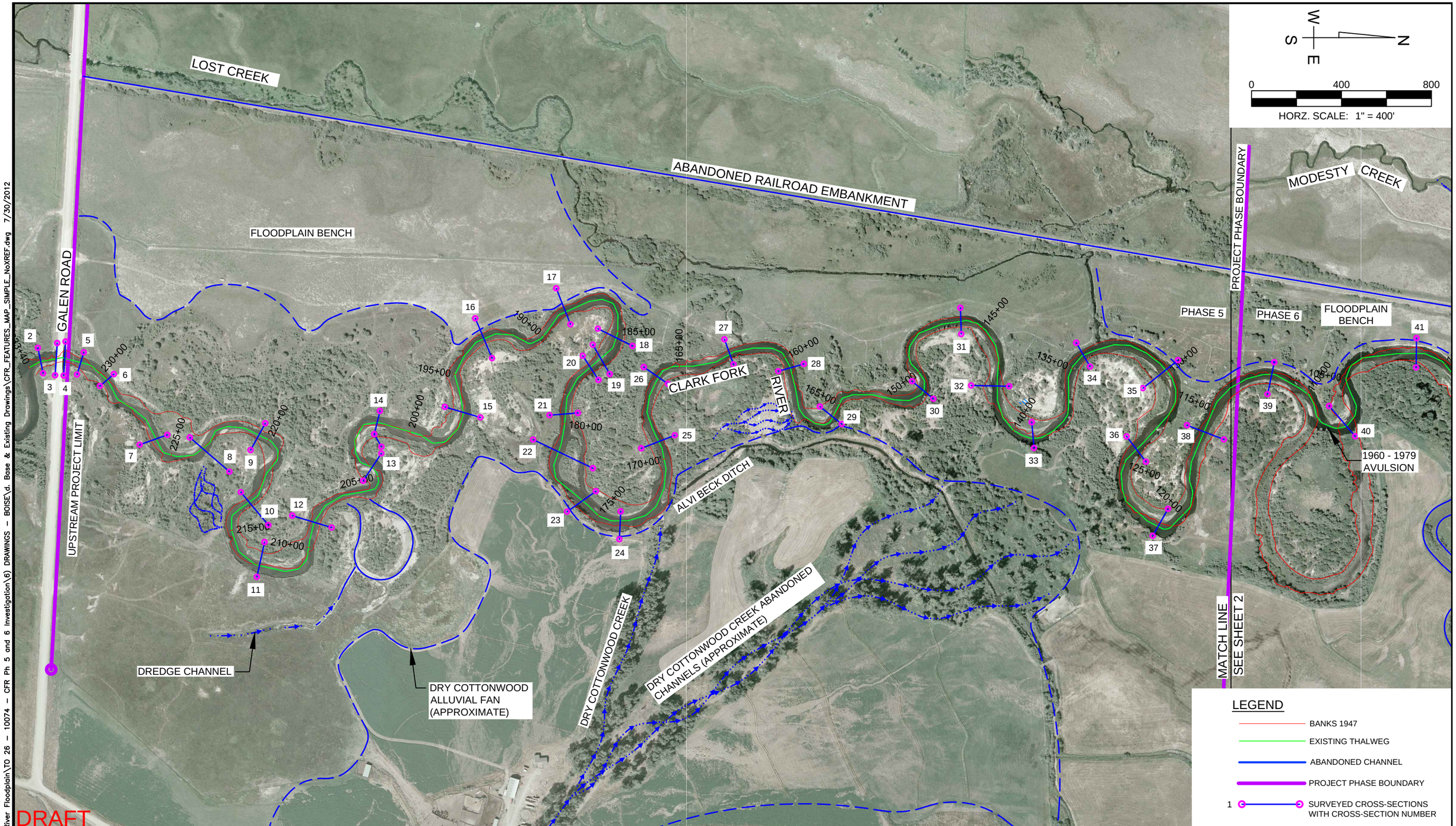
SECTION 41+80



DRAFT

TerraGraphics Environmental Engineering, Inc.	DRAWN: E. EARNEST	PROJECT NO.: 10074-4	CLARK FORK RIVER OPERABLE UNIT, PHASE 5 & 6	FLOODPLAIN CROSS SECTIONS	DRAWING: CS-2
	ENGINEER: M. CULPO	SCALE: HORZ. 1" = 100' VERT. 1" = 5'			DATE: 7/19/2012
	CHECKED: XXXX	APPROVED: XXXX	GEOMORPHIC, HYDROLOGIC & HYDRAULIC INVESTIGATION		SHEET: 2 OF 2
	DATE: XXXX	DATE: XXXX			COORDINATE SYSTEM:

T:\Clark Fork River Floodplain\TO 26 – 10074 – CFR Ph 5 and 6 Investigation\6) DRAWINGS – BOISE\d. Base & Existing Drawings\CFR_SECTIONS.dwg 7/19/2012

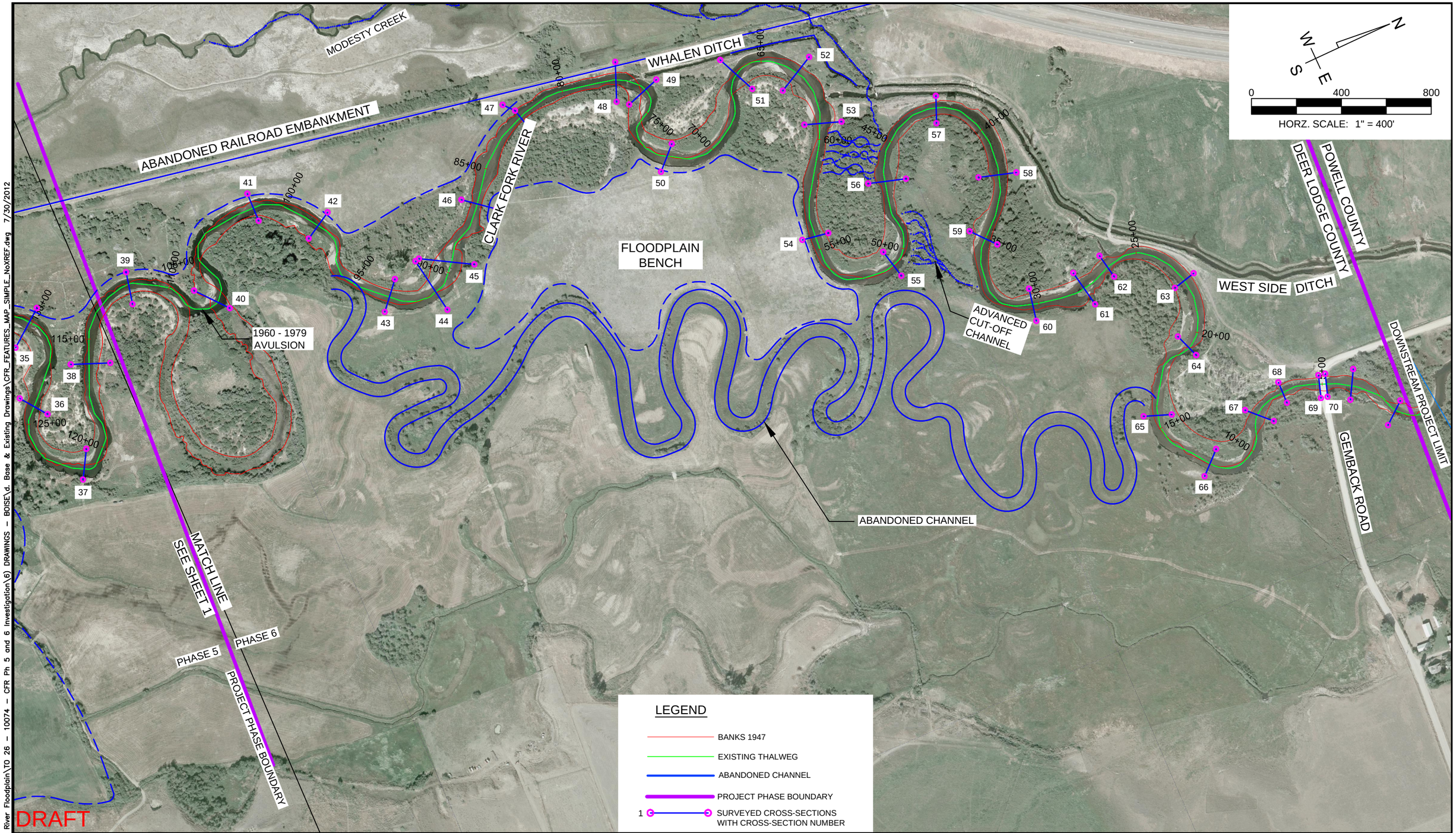


T:\Clark Fork River Floodplain\TO 26 – 10074 – CFR Ph 5 and 6 Investigation\6) DRAWINGS – BOISE\d. Base & Existing Drawings\CFR_FEATURES_MAP_SIMPLE_NoXREF.dwg 7/30/2012

TerraGraphics Environmental Engineering, Inc.

DRAWN: E. EARNEST	PROJECT NO.: 10074-4	CLARK FORK RIVER OPERABLE UNIT, PHASE 5 & 6	GEOMORPHIC AND FLOODPLAIN FEATURES PHASE 5
ENGINEER: M. CULPO	SCALE: 1" = 400'	GEOMORPHIC, HYDROLOGIC & HYDRAULIC INVESTIGATION	
CHECKED: XXXX	APPROVED: XXXX		
DATE: XXXX	DATE: XXXX		

DRAWING:	GFF-1
DATE:	7/30/2012
SHEET:	1 OF 2
COORDINATE SYSTEM:	



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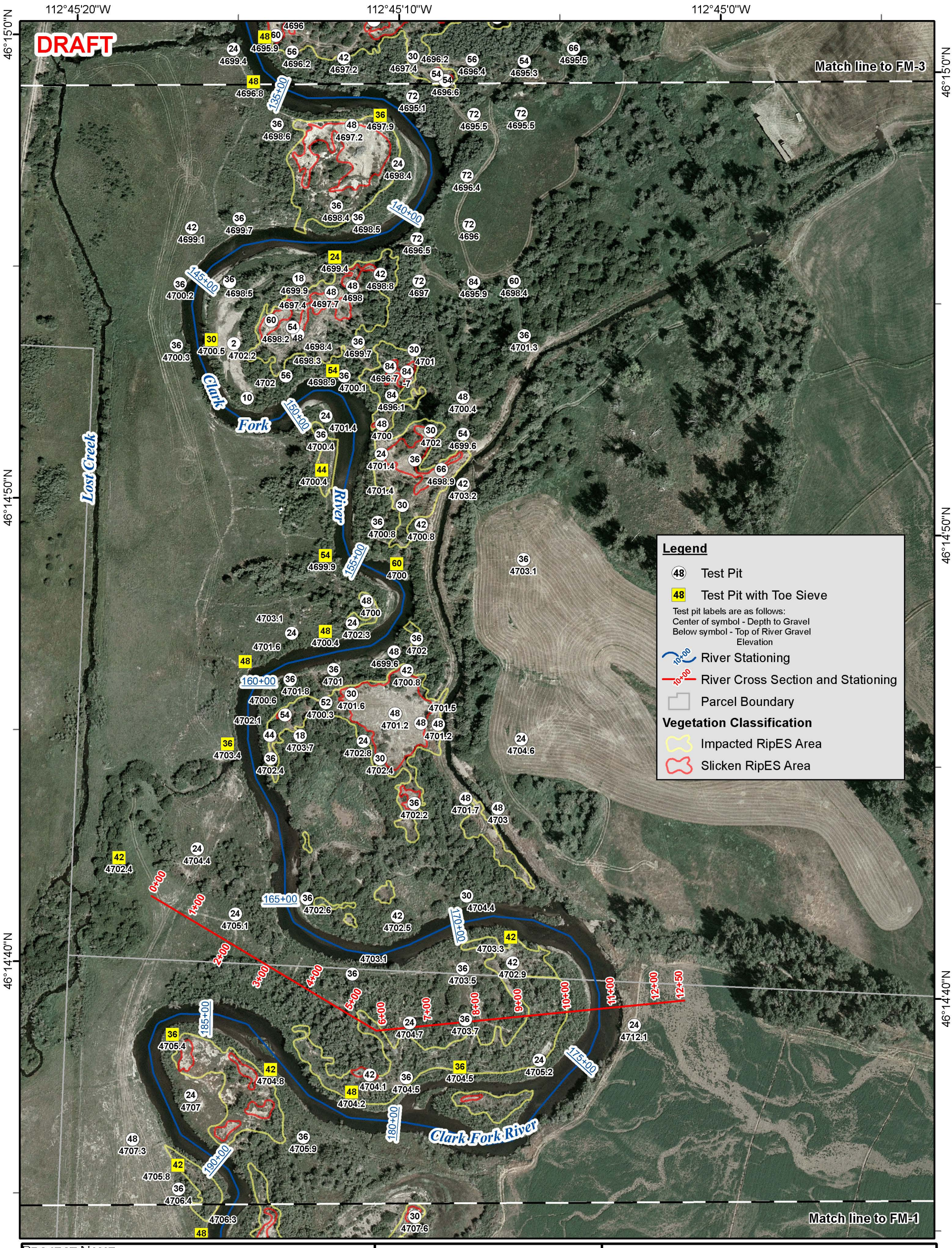
TerraGraphics Environmental Engineering, Inc.

DRAWN: E. EARNEST	PROJECT NO.: 10074-4	CLARK FORK RIVER OPERABLE UNIT, PHASE 5 & 6	GEOMORPHIC AND FLOODPLAIN FEATURES PHASE 6
ENGINEER: M. CULPO	SCALE: 1" = 400'	GEOMORPHIC, HYDROLOGIC & HYDRAULIC INVESTIGATION	DRAWING: GFF-2
CHECKED: XXXX	APPROVED: XXXX		DATE: 7/30/2012
DATE: XXXX	DATE: XXXX		SHEET: 2 OF 2
			COORDINATE SYSTEM:

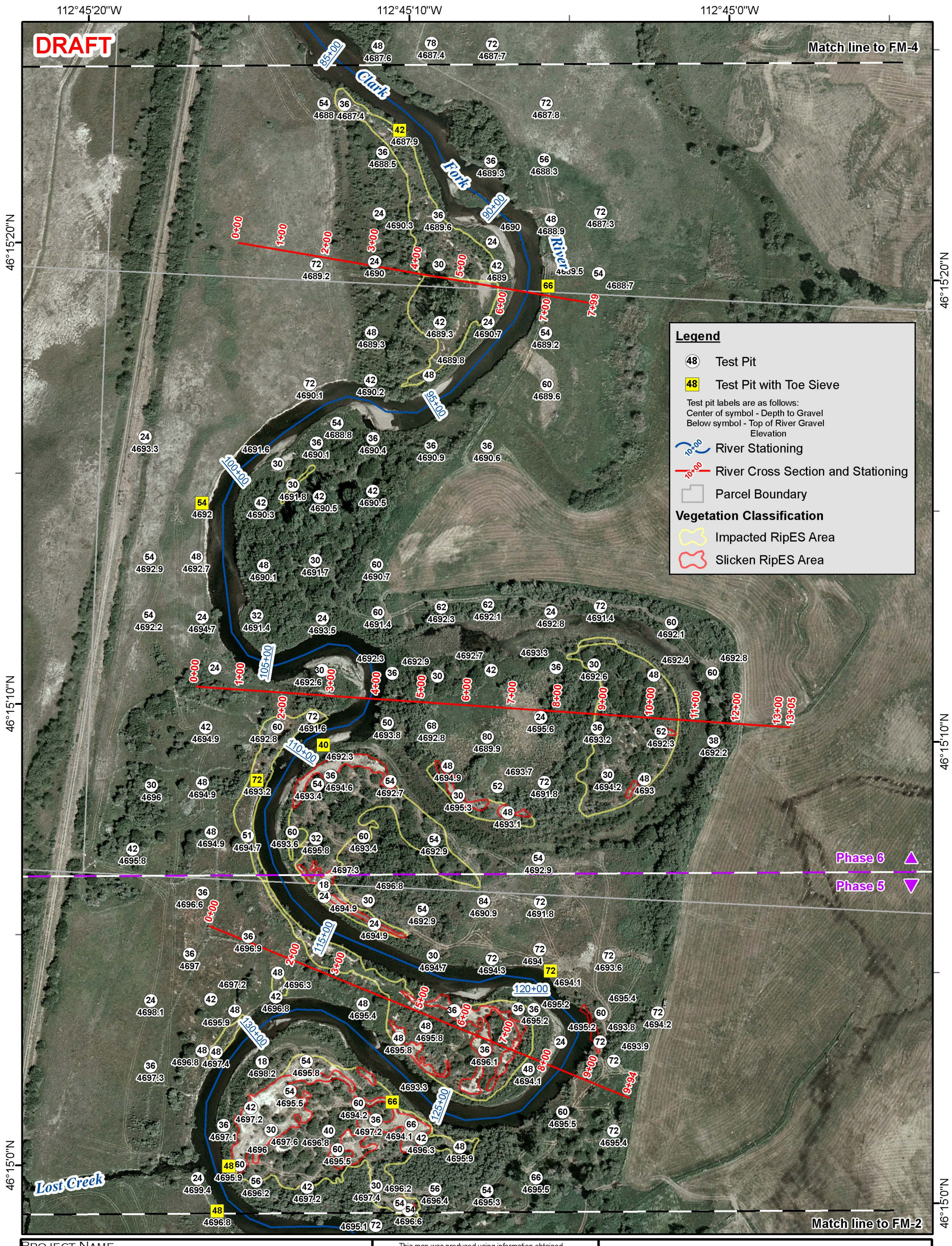
PROJECT NAME **Clark Fork River Operable Unit** **Phase 5 & 6** **Part 2, Geomorphic, Hydrologic & Hydraulic Investigation**	This map was produced using information obtained from several different sources that have not been independently verified. These sources have also not provided information on the precision and accuracy of the data. Information on this map is not a substitute for survey data.	**Floodplain Materials Investigation Map (Phase 5)** **FM-1** **DRAFT**

TerraGraphics Environmental Engineering, Inc. www.TerraGraphics.com	FILE Montana\CFROU_Phase5\mxd\DSR_DepthtoRiverGravel_FM1_20120523	Map Projection: NAD83 UTM12N	Map Scale: **1:2,400** 1 inch = 200 feet 0 50 100 200 Feet
	PRINT DATE May 23, 2012	PROJECT MANAGER M. Culpo / J. Mickey	
	PROJECT NUMBER 10074-3 MDEQ - CFR Investigation - TO #26	CARTOGRAPHER J. Mierzwinski / B. Bailey	



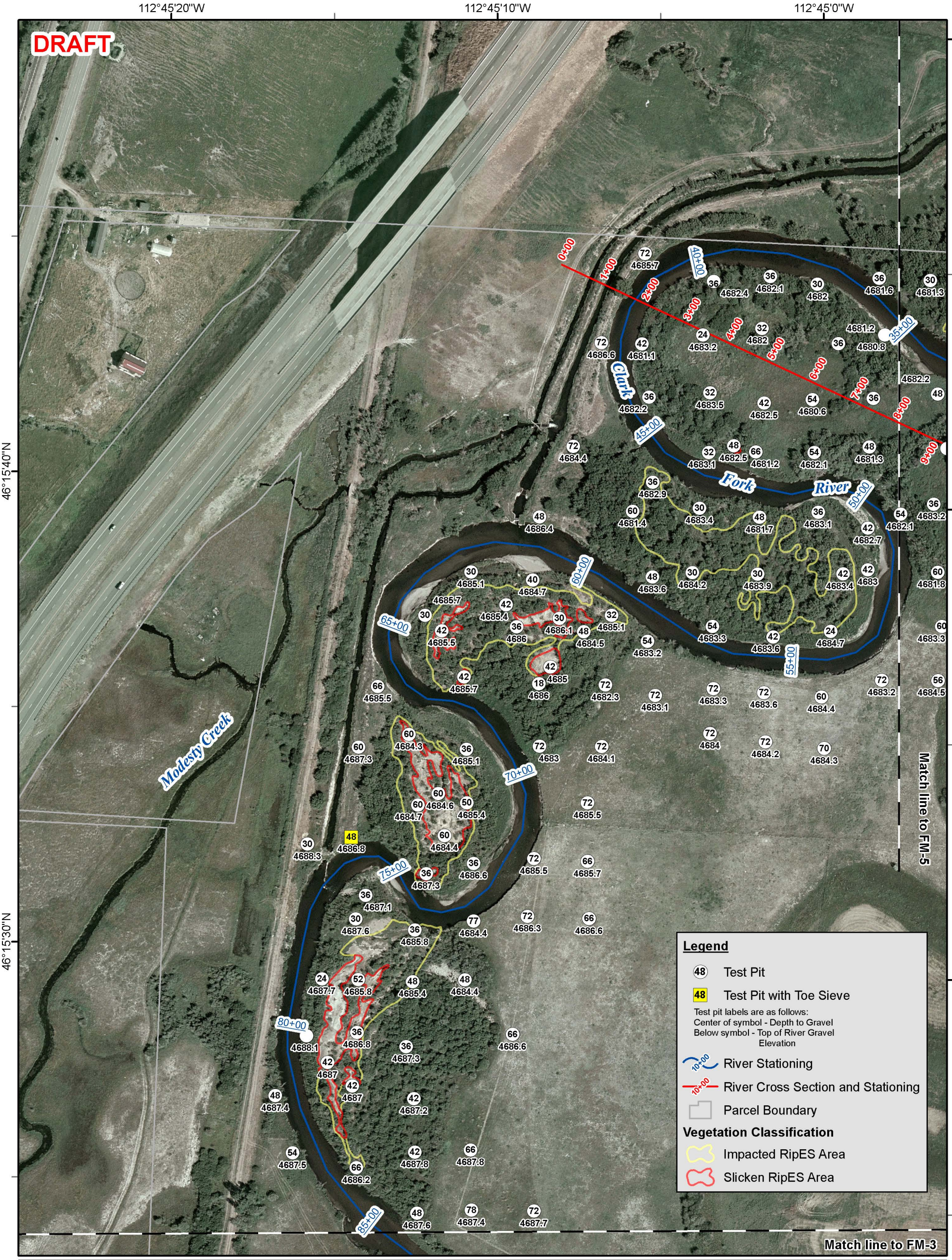
PROJECT NAME **Clark Fork River Operable Unit** **Phase 5 & 6** **Part 2, Geomorphic, Hydrologic & Hydraulic Investigation**	This map was produced using information obtained from several different sources that have not been independently verified. These sources have also not provided information on the precision and accuracy of the data. Information on this map is not a substitute for survey data.	**Floodplain Materials Investigation Map (Phase 5)** **FM-2** **DRAFT**

TerraGraphics Environmental Engineering, Inc. www.TerraGraphics.com	FILE Montana\CFROU_Phase5\mxd\DSR_DepthtoGravel_FM2_20120523	Map Projection: NAD83 UTM12N	Map Scale: **1:2,400** 1 inch = 200 feet 0 50 100 200 Feet
	PRINT DATE May 23, 2012	PROJECT MANAGER M. Culpo / J. Mickey	
	PROJECT NUMBER 10074-3 MDEQ - CFR Investigation - TO #26	CARTOGRAPHER J. Mierzwinski / B. Bailey	



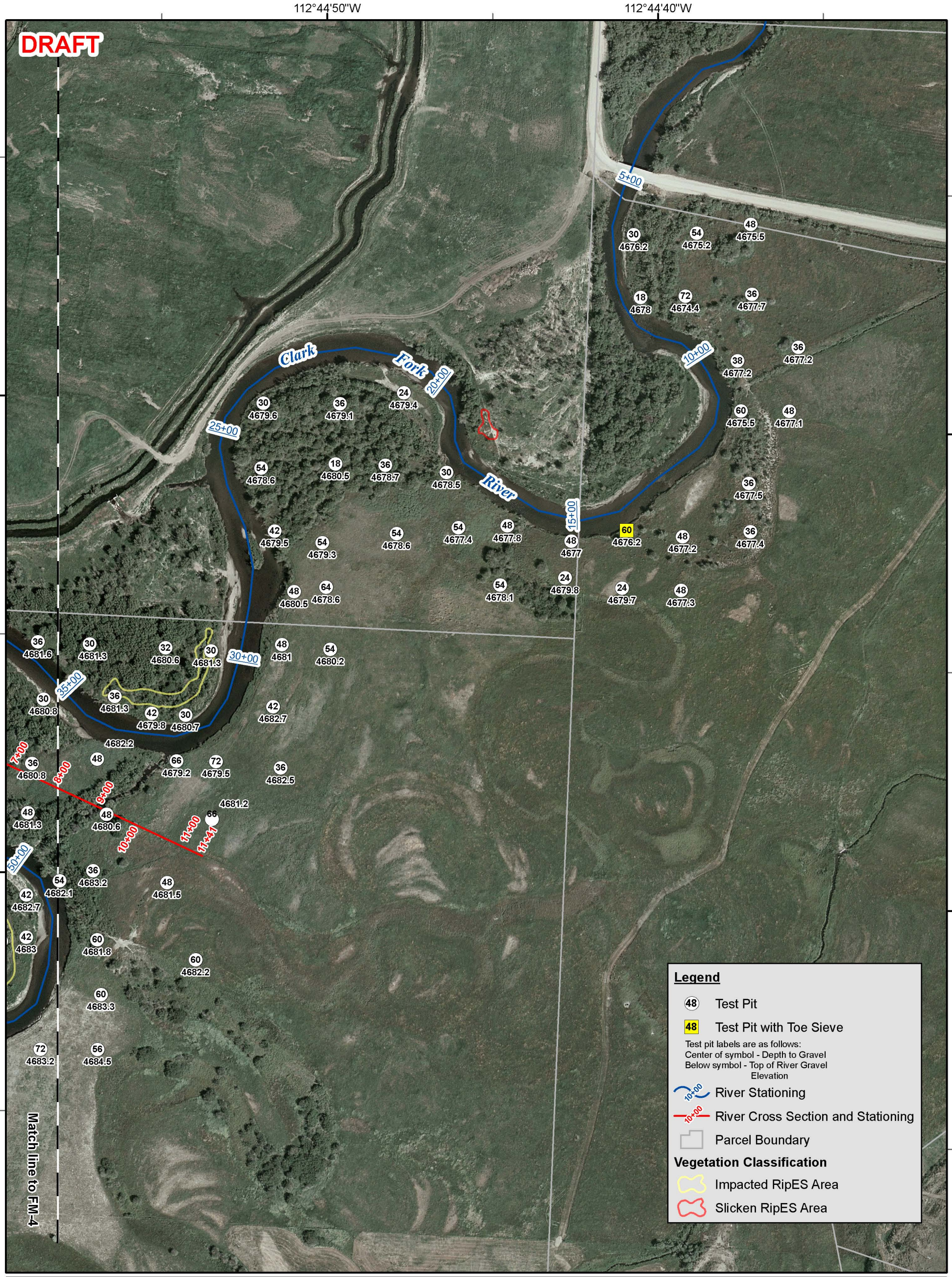
PROJECT NAME **Clark Fork River Operable Unit** **Phase 5 & 6** **Part 2, Geomorphic, Hydrologic & Hydraulic Investigation**	This map was produced using information obtained from several different sources that have not been independently verified. These sources have also not provided information on the precision and accuracy of the data. Information on this map is not a substitute for survey data.	**Floodplain Materials Investigation Map (Phase 6)** **FM-3** **DRAFT**

TerraGraphics Environmental Engineering, Inc. www.TerraGraphics.com	FILE Montana\CFROU_Phase6\mxd\DSR_DepthtoRiverGravel_FM3_20120523	PROJECTION NAD83 UTM12N	Map Scale: **1:2,400** 1 inch = 200 feet 0 50 100 200 Feet
	PRINT DATE May 23, 2012	PROJECT MANAGER M. Culpo / J. Mickey	
	PROJECT NUMBER 10074-3 MDEQ - CFR Investigation - TO #26	CARTOGRAPHER J. Mierzwinski / B. Bailey	



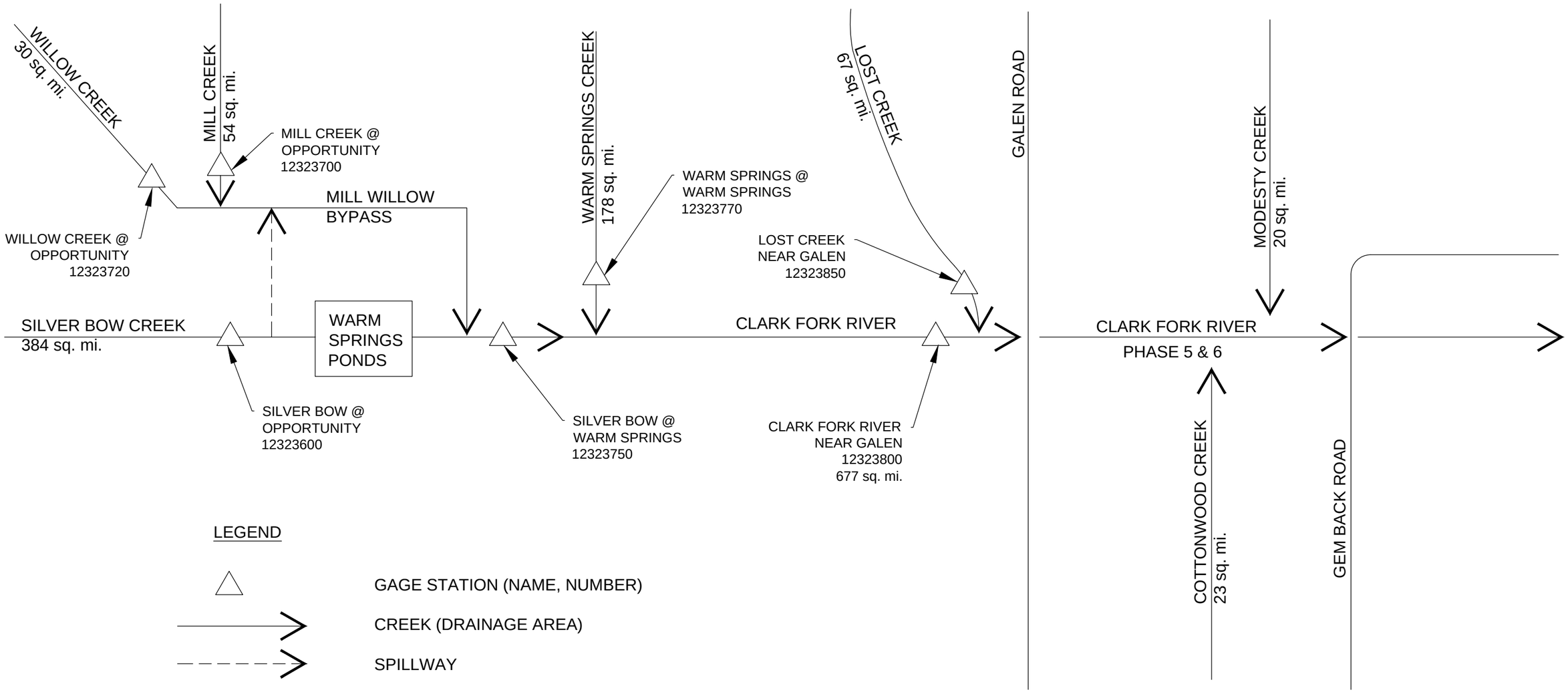
PROJECT NAME **Clark Fork River Operable Unit** **Phase 5 & 6** **Part 2, Geomorphic, Hydrologic & Hydraulic Investigation**	This map was produced using information obtained from several different sources that have not been independently verified. These sources have also not provided information on the precision and accuracy of the data. Information on this map is not a substitute for survey data.	**Floodplain Materials Investigation Map (Phase 6)** **FM-4** **DRAFT**

TerraGraphics Environmental Engineering, Inc. www.TerraGraphics.com	FILE Montana\CFROU_Phase6\mxd\DSR_DepthtoRiverGravel_FM4_20120523	PROJECTION NAD83 UTM12N	Map Scale: **1:2,400** 1 inch = 200 feet 0 50 100 200 Feet
	PRINT DATE May 23, 2012	PROJECT MANAGER M. Culpo / J. Mickey	
	PROJECT NUMBER 10074-3 MDEQ - CFR Investigation - TO #26	CARTOGRAPHER J. Mierzwinski / B. Bailey	



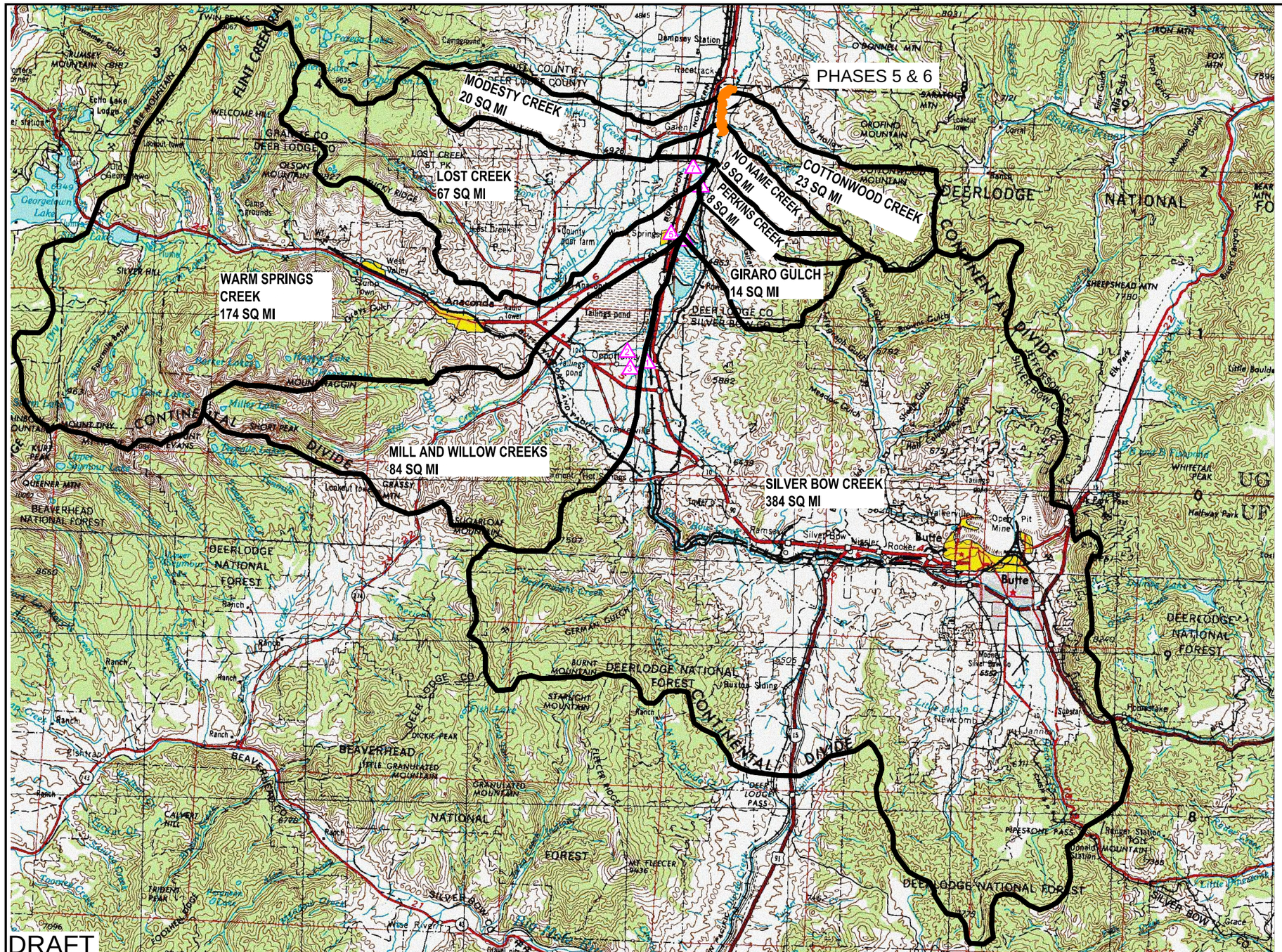
PROJECT NAME **Clark Fork River Operable Unit** **Phase 5 & 6** **Part 2, Geomorphic, Hydrologic & Hydraulic Investigation**	This map was produced using information obtained from several different sources that have not been independently verified. These sources have also not provided information on the precision and accuracy of the data. Information on this map is not a substitute for survey data.	**Floodplain Materials Investigation Map (Phase 6)** **FM-5** **DRAFT**

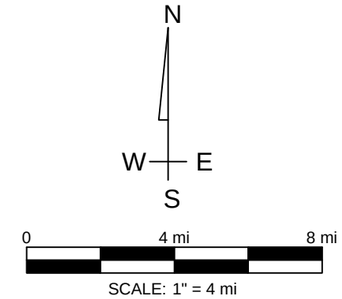
TerraGraphics Environmental Engineering, Inc. www.TerraGraphics.com	FILE Montana\CFROU_Phase6\mxd\DSR_DepthtoRiverGravel_FM5_20120523	PROJECTION NAD83 UTM12N	Map Scale: **1:2,400** 1 inch = 200 feet 0 50 100 200 Feet
	PRINT DATE May 23, 2012	PROJECT MANAGER M. Culpo / J. Mickey	
	PROJECT NUMBER 10074-3 MDEQ - CFR Investigation - TO #26	CARTOGRAPHER J. Mierzwinski / B. Bailey	



DRAFT

TerraGraphics Environmental Engineering, Inc.	DRAWN: E. EARNEST	PROJECT NO.: 10074-4	CLARK FORK RIVER OPERABLE UNIT, PHASE 5 & 6	BASIN ROUTING MAP	DRAWING: DM-1
	ENGINEER: M. CULPO	SCALE: NOT TO SCALE			DATE: 4/12/2012
	CHECKED: XXXX	APPROVED: XXXX	GEOMORPHIC, HYDROLOGIC & HYDRAULIC INVESTIGATION		SHEET: 1 OF 3
	DATE: XXXX	DATE: XXXX			COORDINATE SYSTEM:





LEGEND

- DRAINAGE AREA BOUNDARY
- SILVER BOW CREEK 384 SQ MI — DRAINAGE AREA NAME AND SIZE
- GAGE STATION LOCATION AND DESIGNATION (SEE TABLE FOR DESCRIPTIONS)
- PHASE 5 & 6 AREA

GAGE STATION LOCATIONS

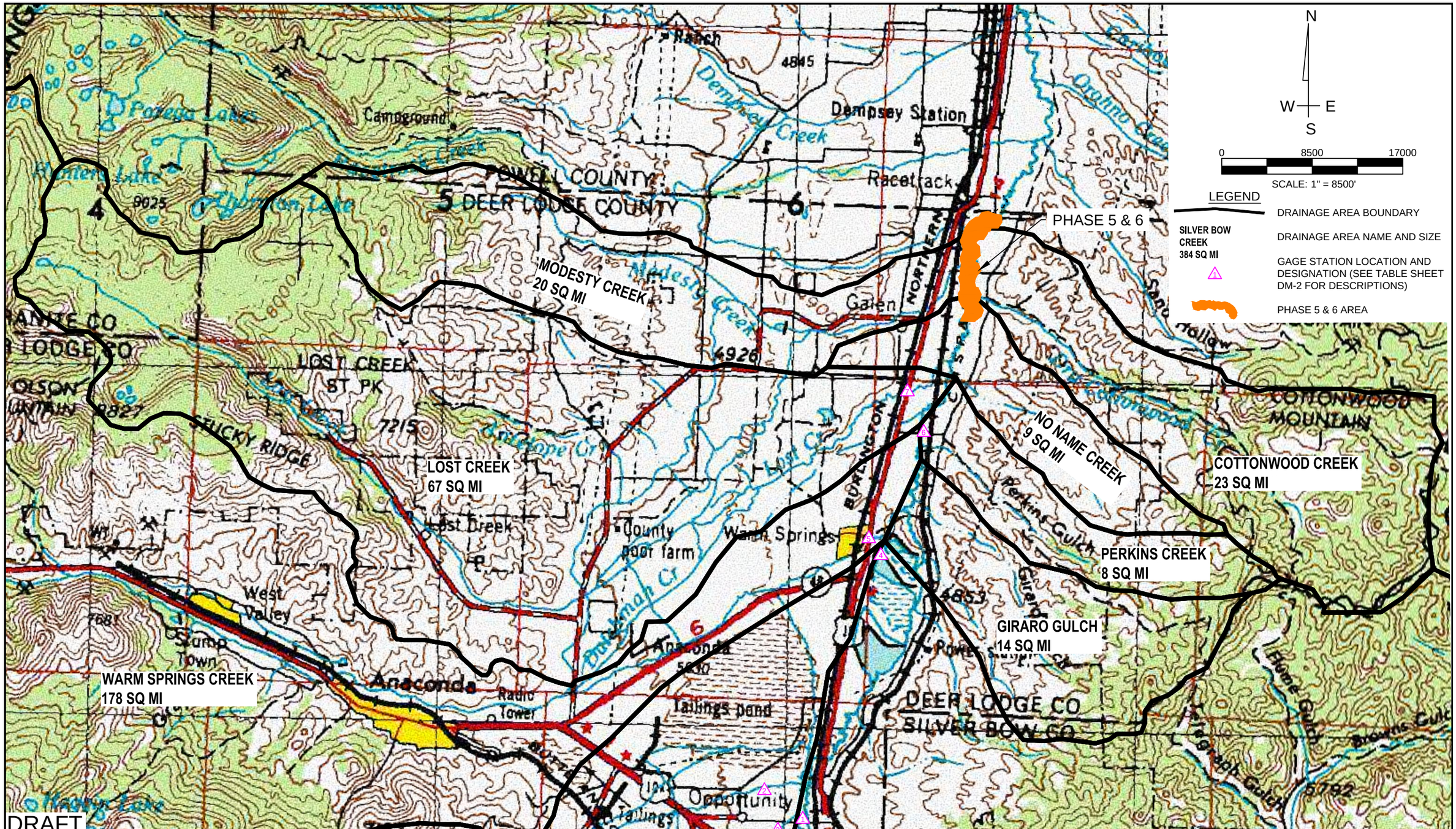
NO.	STATION ID	STATION LOCATION
1	12323600	SILVER BOW CREEK AT OPPORTUNITY
2	12323700	MILL CREEK AT OPPORTUNITY
3	12323720	WILLOW CREEK AT OPPORTUNITY
4	12323750	SILVER BOW CREEK AT WARM SPRINGS
5	12323770	WARM SPRINGS AT WARM SPRINGS
6	12323800	CLARK FORK RIVER NEAR GALEN
7	12323850	LOST CREEK NEAR GALEN

DRAFT

TerraGraphics Environmental Engineering, Inc.

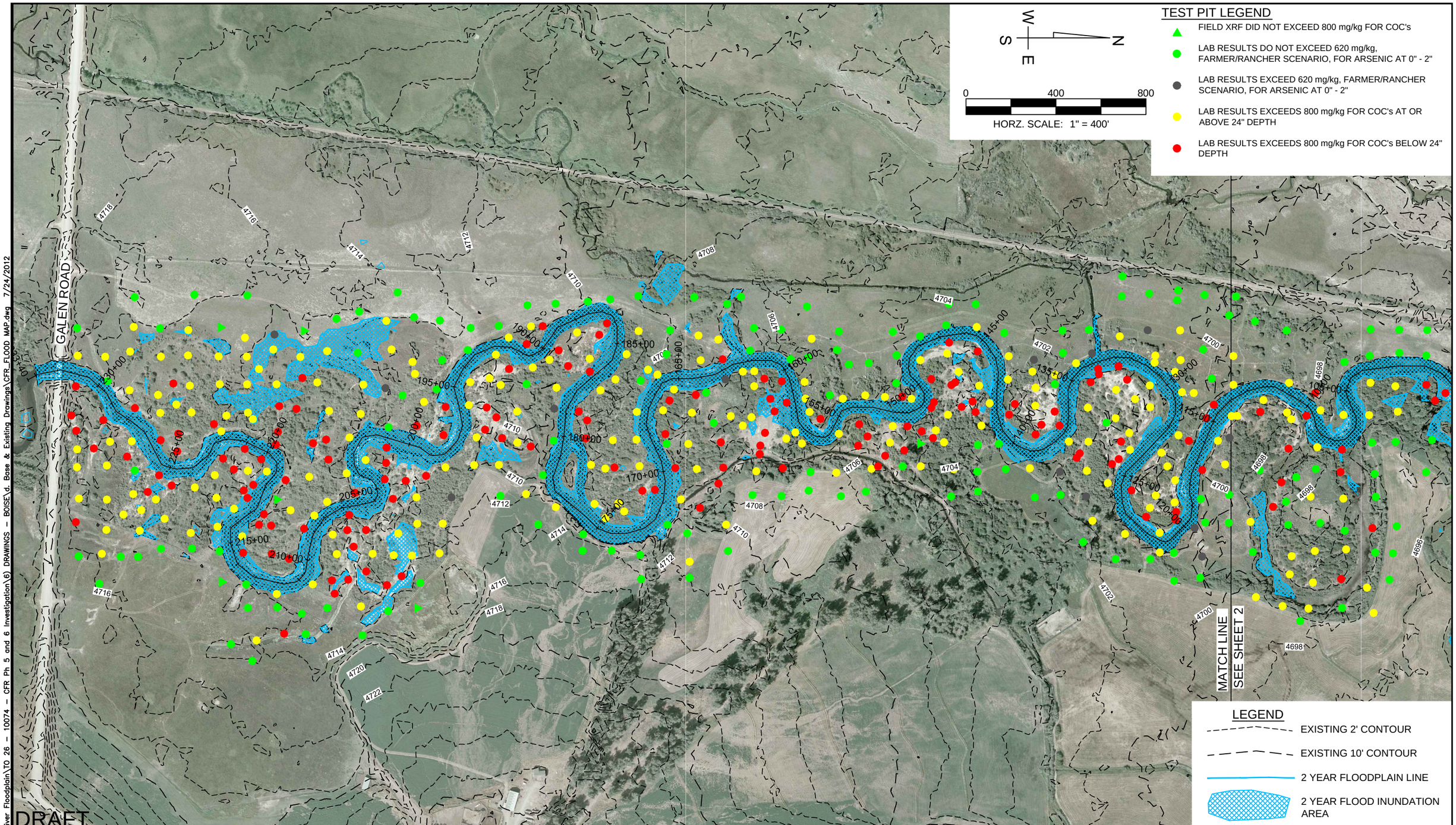
DRAWN: E. EARNEST	PROJECT NO.: 10074-4	CLARK FORK RIVER OPERABLE UNIT, PHASE 5 & 6	BASIN AREA DELINEATION MAP
ENGINEER: M. CULPO	SCALE: NOT TO SCALE	GEOMORPHIC, HYDROLOGIC & HYDRAULIC INVESTIGATION	
CHECKED: XXXX	APPROVED: XXXX		
DATE: XXXX	DATE: XXXX		

DRAWING: DM-2
DATE: 4/12/2012
SHEET: 2 OF 3
COORDINATE SYSTEM:



TerraGraphics
Environmental Engineering, Inc.

DRAWN: E. EARNEST	PROJECT NO.: 10074-4	CLARK FORK RIVER OPERABLE UNIT, PHASE 5 & 6	BASIN AREA DELINEATION MAP	DRAWING: DM-3
ENGINEER: M. CULPO	SCALE: NOT TO SCALE			DATE: 4/12/2012
CHECKED: XXXX	APPROVED: XXXX	GEOMORPHIC, HYDROLOGIC & HYDRAULIC INVESTIGATION		SHEET: 3 OF 3
DATE: XXXX	DATE: XXXX			COORDINATE SYSTEM:



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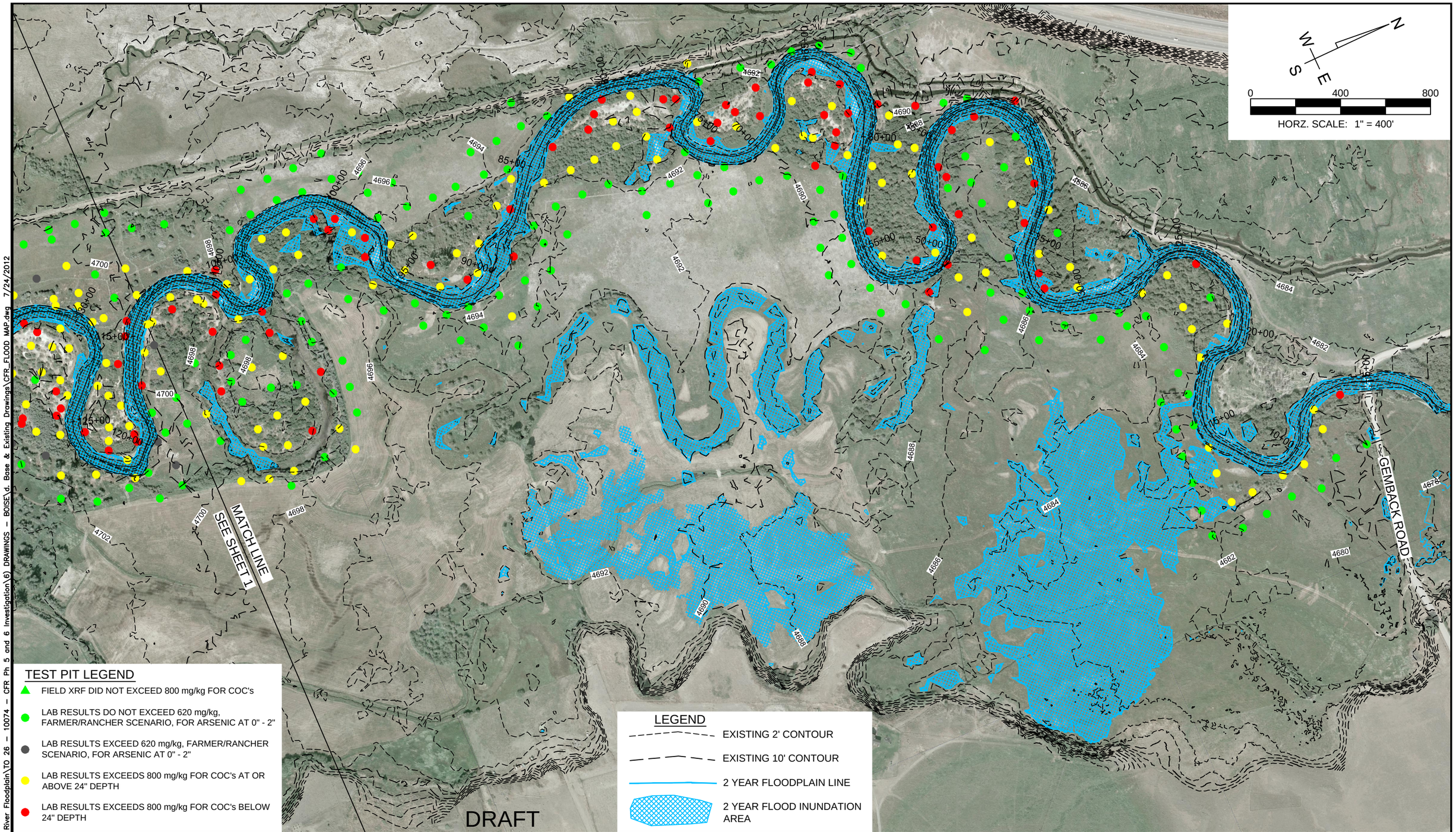
TerraGraphics Environmental Engineering, Inc.

DRAWN: E. EARNEST	PROJECT NO.: 10074-4	CLARK FORK RIVER OPERABLE UNIT, PHASE 5 & 6	2 YEAR FLOODPLAIN INUNDATION MAP
ENGINEER: M. CULPO	SCALE: 1" = 400'	GEOMORPHIC, HYDROLOGIC & HYDRAULIC INVESTIGATION	
CHECKED: XXXX	APPROVED: XXXX		
REVISED: G. HOGGATT	DATE: 7/06/2012		

DRAWING:	FP-1
DATE:	7/24/2012
SHEET:	1 OF 6
COORDINATE SYSTEM:	



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TerraGraphics Environmental Engineering, Inc.

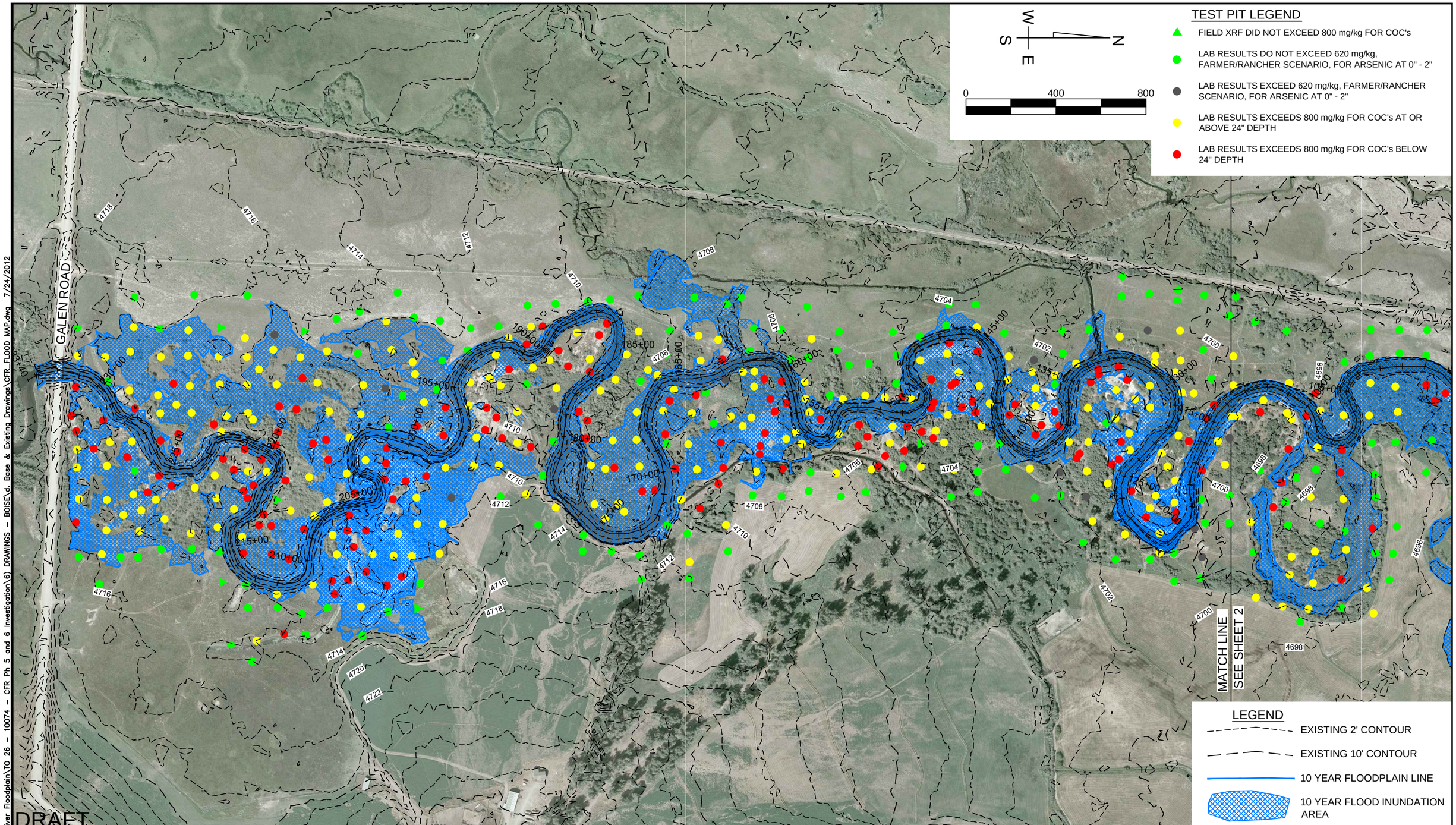
DRAWN:	E. EARNEST	PROJECT NO.:	10074-4
ENGINEER:	M. CULPO	SCALE:	1" = 400'
CHECKED:	XXXX	APPROVED:	XXXX
REVISED:	G. HOGGATT	DATE:	7/06/2012

CLARK FORK RIVER OPERABLE UNIT, PHASE 5 & 6

GEOMORPHIC, HYDROLOGIC & HYDRAULIC INVESTIGATION

2 YEAR FLOODPLAIN INUNDATION MAP

DRAWING:	FP-2
DATE:	7/24/2012
SHEET:	2 OF 6
COORDINATE SYSTEM:	



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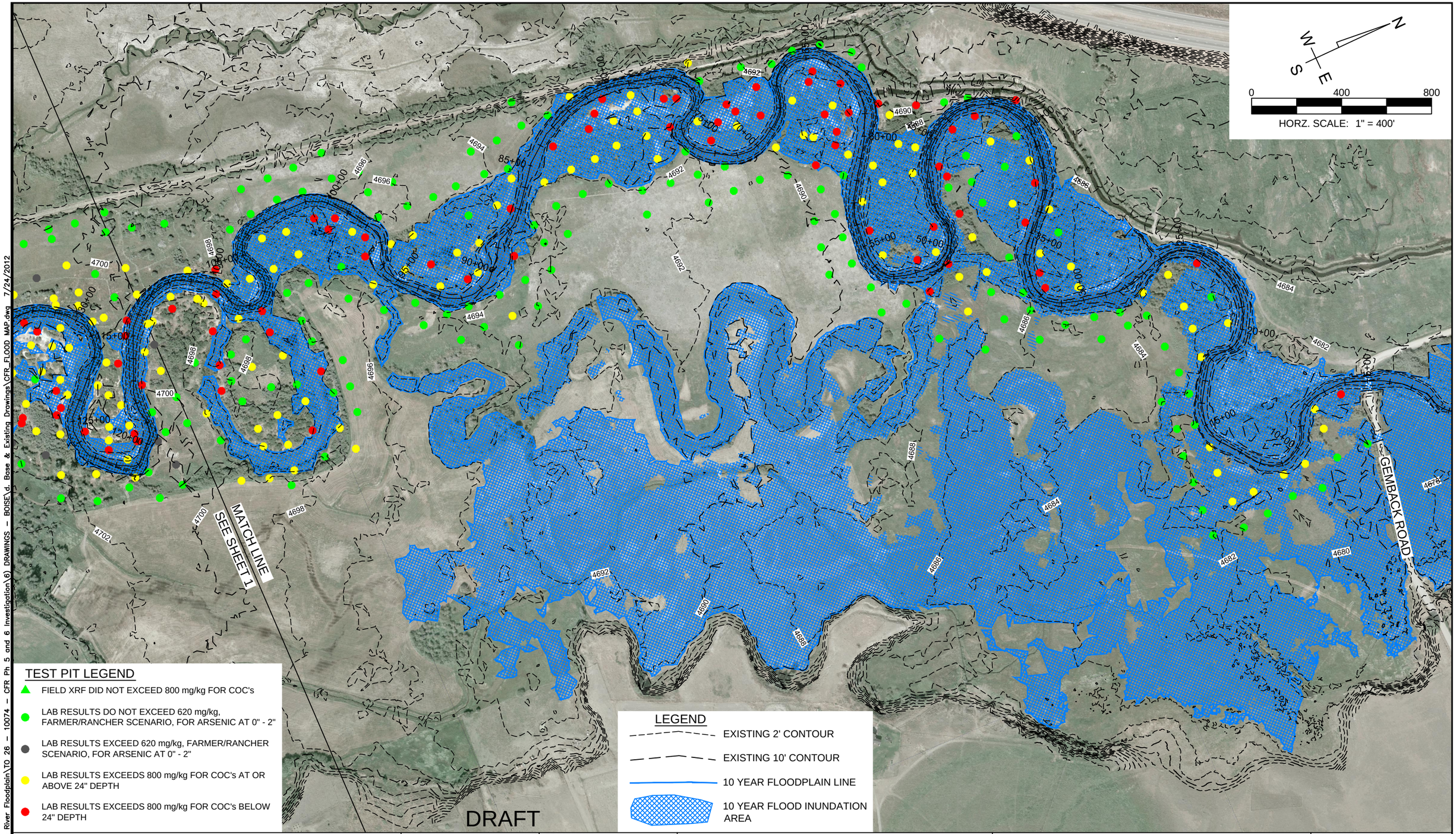
TerraGraphics Environmental Engineering, Inc.

DRAWN: E. EARNEST	PROJECT NO.: 10074-4	CLARK FORK RIVER OPERABLE UNIT, PHASE 5 & 6	10 YEAR FLOODPLAIN INUNDATION MAP
ENGINEER: M. CULPO	SCALE: 1" = 400'	GEOMORPHIC, HYDROLOGIC & HYDRAULIC INVESTIGATION	DRAWING: FP-3
CHECKED: XXXX	APPROVED: XXXX		DATE: 7/24/2012
DATE: XXXX	DATE: XXXX		SHEET: 3 OF 6
			COORDINATE SYSTEM:



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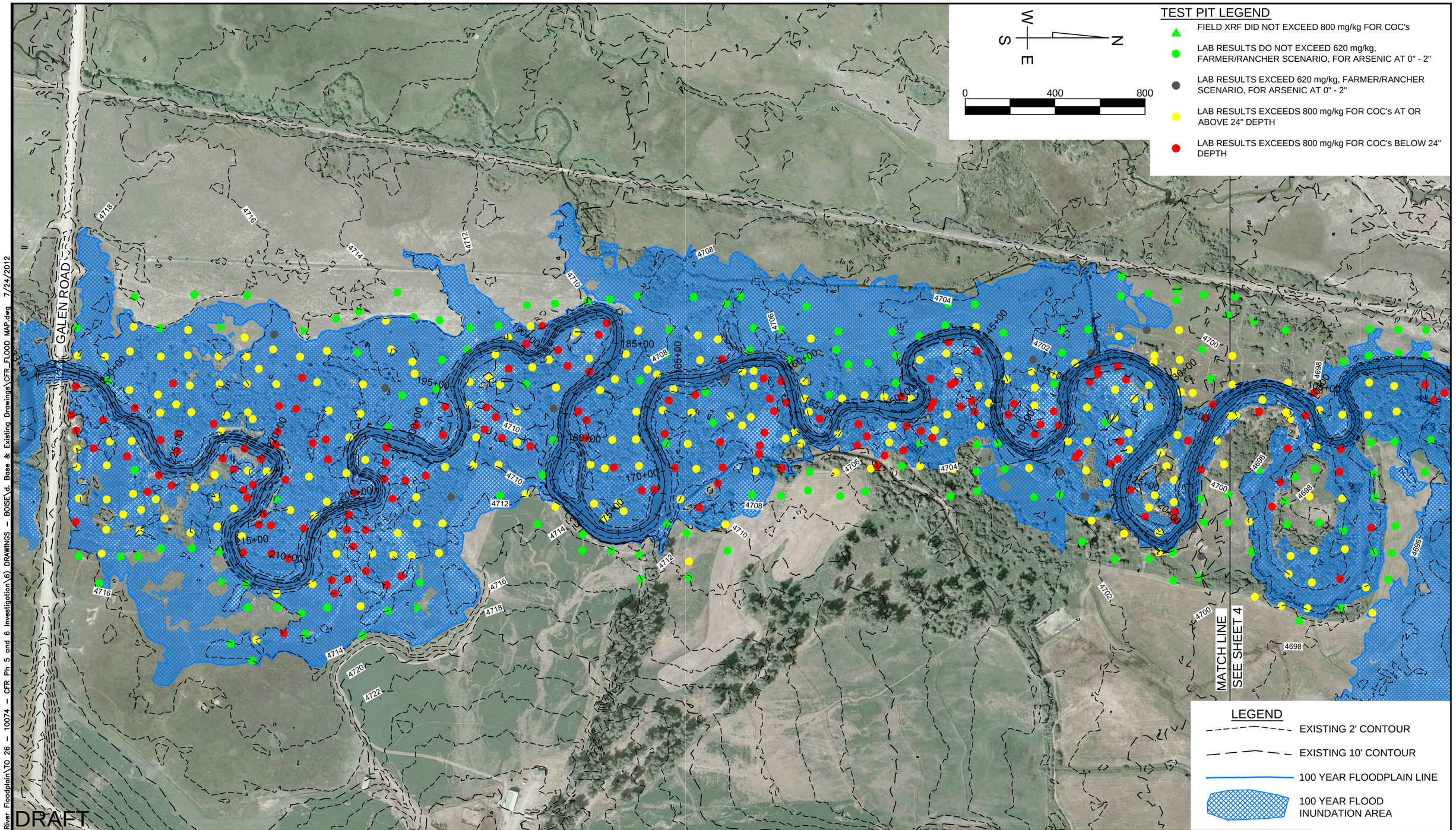
TerraGraphics Environmental Engineering, Inc.

DRAWN: E. EARNEST	PROJECT NO.: 10074-4	CLARK FORK RIVER OPERABLE UNIT, PHASE 5 & 6	10 YEAR FLOODPLAIN INUNDATION MAP
ENGINEER: M. CULPO	SCALE: 1" = 400'	GEOMORPHIC, HYDROLOGIC & HYDRAULIC INVESTIGATION	
CHECKED: XXXX	APPROVED: XXXX		
DATE: XXXX	DATE: XXXX		

DRAWING: FP-4
DATE: 7/24/2012
SHEET: 4 OF 6
COORDINATE SYSTEM:



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TerraGraphics Environmental Engineering, Inc.

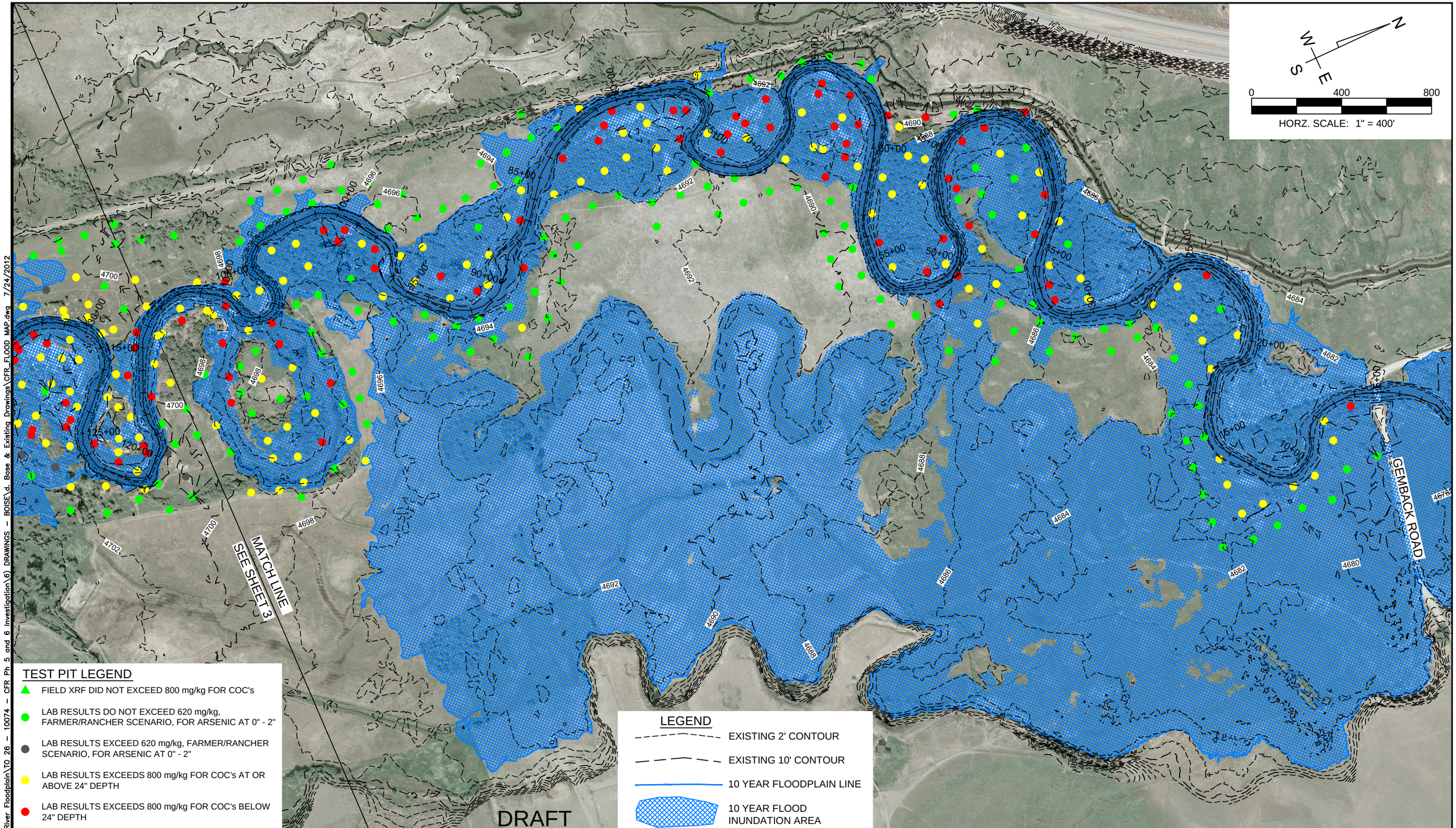
DRAWN:	E. EARNEST	PROJECT NO.:	10074-4
ENGINEER:	M. CULPO	SCALE:	1" = 400'
CHECKED:	XXXX	APPROVED:	XXXX
DATE:	XXXX	DATE:	XXXX

CLARK FORK RIVER OPERABLE UNIT, PHASE 5 & 6

GEOMORPHIC, HYDROLOGIC & HYDRAULIC INVESTIGATION

100 YEAR FLOODPLAIN INUNDATION MAP

DRAWING:	FP-5
DATE:	7/24/2012
SHEET:	5 OF 6
COORDINATE SYSTEM:	



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TerraGraphics Environmental Engineering, Inc.

DRAWN: E. EARNEST	PROJECT NO.: 10074-4	CLARK FORK RIVER OPERABLE UNIT, PHASE 5 & 6	100 YEAR FLOODPLAIN INUNDATION MAP
ENGINEER: M. CULPO	SCALE: 1" = 400'	GEOMORPHIC, HYDROLOGIC & HYDRAULIC INVESTIGATION	DRAWING: FP-6
CHECKED: XXXX	APPROVED: XXXX		DATE: 7/24/2012
DATE: XXXX	DATE: XXXX		SHEET: 6 OF 6
			COORDINATE SYSTEM: