Flint Creek riparian restoration

Flint Creek Assessment and Conceptual Design Report

Near Hall, Montana

Submitted To:

State of Montana Natural Resource Damage Program
P.O. Box 201425
Helena, MT 59620

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RDG
RIVER DESIGN GROUP

www.riverdesigngroup.com

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1 Introduction

1.1 Project Overview

Flint Creek is located in the headwaters of the Upper Clark Fork River Basin southeast of Missoula, Montana. Flint Creek originates from the John Long Range and the Flint Creek Range and flows north to its confluence with the Clark Fork near Drummond, Montana. The watershed has a history of disturbance resulting in altered stream processes, impaired vegetation, poor water quality, and poor aquatic habitat. Flint Creek is listed as impaired for metals under the 303 (d) of the Clean Water Act for metals and sediment (DEQ 2012). The source of metals contamination originates from the watershed's extensive mining history and abandoned mine waste. The source of sediment for the watershed is largely derived from grazing and agricultural activities in the valley floor.

The State of Montana Natural Resource Damage Program (NRDP) has identified the Flint Creek Watershed as a priority area for restoration (NRDP 2012). River Design Group, Inc. (RDG) was contracted by NRDP to develop a conceptual restoration design for the Corbett-Downs property near Hall, Montana (Figure 1-1). Opportunities exist on the Corbett-Downs property to address both NRDP and landowner objectives for restoration and conservation on Flint Creek.

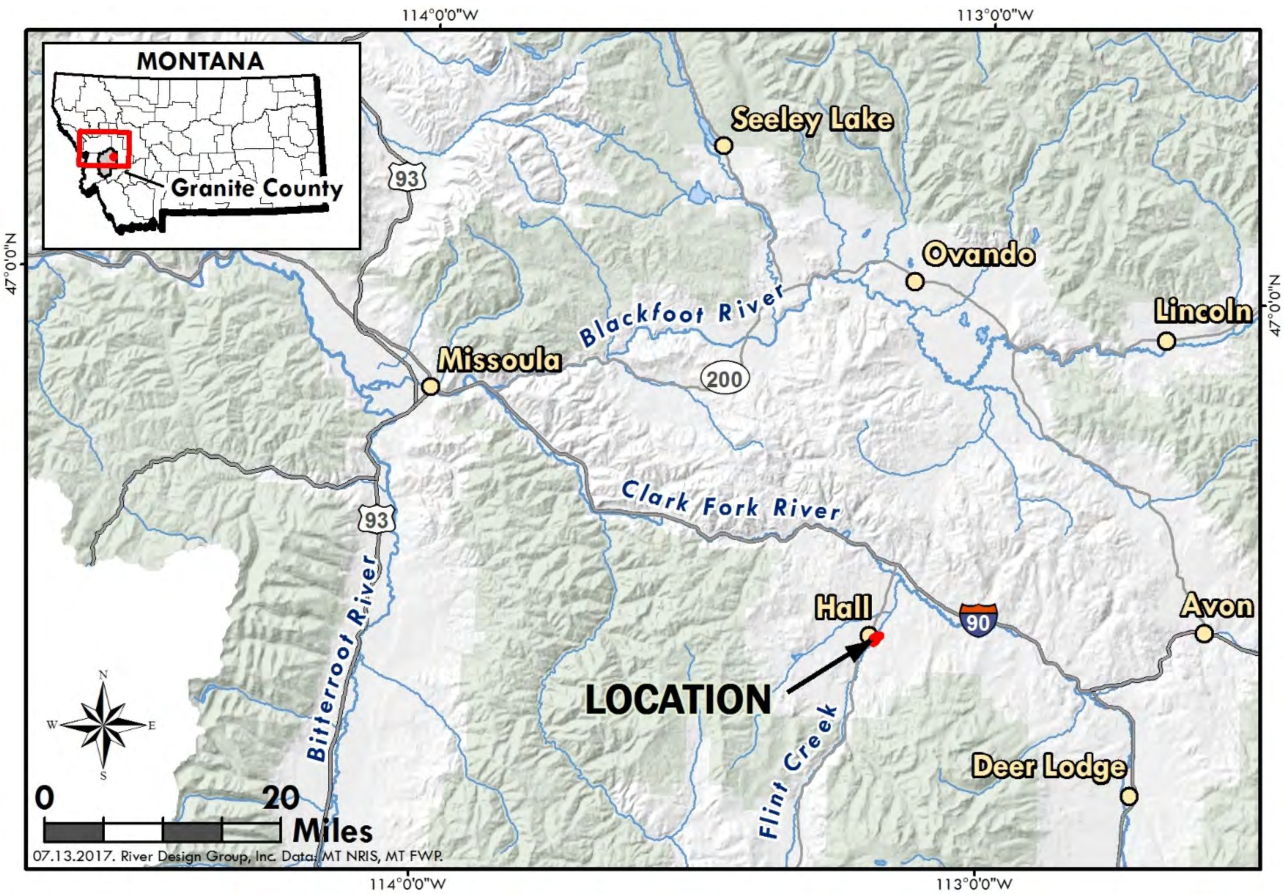

Figure 1-1. Project vicinity map for the Corbett-Downs property near Hall, Montana.

1.2 Goals and Objectives

The Final Upper Clark Fork Basin Aquatic and Terrestrial Resources Plan (NRDP 2012) outlines key objectives for lower Flint Creek as outlined below:

- Improve water quantity through flow augmentation (e.g., water right purchases, water leases, and irrigation efficiency improvements);
- Reduce fish entrainment at irrigation diversions;
- Improve fish passage throughout the reach; and
- Riparian habitat improvements including fencing/protection, woody shrub and tree plantings, and off-site watering.

In addition the landowner has identified objectives that coincide with NRDP's overarching goals for Flint Creek as outlined below:

- Improve fish habitat on the property;
- Improve terrestrial habitat for waterfowl and other wildlife; and
- Maintain a functional ranch and grazing lease.

Not all of NRDP's objectives for Flint Creek apply to the Corbett-Downs property; however, restoration plans will aim to maximize the potential to meet the attainable objectives

1.3 Previous Studies

Several documents describe existing conditions and restoration opportunities in the Flint Creek watershed including:

- Flint Creek Return Flow Study (DNRC 1997)
- Assessment of Fish Populations and Riparian Habitat in the Tributaries of the Upper Clark Fork River Basin Phase II (FWP 2009)
- Flint Creek Planning Area Sediment and Metals TMDLs and Framework Water Quality Improvement Plan (DEQ 2012)
- Upper Clark Fork River Tributaries Fish Passage Assessment (Trout Unlimited 2013)
- Flint Creek Watershed Restoration Plan (Granite Headwaters Watershed Group 2014)
- Riparian Habitat Assessment for Flint Creek and Boulder Creek (Prepared by Watershed Consulting, LLC and Great West Engineering, Inc. for MT NRDP 2015)

In general, previous studies thoroughly document the existing conditions of the Flint Creek watershed and describe the limiting factors responsible for the observed impairments. In addition, previous studies identify restoration opportunities on Flint Creek including potential locations for restoration as well as recommendations for restoration strategies.

1.4 Document Organization

This report is based on existing data from previous studies, remotely sensed data, and data collected during a 2016 field inventory of existing conditions in the Corbett property reach. The following sections are included in this document:

- ***Section 1.0 Introduction;*** provides an overview of the Flint Creek Assessment and Conceptual Design Report, and goals, objectives, and organization of this document;
- ***Section 2.0 Existing Conditions;*** includes discussion of the site assessment and limiting factors identified for the Flint Creek watershed;
- ***Section 3.0 Restoration Strategies;*** presents an overview of restoration techniques that would address limiting factors;
- ***Section 4.0 Conceptual Restoration;*** provides conceptual designs for the project reach with a discussion of alternatives discussed through the process;
- ***Section 5.0 Design and Implementation Considerations***; presents a discussion of what was considered in the design stage and next steps toward project construction;
- ***Section 6.0 References***;
- ***Appendix A – Hydrology Summary*** provides hydrologic data tables and figures**;**
- ***Appendix B - Geomorphic Summary*** provides geomorphic data tables and figures; and
- ***Appendix C – Cost Estimates*** contains engineers cost estimates for the concepts.

2 Existing Conditions

2.1 Watershed Overview

The Flint Creek watershed is located within Granite and Deer Creek Counties and is surrounded by a series of mountain ranges: The Flint Creek mountains to the east, the Anaconda Range to the south, and John Long peaks to the west. The basin is comprised of two large valleys, the Philipsburg valley and Drummond valley (connected by a narrow canyon) and its total drainage area is 499 square miles. Drainage area contributing flow to the project location is 352 square miles. Additional watershed characteristics (Table 2-1) and a map of the watershed (Figure 2-1) are given below.

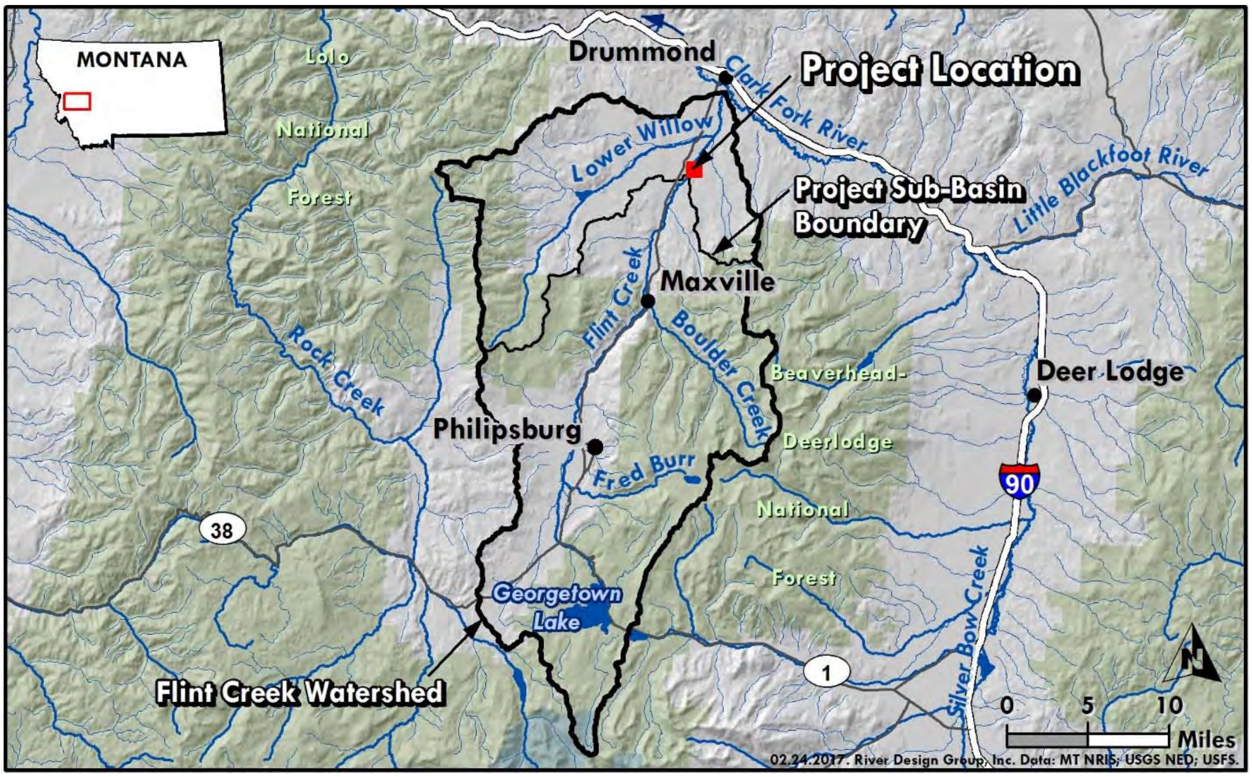

Figure 2-1. Flint Creek watershed and vicinity map.

Flint Creek originates at Georgetown Lake and reaches its confluence, after flowing 36 miles, with the Clark Fork River at Drummond. Primary tributaries of Flint Creek include Fred Burr Creek, Boulder Creek, and Lower Willow Creek. Fred Burr Creek, which has an annual average flow of approximately 7,000 acre-feet per year, flows into Flint Creek in the Philipsburg Valley, while Boulder and Lower Willow Creeks enter Flint Creek in the Drummond Valley. There are two managed reservoirs within the watershed, one at Georgetown Lake, which has a capacity of 31,000 ac-ft and serves hydroelectric purposes, and Lower Willow Creek Reservoir, which has a capacity of 4,800 acre-feet and is utilized for consumptive use by agriculture (Watershed Consulting, LLC, 2015). Flow within upper Flint Creek is controlled by the dam at Georgetown Lake. The flow is augmented seasonally from a trans-basin diversion in the East Fork of Rock Creek and a trans-basin diversion in Trout Creek.

Table 2-1. Flint Creek Watershed Characteristics.

Parameter	Description	Value
Drainage Area	Total area that contributes flow to the beginning of the study reach	351.5 mi^2
Precipitation	Mean annual precipitation	22.9 in
Temperature	Mean annual temperature	38.3˚ F
Mean Elevation	Average elevation of watershed	6213.3 ft
Max Elevation	Maximum watershed elevation	9829 ft
Min Elevation	Minimum watershed elevation	4182 ft
% Above 6000	Percent of area above 6000 ft in elevation	54.8%
>30% Slope	Percent area with slopes greater than 30% from 30 m DEM	26.9%
>50% Slope	Percent area with slopes greater than 50% from 30 m DEM	6.5%
Forest Cover	Percentage of area covered by forest	60.4%
Cultivation	Percentage of area covered by cultivated land from NLCD 2001	7%
Irrigation	Percentage of area irrigated based on Montana Final Land Unit (FLU)	5%
Wetlands	Percentage of area covered by wetlands from NLCD 2001	0%
Lakes	Percentage of area covered by lakes, pond, and reservoirs	1%

2.1.1 Geology

The Flint Creek watershed has a complex and still debated geologic history with new interpretations leading to fundamental changes how geologists view the region. The Drummond Valley is bounded by the Philipsburg-Georgetown Thrust fault on the eastern edge. The John Long Mountains rise from this fault zone and are predominately made up of the Belt Super group. Additionally, Tertiary volcanics (rhyolitic) are present in the Rock Creek volcanic field, which is believed to be the source of the sapphires in the range. The Flint Creek Range is comprised of meta-sedimentary bedrock that has been intruded by Cretaceous and Tertiary igneous rocks. Significant compressional forces led to the metamorphism, folding, and faulting in the range making this unit difficult to interpret. The core of the range is the Philipsburg pluton, which is exposed with the peaks at higher elevations (DEQ 2012).

The Drummond Valley has nearly 4,000 feet of sediment accumulated in the basin at its thickest point (Stalker and Sherrif 2004). This accumulation occurred largely during the Tertiary and is what Flint Creek has been downcutting through since the start of the quaternary. The lower portion of the Drummond Valley, the location of the project site, was likely inundated by Glacial Lake Missoula and lacustrine sediments can be found. Glaciers carved out the landscape in the Flint Creek Range leaving behind jagged ridgelines and U-shaped valleys, but these glaciers did not migrate into the lower Drummond Valley where the project reach exists (DEQ 2012).

2.1.2 Hydrology

Flint Creek hydrology is largely influenced by irrigation practices and flow releases from Georgetown Lake (Montana DEQ, 2012). As result, flows in Flint Creek and its tributaries can vary significantly over the water year. Flint Creek typically experiences peak flow in June, followed by a slow and gradual decline into the fall months, with a plateau in the late summer months and slight increase in the fall (after discontinuation of irrigation) (Montana DEQ, 2012). This prolonged decline can be attributed to the management of Georgetown Lake, inputs from the East Fork and Lower Willow Creek Reservoirs, and seasonal irrigational practices (Montana DEQ, 2012). Discharge within Flint Creek's tributaries typically reaches a peak in June, which is followed by a steady decline in flow into September. The four highest recorded discharges at Flint Creek near Maxville were likely triggered by rain-on-snow events and ranged from 900 to 1,680 cfs (Montana DEQ, 2012). Mean annual hydrographs for three Flint Creek USGS gages are provided in Figure 2-2. The project site is situated downstream of the Maxville Gage and upstream of the Drummond Gage.

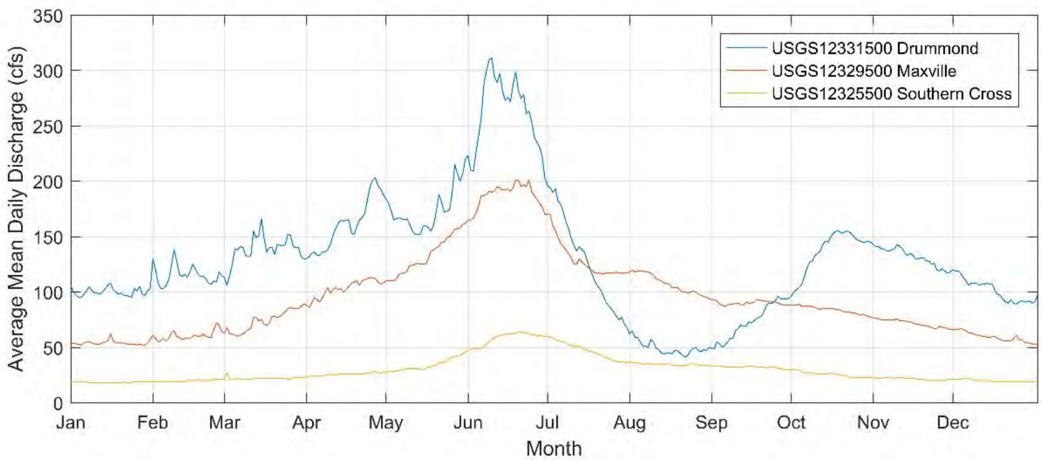

Figure 2-2. Average mean daily discharges for three active Flint Creek USGS gages.

2.1.3 Vegetation

Cool temperate forest and woodland in Beaverhead-Deerlodge National Forest account for 52% of the Flint Creek watershed (NW GAP 2011). Dominant species include Douglas-fir (*Pseudotsuga menziesii*) and lodgepole pine (*Pinus contorta*) in lower elevation locations, and Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) in subalpine and high montane conifer forests. Forest understory varies by forest type. Diverse shrubs, grasses, and forbs accentuate the high elevation conifer forests, while lodgepole pine forests can support dense shrub or grass cover in the understory, or remain barren. Drier Douglas-fir forests commonly sustain shrubs such as snowberry (*Symphoricarpos albus*) and common juniper (*Juniperus communis*), and grass cover is usually low (NW GAP 2011).

In lower elevation environments outside forested areas, cool semi-desert scrub and grassland (17% of watershed), and temperate grassland, meadow, and shrubland (15% of watershed) dominate. Semi-desert vegetation includes montane sagebrush-steppe vegetation dominated by big sagebrush (*Artemisia tridentata*), with a significant grass component. Low to mid-elevation grasslands include native bunchgrasses with scattered shrubs and diverse forbs (NW GAP 2011). Vegetation in the vicinity of the project area, outside of agricultural development, is a mix of sagebrush-steppe and grassland/shrubland. Agricultural vegetation accounts for approximately 10% of Flint Creek watershed area (NW GAP 2011), and is confined to valley bottom locations.

The Flint Creek project area is within the broad agricultural vegetation and land use category, and is predominantly agricultural and grazing land. Riparian vegetation around Flint Creek has been cleared by cattle grazing and land cultivation, and in the downstream end by the Eagle Stud sawmill. Common pasture grasses are prolific within the riparian corridor, punctuated by small groups of willow (*Salix spp*.) and spring birch (*Betula occidentalis*) (Watershed Consulting 2015), which are remnants of larger populations that were present prior to land development. Black hawthorn (*Crataegus douglasii*) and woods' rose (*Rosa woodsii*) are also found throughout the project reach in small patches, indicative of prolonged grazing pressure as the thorned species are not as palatable to livestock as other native shrubs (Watershed Consulting 2015). A few black cottonwood (*Populus trichocarpa*) stands are present at the upstream end of the project reach, representing a small fraction of pre-development cottonwood extent along low elevations of the Flint Creek riparian zone.

2.1.4 Fisheries

Flint Creek is dominated by populations of resident Brown Trout (*Salmo trutta*), with small populations of westslope cutthroat (*Oncorhynchus clarki lewsi*) and rainbow trout (*Oncorhynchus mykiss*). Electrofishing efforts conducted in 2007 by Montana Fish Wildlife and Parks estimate the population in the Flint Creek at 1288 and 940 brown trout per mile at sites above the Allendale diversion. Populations of Cutthroat and rainbow trout were too low to estimate. Fish habitat surveys indicate that the sections of Flint Creek above the Allendale diversion are higher quality habitat than below the Allendale diversion. They cite the lack of deep pools, low summer flows, and lack of woody riparian vegetation as key drivers for poor habitat. Bull trout (*Salvelinus confluentus*) are thought to use Flint Creek as a migration corridor to access spawning grounds in the Fall, but do not reside in the main stem year-round. During the fish survey in 2007 only one bull trout was found and the size or age was not mentioned in the report (FWP 2009).

2.2 Site Assessment

The Corbett-Downs property is a 139-acre parcel located approximately one-half mile southeast of Hall, MT (Figure 2-3). Cattle ranching has been the predominant land use on the parcel, and riparian conditions reflect the impacts of grazing. At the downstream end of the property, an irrigation ditch diverts flow from Flint Creek to the downstream landowner (water right of 8.13 cfs maximum). At least two springs flow through the property and flows are presumed to be enhanced by irrigation ditch return flows. A wetland mitigation project constructed by Montana Department of Transportation (MDT) is located in the southwest portion of the property. The Eagle Stud Mill is located west of the property along Flint Creek. Other adjacent land uses are residential and agricultural. The following sections summarize hydrology, geomorphology and vegetation assessments that were completed in support of evaluating existing site conditions and restoration potential.

Figure 2-3. Project site map for the Corbett-Downs property near Hall, MT.

2.2.1 Hydrologic Analysis

A flood frequency analysis was completed to estimate discharge values for standard flood recurrence intervals at two USGS gage sites on Flint Creek located upstream and downstream of the project area. Discharges for the project site were estimated by interpolating between the two gage sites based on contributing watershed area. In addition, estimates of bankfull discharge were completed for the project site using field survey data and standard hydraulic relationships. Results of the hydrologic analysis are summarized in Table 2-2. Hydrologic methods and additional information including baseflow estimates are provided in Appendix A.

Table 2-2. Flood frequency analysis results (cfs).

Recurrence Interval (yrs)	USGS Gage Maxville	Corbett-Downs Property	USGS Gage Drummond
1.25	264	271	310
Bankfull	N/A	375 – 425	N/A
1.5	327	341	412
2	410	432	550
2.33	450	477	617
5	637	684	932
10	803	868	1210
25	1030	1117	1570
50	1200	1304	1850
100	1390	1509	2130
200	1580	1713	2410
500	1850	2001	2790

2.2.2 Geomorphic Site Assessment

In October 2016, a geomorphic field assessment was completed for Flint Creek on the Corbett-Downs Property. Cross sections, longitudinal profiles, pebble counts, and bank erosion data were collected for Flint Creek and the irrigation ditch. The objective of this assessment was to collect field data that would be used to characterize the existing conditions of the reach and establish limiting factors to be addressed in the restoration plan. Additionally, the data collected was used to set design criteria for the conceptual designs. The methods used for the geomorphic assessment can be found in Appendix B, along with a detailed summary of data collected in the effort. The field efforts also included unmanned aerial system (UAS) flights to capture aerial images of existing conditions and support design work.

The project reach on Flint Creek exhibits geomorphic conditions that are indicative of degradation from a number of sources. The channel planform has a sinuosity of 1.5, which is lower than expected for the morphologic setting. The upper and lower portions of the reach appear to have been straightened at some point in history resulting in the decreased sinuosity and increased slope in these segments (Appendix B, Figure B-3).

Channel geometry in the riffles and pools have been impacted from grazing practices. The riffles are over-widened with an average bankfull width of 51 feet and average width-to-depth ratio of 31 (Appendix B, Table B-3). Average pool width was 43 feet with a width-to-depth ratio of 16. Average maximum pool depth was 4.5. Fine sediment accumulation was present in all of the pools surveyed and indicates a reduced maximum pool depth. Point bars adjacent to the pools lacked fresh sand deposits and had significant vegetation encroachment. Grain size did not vary significantly in the riffles throughout the reach with an average D_{50} of 59 millimeters and D_{84} of 106 millimeters (Appendix B, Table B-4).

Bank erosion was field-mapped throughout the reach and results show localized areas of high to very high bank erosion (Appendix B, Figure B-27). These locations are predominantly on the outside of meander bends or against the terrace located at the upstream end of the property. Bank erosion from the terrace and other upstream sources appear to be the main source of fine sediment that is being deposited in the pools (Appendix B, Table B-5). In addition to field-mapping of bank erosion, a remote sensing analysis was conducted to determine the channel migration rate between 2004 and 2015 using aerial images (Figure 2-4). Migration rates ranged from 0.01 to 3.5 feet per year with the highest rates occurring on the meander bend located 400 feet upstream of the Corbett-Downs residence. Not all locations that were field-determined to have high bank erosion rates exhibited high rates of lateral migration.

Floodplain and stream connectivity is vital to the maintenance of stable channels and productive riparian ecosystems. River channels convey one- to two-year flow events (i.e. bankfull), and larger over-bank flows are often dissipated over floodplain surfaces adjacent to channels. When forced to convey large flows within the bankfull channel margin, channels can exhibit incision, bank erosion, and widening. Floodplains disperse stream energy over a much larger area than what is available within the bankfull channel margin. Benefits of connected floodplains include flood water storage and attenuation, slowing of stream velocities, and reduction of bank erosion. In addition, over-bank flows deliver nutrients and fine sediment to floodplain areas, which helps sustain riparian vegetation communities and provide natural seed recruitment opportunities. Floodplain connection was analyzed using LiDAR data and surveyed bankfull elevations from field work (Figure 2-5). Results from this analysis show a connected floodplain in the upper half of the reach until reaching the mill where connectivity is significantly decreased by floodplain encroachment.

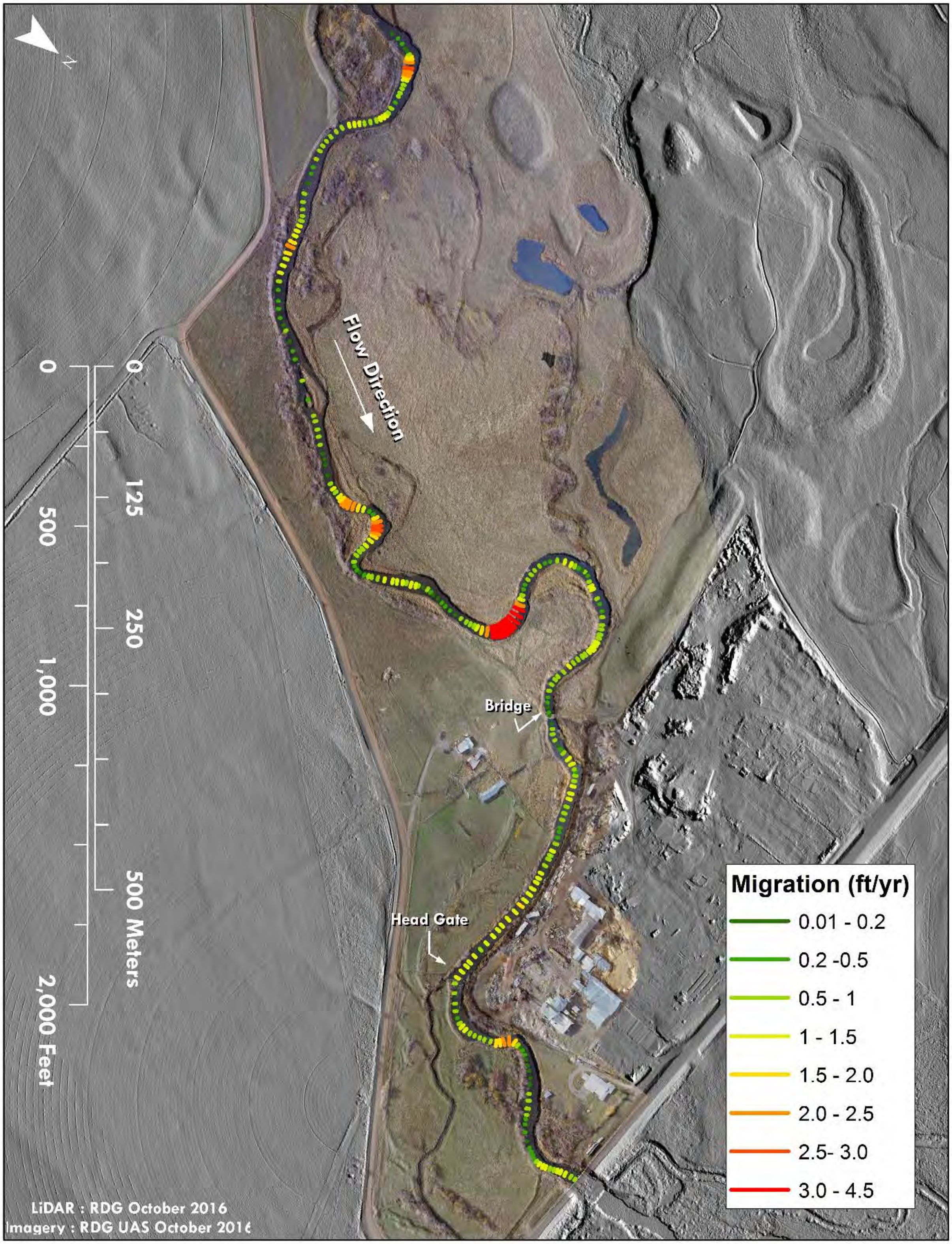

Figure 2-4. Map of channel migration rates calculated from aerial photos 2004 to 2015.

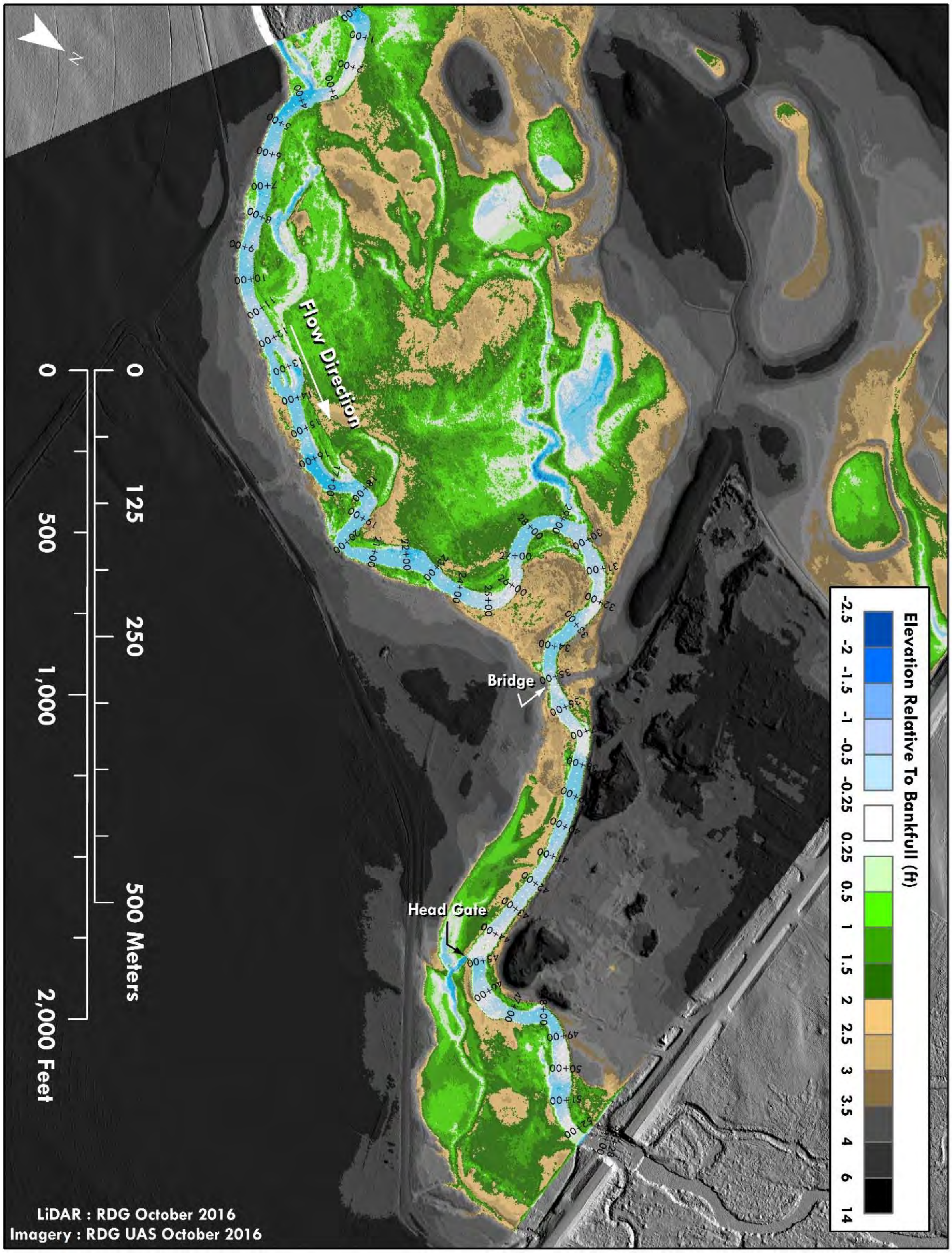

Figure 2-5. Map of floodplain connectivity of the Flint Creek Assessment reach derived from the LiDAR collected in October, 2016.

2.2.3 Vegetation Site Assessment

Field work to assess existing vegetation conditions at the project site was completed on June 19, 2017. Dominant vegetation type and condition was noted for habitat units, as were any grazing impacts. Figure 2-2 provides a summary of existing vegetation in the project area, with a focus on dominant species and distinctive features.

Impacts of prolonged grazing are apparent in the existing vegetation community on Flint Creek banks and the floodplain environment at the project site. Willows and cottonwoods are remnants of much larger populations that were present prior to grazing and agricultural land use. Woody vegetation has been either cleared in favor of pasture grasses, or heavily browsed by cattle. One black cottonwood stand remains on site (point 3, Figure 2-2), indicative of the historical canopy composition. Pasture grasses including Kentucky bluegrass (*Poa pratensis*) and Garrison creeping foxtail (*Alopecurus arundinaceus*) dominate the understory, and large patches of Rocky Mountain iris (*Iris missouriensis*) are also present under the cottonwood canopy. Unpalatable to livestock, the iris species reacts positively to grazing disturbance and is often present on active pastures in southwest Montana.

In addition to black cottonwood riparian forest as a historically significant community type, willow and red-osier dogwood (*Cornus sericea*) associations were also key components of the habitat at the project site and surrounding areas along Flint Creek. The riparian shrubs are present as relic clusters throughout the site, with willows often in decadent form, indicating overbrowse and continued heavy livestock grazing. Portions of the Flint Creek floodplain upstream and downstream of the Corbett-Downs land remain intact and represent pre-disturbance conditions at the project site. These cottonwood and willow-dominated riparian communities provide important habitat for a variety of birds and mammals, and afford stream shading and cover for fish, as well as sources of large woody debris to Flint Creek.

1. Decadent willow stand; some younger shoots regenerating.
2. Decadent willow stands, some young dogwood in understory. Small side channel cuts through area at high flow.
3. Remnant black cottonwood stand; 60-ft tall individuals, with pasture grasses and rocky mountain iris in understory.
4. Healthier sedge than at (5).
5. Mostly Garrison creeping foxtail. Some baltic rush, decent common beaked sedge, some areas with 30-50% cover.
6. Large crack willow stand, very large spring birch.
7. Cattails along pond fringe, as well as in upstream and downstream swale areas. Beaver seen in pond.
8. Healthy sandbar willow stand with multiple age classes. Some Canada thistle, cheatgrass, and houdstongue, mostly above floodplain elevation. Small very low lying floodplain areas with small-winged bulrush, proliferation of garrison creeping foxtail, along with common beaked sedge. 1 - 2 year old sandbar willow on river bank.
9. Mostly Garrison creeping foxtail encroached by Canada thistle and houdstongue; stinging nettle by stream bank.
10. Garrison creeping foxtail, 100% cover. Large downed black hawthorn.Willows on bank, inside fence.
11. 30' - 40' spring birch.
12. Garrison creeping foxtail, 80% cover. Kentucky blue grass, 20% cover. Some dead sandbar willow. Healthy but narrow sandbar willow stand along river bank.
13. 30' river birch, right along fenceline, heavy browse underneath. Dogwood and snowberry also present on inside of fence by stream.
14. Garrison creeping foxtail, small-fruited bulrush, common beaked sedge, juncus spp, kentucky blue grass. Fairly wet, inundatinon in areas at time of sampling.
15. Same as (14), but drier with less bulrush/sedge/juncus spp.
16. Sandbar willow, chokecherry, woods' rose in overstory; smooth brome and Kentucky blue grass in understory.

07.06.2017. River Design Group, Inc. Imagery: NAIP 2015.

Figure 2-6. Summary of existing vegetation communities at the project site.

Other notable woody species remaining in the project area include spring birch (*Betula occidentalis*), black hawthorn, Woods' rose, and chokecherry (*Prunus virginiana*). A few large spring birch individuals are scattered throughout the site, including two 40 ft. tall trees which are shaped by cattle browse. Black hawthorn and Woods' rose are resistant to browse in general due to sharp thorns; their presence in the project area is not surprising.

The majority of the vegetation community at the Flint Creek project area consists of nonnative pasture grassland. The dominant species in low elevation floodplain environments is Garrison creeping foxtail, which is extremely palatable and preferred by livestock, produces aggressive underground rhizomes, and recovers quickly from heavy grazing (USDA-NRCS, 2013). It is a nonnative invasive species which can outcompete native species, especially sedges and rushes in wetlands and floodplains. Common beaked sedge (*Carex utriculata*), small-fruited bulrush (*Scirpus microcarpus*), and rushes (*Juncus* spp.) were often found in the lowest-lying floodplain locations, but were mostly outnumbered by Garrison creeping foxtail except in a few small patches. Other notable pasture grass species at the site include Kentucky bluegrass, creeping bentgrass (*Agrositis stolonifera*), and smooth brome (*Bromus inermis*).

Weeds and noxious weed species are not prolific in floodplain environments at the project site. Noxious weeds Canada thistle (*Cirsium arvense*) and houndstongue (*Cygnoglossum officinale*), and the weeds field mustard (*Brassica rapa*) and common dandelion (*Taraxacum officinale*) were the only notable weedy species found. The lack of weed monocultures can be attributed to adequate river and floodplain connectivity, and the prevalence of competitive pasture grasses.

2.3 Limiting Factors

In the context of this assessment, limiting factors are defined as physical, biological, and ecological conditions within the assessment area that: 1) limit the ability of the ecosystem to sustain diverse native plant and wildlife populations, and to accommodate natural disturbances; 2) limit the quality or availability of habitat that supports all life stages of trout and other focal species; and 3) limit resiliency of local agricultural and residential activities. Limiting factors can be addressed by active restoration or changes in management. In contrast, constraints are components like roads, bridges and other infrastructure that cannot be changed by management or active restoration, but must be considered during the design process.

The three general categories used to organize the limiting factors in this assessment include:

- **Aquatic habitat limiting factors –** missing components of the ecosystem that support habitat requirements for all life stages of the focal aquatic species. Aquatic habitat limiting factors are directly influenced by morphological and riparian vegetation limiting factors.
- **Geomorphic limiting factors –** physical conditions that are on a trajectory away from normative habitat conditions or exhibit departure from historical conditions. Although returning the physical environment to the conditions of pre-European settlement is not

feasible, addressing the morphological limiting factors is aimed at restoring a trend towards more normative morphological conditions.

- **Riparian vegetation limiting factors** – processes or conditions that prohibit establishment of native plant communities. Riparian vegetation limiting factors are directly influenced by morphological limiting factors.

Identification of limiting factors in the project area was based on site observations, field data collection, knowledge of regional watershed conditions and previous studies completed by others as summarized in Section 1.3.

2.3.1 Aquatic Habitat Limiting Factors

This section summarizes aquatic habitat limiting factors in the project area.

Shallow, infrequent pools: Pools offer important overwintering habitat for resident adult and juvenile fish, and may offer holding habitat during periods of high water temperature or low flow. Although pools exist in the project area, they lack the depth, cover and complexity preferred by native species. Poor pool quality is a result of altered pool forming processes such as large wood recruitment and lateral scour caused by channel sinuosity. Consequently, the straightened channel planform and lack of woody vegetation are contributing to shallow, infrequent pools in the project area.

Lack of habitat diversity: Disturbed riparian conditions and altered stream morphology are influencing the availability of large wood and function of pool-riffle sequences, which offer cover and complexity in the form of variable depth, velocity and substrate. Processes responsible for development of cover and complexity include floodplain interaction, channel migration, and large wood recruitment. In addition, the project area lacks off-channel habitat for juvenile rearing. Suitable juvenile rearing habitat consists of refuge from the main channel in areas of lower velocity, alternate food sources, variable substrate and warmer temperature. Side channels, alcoves and connected wetlands can provide suitable off-channel juvenile rearing habitat. Development of off channel habitat is dependent on floodplain connection and riparian forest establishment.

Fine sediment accumulation: A gravel channel bottom with clean interstitial spaces is the substrate condition preferred by native fish and macroinvertebrate species. Clean gravel substrates provide spawning surfaces and egg incubation habitat for larvae as well as hiding cover for juveniles. Bank erosion is contributing to altered substrate conditions in the project area. High, non-vegetated banks are delivering fine sediment loads to the project area. Fine sediment accumulates on the channel bottom and fills the interstitial spaces of preferred gravel substrates. The accumulation of fine sediment in pools throughout the reach indicates that there is an excess amount of fine sediment. Fine sediment can cause a number of problems for aquatic species including suffocating eggs, altering the food web by decreasing sunlight input, decreasing the max depth of pools, embedding bed particles through the filling of interstitial spaces, and altering macroinvertebrate assemblages.

Fish entrainment: The diversion structure in the project reach allows for fish entrainment and at low flows cuts off their ability to regain access to the main channel. Studies have shown that structures that lack a fish screen lead to increased mortality for fish species and lower populations. During the survey efforts, nearly a dozen brown trout were seen occupying the diversion ditch.

2.3.2 Geomorphic Limiting Factors

This section summarizes geomorphic limiting factors in the project area.

Straightened channel planform: Channel planform geometry is affecting bedform development and creating simplified habitat conditions. Sinuous planform geometry supports pool development at meander beds and creates hydraulically complex habitat in the form of variable depth, velocity and substrate. Moreover, channelization of Flint Creek means there is less available habitat due to decreased channel sinuosity and loss of overall channel length. Floodplain filling at the adjacent mill site has also contributed to planform alteration by limiting the available meander belt width.

Altered pool development processes: Processes responsible for pool development on Flint Creek include lateral scour caused by meandering planform and contraction scour caused by flow acceleration or a constriction, and vertical scour caused by bedrock, boulders, or wood. Historical pool development processes were likely influenced by channel complexity such as pool-riffle morphology and large woody debris derived from floodplain vegetation. Lateral migration and beaver dams may also have influenced pool development. Despite moderate pool availability in the assessment areas, pool-forming processes such as lateral migration, flow acceleration and large wood recruitment are affected by altered conditions.

Bank erosion: Flint Creek is responding to altered channel morphology and vegetation conditions. Steep, sparsely vegetated banks composed of fine grained soils are susceptible to bank erosion as Flint Creek attempts to establish equilibrium in its altered landscape. Bank erosion delivers fine sediment to the channel bed and causes damage to private property along the creek. These fine sediments impact the ability of the watershed to meet TMDL targets for sediment.

Altered flow regime: Irrigation and upstream reservoirs impact Flint Creek's hydrology by decreasing peak flow and altering the timing of peak flow. A decrease in peak flow alters the ability of the channel to move larger particles in the channel and inundate the floodplain. Evidence of this can be seen with many of the point bars being heavily occupied by grasses and lacking bare sand that would indicate recent deposition. This reduces the ability of the channel to deposit excess sediment outside of the channel leading to more accumulation in pools and the intestinal spaces between larger particles.

Over-widened riffles: Width to depth ratios in the riffles on Flint Creek are too high. Many of the riffles in the reach appear to have been crossing points for cattle when they had access to the channel. This over-widening reduces shear stress in the riffle and has led to more fine sediment accumulating in the interstitial spaces of gravels and cobbles. This is also likely a product of a less mobile bed due to the decrease in shear stress.

2.3.3 Vegetation Limiting Factors

Insufficient riparian buffers: The current land uses adjacent to Flint Creek (residential, grazing, agriculture, and industrial facilities) require active management and result in the frequent removal of woody riparian vegetation. Frequent clearing reduces the amount of area available for diverse riparian and floodplain vegetation to develop. Vegetation clearing has also resulted in bank erosion in some areas which further limits the establishment of riparian vegetation. In many areas, streambank vegetation has been converted from woody vegetation to grasses which provide limited soil stabilization along the land-water interface. Land use also results in localized impacts to existing vegetation through trampling and compaction of frequently accessed areas. A wide, densely vegetated riparian buffer is needed to promote stable geomorphology and maximize aquatic habitat potential through the reduction of fine sediment inputs, filtration of nutrients and other potential contaminants, increase of stream cover and shade, and input of woody-material.

Lack of woody vegetation and riparian diversity: Woody riparian vegetation provides stream cover, food, and temperature reduction for aquatic species, while also increasing bank stability. At the Flint Creek project reach, riparian vegetation is dominated by pasture grasses. Woody shrubs and trees are limited to small remnant patches of the historically extensive cottonwood and willow communities. Upstream and downstream riparian habitat is considerably more intact, with cottonwood forests and willow and dogwood shrub communities. Natural recruitment of woody vegetation to the project reach is hindered by the altered flow regime, grazing practices, and dominance of invasive pasture grasses which limits woody seed germination and survival. Despite having excluded cattle from the immediate area surrounding Flint Creek, pasture grasses are prolific and dominate the riparian vegetation community.

3 Restoration Strategies

3.1 Constraints

Project constraints are existing features, infrastructure, or land uses that influence project extents and ability to achieve restoration potential. The restoration potential for Flint Creek is significantly influenced by the agricultural setting the stream flows through. The following constraints have been identified in the project area:

Infrastructure: The Farm to Market Road bridge is located at the downstream extent of the project site and will likely not exhibit a major constraint to restoration efforts, but modeling efforts may be required depending on the scope of restoration work and permitting. The mill located adjacent to the project area encroaches on Flint Creek thereby limiting restoration opportunities along the northwest (left) bank in the downstream end of the project area.

Land-Use: Restoration actions must be compatible with adjacent land uses, and actions must be evaluated for potential effects to adjacent property. Restoration actions must take into consideration potential future land uses as well.

Water Quality and Upstream Watershed Effects: Flint Creek is listed for both sediment and metals as an impaired under the Clean Water Act. These pollutants will impact the biological recovery that is possible for our project site.

Flow Alteration: Several of the limiting factors for Flint Creek are driven by the flow alteration from upstream dams and diversions. The conceptual designs in this report will not be able to address this constraint and should be accounted for in the design process.

3.2 Conservation

Conservation is a restoration strategy applied to protect existing areas that exhibit, or have potential to exhibit, high quality ecological function. Areas proposed for conservation typically display few limiting factors, and those factors that exist usually can be addressed with passive treatments such as changes in land use or weed control. Conservation can be compatible with recreational uses.

3.3 Revegetation

Revegetation is a restoration strategy applied to moderately stable areas with few geomorphic limiting factors or in conjunction with other restoration strategies such as wetland construction, streambank reconstruction or floodplain construction. Revegetation is a viable strategy for improving aquatic and terrestrial habitat in the longer term through gradual development of a riparian buffer. Revegetation encompasses a range of treatments including:

- Planting;
- Seeding;
- Plant protection;
- Irrigation; and
- Invasive plant species management.

Revegetation is not suitable for areas prone to high disturbance or areas with incompatible land uses such as grazing or agriculture. Revegetation strategies should only be implemented in areas where adequate site preparation is completed. Site preparation includes a wide range of treatments including weed control, grading to appropriate elevations, incorporating surface roughness, and soil placement or amendments. Most of these treatments are included as part of other restoration strategies such as floodplain construction.

3.3.1 Planting

Planting of nursery grown plant material is a strategy used to promote vegetation establishment along the channel and within newly constructed floodplains. Planting can consist of installation of a wide range of container size plants and for floodplains typically includes both native tree and shrub species and herbaceous wetland species. A diverse mix of trees and shrubs are planted in select areas of the new floodplain, typically along streambanks and within floodplain swales, to develop a range of riparian vegetation communities based on expected floodplain hydrology. Wetland vegetation such as sedges and rushes are also planted in depression features within the floodplain (swales and wetlands) and occasionally along streambanks. The species planted at the site should be determined during the design phase and consist of native riparian species that represent an early successional stage of the desired vegetation communities. Planting should be done in the spring or fall when temperatures are moderate and soil moisture is relatively high.

Planting helps address a range of geomorphic, aquatic and vegetation limiting factors. Planting helps achieve geomorphic objectives by providing bank and floodplain stability via the extensive root system produced by riparian plants and by providing roughness to slow waters during higher flows and minimize erosion along the banks. Planting woody vegetation will also help improve streambank cover. The shade provided by streambank vegetation also addresses aquatic habitat objectives by keeping waters cooler and contributing detritus and nutrient sources to the channel. Planting will also help restore diverse native vegetation communities. Selecting native species for planting provides more self-sustaining and diverse vegetation communities and also prevents weed establishment by colonizing the available space.

3.3.2 Seeding

Seeding is a strategy used to promote rapid vegetation establishment on newly constructed surfaces or disturbed areas. Seeding can provide species diversity to a site for relatively low cost. Multiples seed mixes may be required and should be determined during the design phase. The species included in each seed mix should take into account: desired vegetation community, germination timing and growth period, growth form, rooting depth. In general, seed mixes should include species that have varying rooting depths and will occupy a wide range of habitats. To ensure quick, long-lasting vegetation establishment a two-stage seed mix should be used. The two-stage seed mix includes two components: a mix of quick germinating species (nurse crop or cover crop) that will provide immediate cover to limit colonization by invasive species and a mix of long-term, desired species that may not germinate immediately because they may require a stratification period.

Seeding helps address a range of geomorphic, aquatic and vegetation limiting factors. Establishing native vegetative cover on newly created streambank and floodplain surfaces is essential for maintaining soil stability and preventing weed infestations. Planting will establish native vegetation in portions of the floodplain, but seeding is the primary mechanism for stabilizing soil. Seeding helps achieve geomorphic objectives by providing streambank and floodplain stability through root system development and surface cover. Vegetation established from seed can help prevent weed infestations. The vertical (soil depth) and temporal diversity of the seeded species can prevent weeds from establishing by occupying available habitats that weeds may otherwise occupy.

3.3.3 Plant Protection

Most riparian woody plants are highly palatable and are targeted by a number of wildlife species. Protecting planted vegetation for several years after implementation is necessary to allow vegetation to establish without stresses from browse and animal damage. The two primary plant protection treatments for the project area include fencing and individual plant protectors. Individual plant protectors are installed around plants that are most desirable to beavers and wildlife or around plants where fencing is not feasible, such as those located on streambanks. Fencing entire areas for protection is often more affordable, requires less maintenance and is less aesthetically intrusive than individual protectors. Fencing can also protect large seeded areas during the establishment period. The material used to construct plant protection measures should take into consideration the expected degree and type of animal damage expected. For protection against deer and elk, rigid plastic mesh may be sufficient. For protection against beaver, metal fencing is typically more effective.

3.3.4 Irrigation

Successful revegetation typically requires supplemental irrigation following planting while the root systems of the plants establish. Supplemental irrigation may only be required in select areas, such as higher surfaces in the floodplain, but in drought years it is likely that all plantings will require at least one round of irrigation.

3.3.5 Invasive Plant Species Management

Management of invasive plant species is an important strategy to implement in all areas where construction activities are proposed. Invasive species management strategies can be implemented prior to construction, during construction and after construction. Prior to construction, treating existing invasive species infestations will reduce the amount of seed spread during construction. During construction, best management practices (BMPs) should be implemented that prevent the spread of invasive species such as cleaning of equipment prior to arriving on site; ensuring equipment avoids tracking through weedy areas outside of construction limits during construction; and ensuring any imported material is free of invasive species and seeds.

3.3.6 Soil Amendments

Soils are one of the most important factors that can influence plant survival and establishment of desired vegetation communities. Some of the more important characteristics of soils that can affect plant health and survival include: soil texture, pH, organic matter, salinity, compaction and the presence of contaminants such as metals or residual herbicides or pesticides. Typically, native soils with no known or suspected contaminants that currently support native riparian vegetation are adequate to support planted, seeded and naturally recruited vegetation on the floodplain over time. Because the soils in most of the project area currently support native riparian vegetation it is assumed that soil texture, pH, and organic matter are sufficient and compaction is not present to a degree that precludes the establishment of desired vegetation and import of suitable growth media will not be required. It is possible that contaminants are present in the soil in some of the project reaches and a soil investigation should be completed during the design phase to verify existing soils are suitable as growth media or whether soil amendments will be required. The type of soil amendment needed will depend on this investigation.

3.3.7 Vegetation Salvage and Transplant

Plant salvage and transplant is a technique where healthy plants are harvested from areas inside the construction limits (or from nearby donor locations) and then transplanted back into the re-graded floodplain or along streambanks. This promotes establishment of mature vegetation on streambanks and constructed floodplain surfaces. Vegetation salvage and transplant helps address a number of limiting factors including insufficient riparian buffer, altered pool development processes and bank erosion. Salvaging native plants and sod is a viable method for obtaining large, site-adapted plan stock for rapid vegetative reestablishment. Because this vegetation is typically mature it can quickly add natural vegetation function to streambanks and floodplains. Mature plants and high quality sod located within construction and grading areas should be salvaged and relocated to streambanks. Specific opportunities for vegetation salvage and transplant should be identified during the design and construction phase.

3.4 Instream and Streambank Structures

Installation of streambank structures is a strategy applied to the channel margins in order to establish vegetation, enhance aquatic habitat and/or improve bank stability. Depending on the application, streambank structures may be localized installations or contiguous reach-scale treatments. Streambank structures used for restoration may be deformable whereby the structures serve a temporary purpose to establish vegetation. Streambank structures used for bank stability may be more permanent in order to manage risk by protecting infrastructure or preventing channel migration. Potential streambank treatments for the Corbett property include:

- Bioengineering;
- Brush banks and fascines;
- Large woody structures; and
- Aquatic habitat enhancement.

3.4.1 Bioengineering

Bioengineering is a category of streambank treatments consisting of live plant material and biodegradable coconut fiber fabrics (coir). Bioengineering treatments create bank conditions that support the establishment of woody vegetation. Figure 3-1 shows a conceptual cross section view of a typical bioengineering streambank treatment called a vegetated soil lift. Figure 3-2 shows example photos of bioengineering streambank structures.

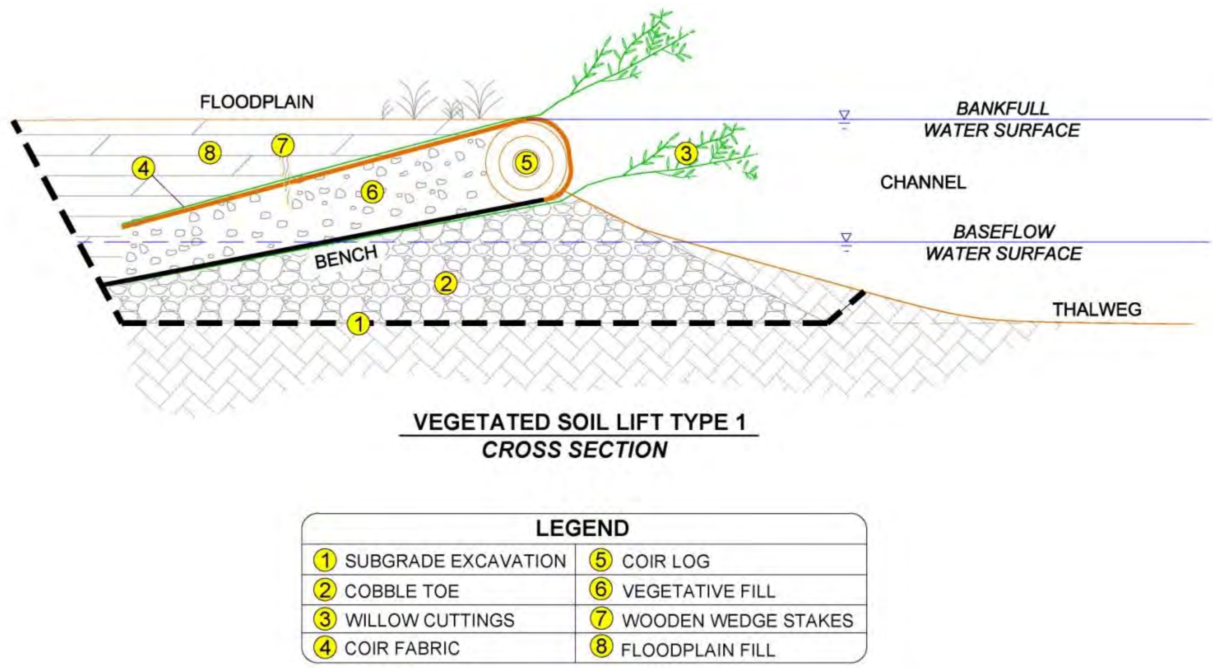

Figure 3-1. Conceptual cross section of a vegetated soil lift bioengineering treatment.

Purpose: The purpose of bioengineering is to provide temporary bank protection in order to allow bank vegetation to become established.

Placement Criteria: Bioengineering is suitable for low to moderate stress banks with low curvature.

Aquatic Habitat Objectives Addressed: Bioengineering promotes the rapid development of woody vegetation on streambanks. Woody vegetation on the streambank provides instream cover, shade for temperature reduction, large wood recruitment over time, refuge during high flows, organic matter inputs, and supports emerging aquatic insects.

Vegetation Objectives Addressed: Bioengineering promotes rapid development of desired woody vegetation. The development of woody vegetation along the streambank provides floodplain stability, and provides a source of seeds and vegetative material to promote the establishment of desired vegetation communities in the floodplain.

Geomorphic Objectives Addressed: Bioengineering structures are composed of biodegradable fabrics and native materials. Short-term streambank stability provided by fabric and long-term stability provided by rooted woody vegetation supports desired disturbance regimes and relatively low erosion rates.

Supplemental Information: Bioengineering provides conditions along the channel banks that are suitable for growing woody riparian vegetation. Bioengineering is built on a gravel or cobble toe. Short term structure performance is dependent on toe stability as well as smooth transitions to stable upstream and downstream tie-in points. Placement of healthy woody vegetative cuttings that are placed to a depth to ensure contact with the water table throughout the growing season is critical, and long term structure performance is dependent on development of dense rootmass.

Figure 3-2. Example of vegetated soil lift 5 years after construction.

3.4.2 Brush Banks and Fascines

Brush banks and fascines are a category of streambank structures consisting of brush bundles and live plant material. Depending on the application and availability of materials, structures may also include woody debris and/or wetland sod mats. Figure 3-3 shows a conceptual cross section view of a typical streambank treatment called a sod and brush fascine.

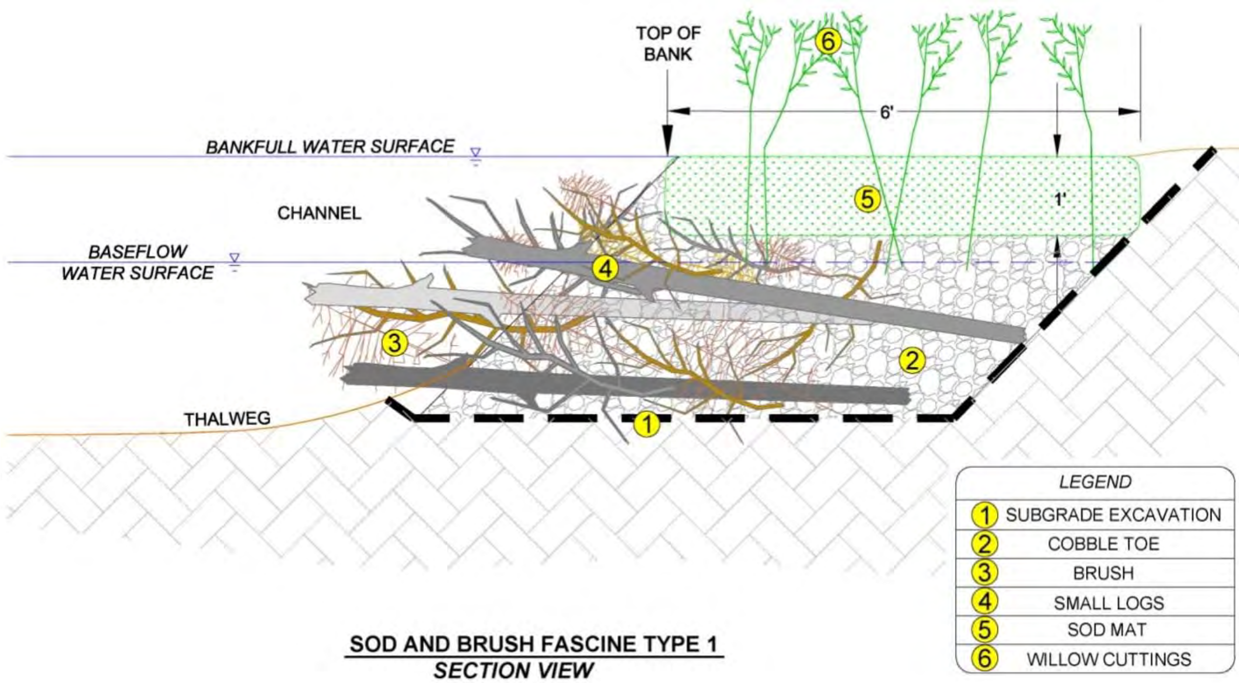

Figure 3-3. Conceptual cross section of a sod and brush fascine.

Purpose: The purpose of the treatments is to create a rough, complex and vegetated bank margin.

Placement Criteria: Brush banks and fascines are designed to function on moderate stress banks with low to moderate curvature.

Aquatic Habitat Objectives Addressed: Brush and vegetation provide cover and hydraulic complexity. Fascines promote the rapid development of woody vegetation on streambanks. Woody vegetation on the streambank provides instream cover, shade for temperature reduction, large wood recruitment over time, refuge during high flows, organic matter inputs, and supports emerging aquatic insects.

Vegetation Objectives Addressed: Structures promote rapid development of desired vegetation communities. The structure surface provides microsites to support natural recruitment of early successional species of desired vegetation community types. The elevation of the structure allows floodplain connection.

Geomorphic Objectives Addressed: The structures are composed of native materials and provide bank margin roughness similar to natural bank conditions. Structure stability supports desired disturbance regimes and relatively low erosion rates.

Supplemental Information: Brush banks and fascines employ native materials to provide preferred habitat conditions along streambanks. The structure is built on a cobble and wood toe. Structure performance is dependent on toe stability as well as smooth transitions to stable upstream and downstream tie-in points. Maintaining adequate backfill ballast is critical to counteract buoyancy of wood. Placement of wood at or below bankfull and placement of healthy woody vegetation in contact with the water table throughout the growing season is critical for rapid vegetation establishment.

3.4.3 Large Wood Structure

Large wood structures are a category of streambank structures consisting of logs and brush buried into the streambank and projecting out into the channel. Large wood structures are intended to emulate natural accumulations of large wood along the bank margins. Figure 3-4 shows a conceptual cross section view of a large wood jam structure.

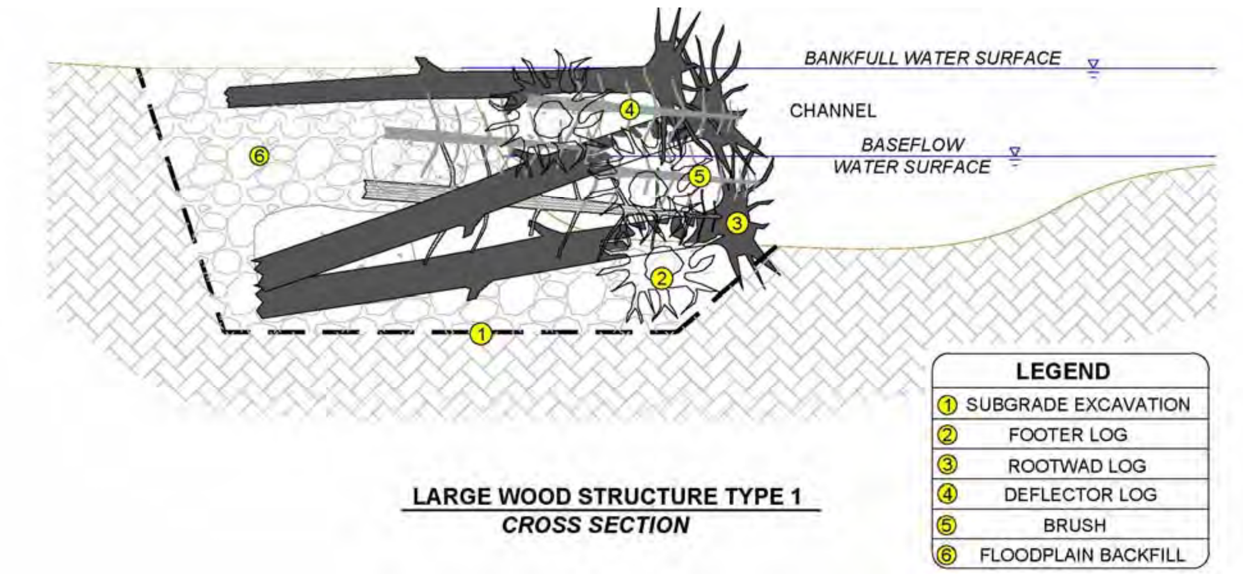

Figure 3-4. Conceptual cross section of a large wood structure.

Purpose: The purpose of this structure is to create hydraulic conditions that maintain a deep pool.

Placement Criteria: This structure is designed to function on a high stress bank with moderate to high curvature.

Aquatic Habitat Objectives Addressed: This structure creates complex hydraulics such as eddies and secondary flow circulation. Wood provides instream cover and shade for temperature reduction. Deep pools improve hyporheic flow for temperature management. Residual pools provide low-velocity holding habitat and over-wintering habitat.

Vegetation Objectives Addressed: Creates stable conditions to support development of desired vegetation community types.

Geomorphic Objectives Addressed: This structure supports pool development processes. Pools provide planform variability and foster point bar development. The structure is composed of native materials.

Supplemental Information: Large wood structures provide temporary bank protection by re-directing flow away from the bank and dissipating flow energy into the riverbed. The structure creates complex hydraulics and turbulence, which require attention to how the structure is tied in to existing features or other bank structures. Maintaining adequate backfill ballast is critical to counteract buoyancy of wood. Structure performance is dependent on structure size and use of adequately-sized wood with intact rootwads. Excavation of the pool in conjunction with the structure is recommended. The structure will tend to recruit additional large wood. Over time, the structure will decompose or become abandoned. Integrating mature shrub transplants or plantings on the floodplain surface behind this structure creates rooting structure for long term bank stability.

3.5 Channel Reconstruction

Channel reconstruction is a strategy applied to areas with altered stream function through modification of channel geometry. Modification of channel geometry changes stream hydraulics, which can have an effect on depth, velocity and substrate components of aquatic habitat. Channel reconstruction is also a viable strategy for improving stream stability and establishing riparian vegetation. Channel reconstruction encompasses a range of treatments including:

- Channel shaping (modifying cross section geometry and width-depth ratio);
- Channel realignment (modifying planform geometry and channel location);
- Pool-riffle sequences (modifying profile geometry and longitudinal bedforms);
- Revegetation (including treatments described previously);
- Streambank structures (including treatments described previously); and
- Floodplain excavation (including treatments described previously).

Channel reconstruction may also include reconstruction of the stream bed, whereby riffles are built from imported streambed material. Riffle construction can provide vertical streambed stability in new channel segments. In addition, riffle construction can introduce appropriate spawning substrate for focal aquatic species.

3.6 Irrigation and Fish Passage Improvements

The following section provides a summary of design criteria considered during development of the diversion structure and fish screen alternatives. Diversion structure and fish screen alternatives are described in the following sections.

3.6.1 Diversion Structure Design Criteria

Where practical, installation of instream structures such as those shown in are recommended to divert flow into the ditch while allowing the bulk of the sediment entrained in the flow to be channeled down the stream. Construction of such structures requires adequate drop in the stream channel upstream of the structure to ensure that backwater conditions are not induced. Typically, one half foot of drop between the throat of the cross vane and the invert of the headgate is required to ensure adequate flow into the ditch.

An operable headgate located at the entrance to the ditch is required to enable control of flow into the ditch. The headgate must be designed to ensure that it will pass the maximum design flow rate. Additionally, it is recommended that the headgate be installed in a sheet steel panel or concrete structure buried below the channel invert to ensure that seepage into the ditch is minimized. Installation of multiple screens side-by-side may require installation of multiple headgates to enable control of flow to the screens.

Channel shaping is typically recommended to stabilize the channel and provide smooth transitions to and from the diversion structure. Grading of the ditch may also be required to ensure that there is a hydraulically smooth transition between the ditch and fish screen entrance and exit. Hydraulically smooth transitions are defined as not exceeding 1 foot of contraction or expansion per 10 lineal feet of ditch.

3.6.2 Diversion Structure Alternatives

Several types of diversion structures could be constructed to divert the required flows to the ditches. Typical structures, including include rock and log structures, are shown in Figure 3-5. One potential pitfall of constructing such structures is the potential for beaver dams to be built on them. This could result in the need to remove the beaver dams as part of routine maintenance.

Figure 3-5. Typical rock diversion structure (left), and typical log diversion structure (right).

3.6.3 Fish Screen Design Criteria

Because anadromous fish are not present in the Flint Creek watershed, fish screening and passage are not regulated by the National Marine Fisheries Service Fisheries (NMFS). Fish screen designs in Montana are not typically subject to regulatory requirements other than those normally required for in-stream work. Federal fish screen guidelines (NMFS 2011) were used to develop and evaluate screen options for the Flint Creek diversion with some adaptations of the design guidelines made on a site-specific basis. A summary of pertinent guidelines regarding screen placement and fish bypass criteria that were considered for this project is provided in Table 3-1. Channel design elements are described in following section.

Table 3-1. Fish Screen Criteria.		
Consideration	**Standard / Guidance / Note**	**Site Specific Criteria (if applicable)**
Screen Placement	Ditch Installation with bypass system	Ditch realignment considered to accommodate sediment and debris
Design Flow	All installation types to consider 5% to 95% hydraulic conditions	
Screen Area	Sized for approach velocity and diversion rate	
Screen Hydraulics	Approach Velocity: 0.4 ft/s for active screen	0.8 ft/s acceptable for fingerling size and larger salmonids
Sweeping Velocity	Greater than Approach Velocity (Optimally: 0.8-3 ft/s)	
Submergence	Consideration for drums	65% to 85% of drum diameter submerged in water
Screen material	3/32" perforations or 1.75 mm slots Minimum 27% open area Corrosion resistant	Farmers (FCA) screen: <3/32" Hydroscreen: 3/16" slots Pitman screen: 3/16" perforations 50% open area assumed for preliminary design
Bypass Flow	For diverted flows of 0 - 25 cfs, minimum 5% of diverted flow	Estimate 10% - 15% of diverted flow
Bypass Location	For Screens > 6 ft, end of screen terminates at bypass entrance	
Bypass Pipe Diameter / Geometry	The bypass pipe should be designed to maintain velocity of 6 - 12 ft/s (NMFS 2011 11.9.3.8) with a minimum depth of 40% of the bypass pipe diameter (NMFS 2011 11.9.3.9)	For diverted flows of 0 - 25 cfs, this equates to10 in. diameter with slope of 1.3% (NMFS 2011 Table 11-1). Other designs should meet depth and velocity criteria

3.6.4 Fish Screen Alternatives

Three fish screen alternatives were developed for the diversion. Each alternative consists of a screen placed in the ditch with a return pipe for discharging fish and debris back to Flint Creek. The following sections contain a general description of the each of the fish screens. Alternatives proposed for these sites include horizontal flat panel screens, vertical flat panel screens and rotary drum screens.

Additional alternatives considered include horizontal screens designed to exclude sediment from irrigation pipes (ie. Watson screens), passive vertical/inclined screens (eg. inline bank/vault, Coanda and flat plate down ramp screens), and infiltration galleries. These alternatives are not proposed due to uncertainty in one or more operating requirements including low flow depths, instream sediment load, difficulty controlling bypass flow and potential for fish stranding.

3.6.4.1 Alternative 1: Farmers Conservation Alliance (FCA) Screen

The first alternative considered consists of a horizontal plate screen manufactured by Farmers Conservation Alliance (FCA) of Hood River, Oregon. FCA screens have no moving parts and require relatively little maintenance. The FCA screen is installed in an existing ditch (off-channel), and consists of a screen box constructed from plate steel and a fish screen constructed from perforated stainless steel plate. FCA screens meet or exceed all NMFS (2011) criteria. An example installation is shown in Figure 3-6.

Figure 3-6. Example modular FCA screen on Sixmile Creek near Frenchtown, MT, courtesy of FCA. Water flows down the flume to the screen.

The screen and screen box are modular and are delivered in 10 ft-long sections that are bolted together on-site. The fish screen is placed in line with the ditch. Water flows over the screen and the bulk of diverted water is screened and delivered downstream to the irrigation ditch. A portion of the diverted flow (0.5 cfs - 1.5 cfs) washes fish and debris from the screen face, and is returned to the stream by the return pipe. A sketch illustrating how this screen functions is shown in Figure 3-7. This screen is considered a passive screen because there is not a mechanical system to remove debris from the screen face. Therefore, passive screen design criteria were used for the analysis. Screen cleaning is accomplished by flowing water, which reduces screen maintenance.

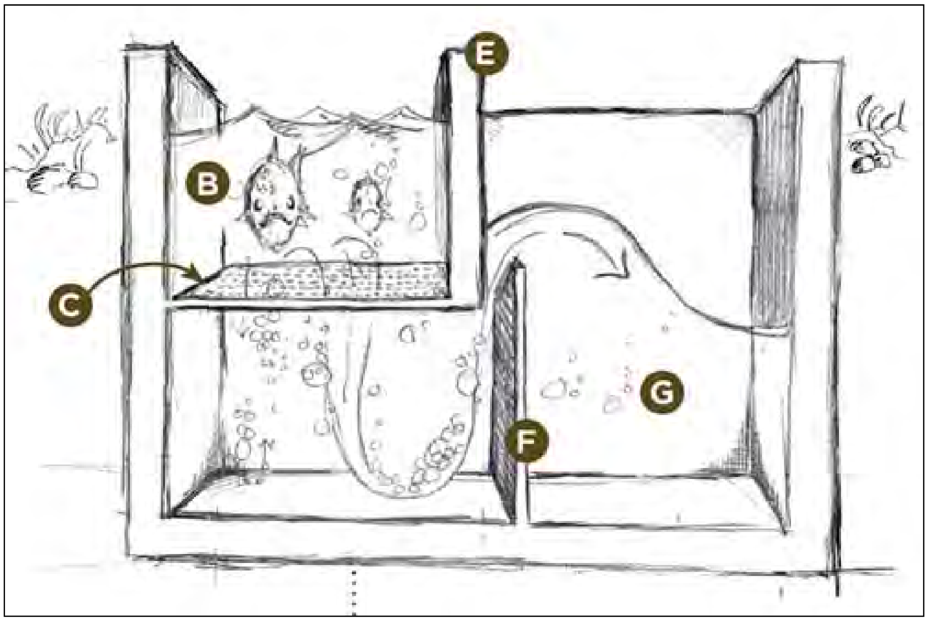

Figure 3-7. Schematic of a Farmers Screen, courtesy of FCA. View of schematic is facing upstream. Water flows over the screen (C) approximately 16 times faster than it flows through the screen, which passes fish and debris downstream. Screened water passes over a weir wall (F) and is conveyed to the irrigation ditch (G). Fish and debris are returned to the channel.

Installation of the modular Farmers screen typically takes two days with a small field crew and light equipment (small excavator). The screen is placed on a bed of compacted gravel, and the screen box is backfilled with native soil. The inlet and outlet to the screen and flume are armored with larger rocks. The typical performance, maintenance and constructability for this type of screen is compared with other screen options in Table 3-2.

3.6.4.2 Alternative 2: Vertical Flat Panel Screen

Alternative 2 consists of a vertical flat panel screen placed within the irrigation ditch. Vertical flat panel screens have a good track record of operating in the Blackfoot River Basin and are manufactured locally in Seeley Lake, Montana and other custom fabricators. The screen consists of a metal or concrete screen box placed within the existing ditch, vertical flat panel screen(s) angled to the path of flow, and a paddle wheel mechanical system to move the brushes. An example installation is shown in Figure 3-8.

Figure 3-8. Example of a vertical flat plate screen set at an angle to flow in the ditch. A portion of flow passes through the flat plate screen and down the irrigation ditch, and a portion of flow passes down the bypass pipe (upper right) and is returned to the channel. Brushes driven by the paddle wheel move back and forth across the screen to remove debris.

Vertical flat panel screens have similar fish return and bypass flow requirements as for the Farmers screen in Alternative 1. The typical performance, maintenance and constructability for this type of screen is compared with other screen options in Table 3-2.

Alternative 3: Rotary-Drum Screen

Alternative 3 consists of a rotary drum screen placed within the irrigation ditch. Rotary drum screens have a good track record of operating in the nearby Blackfoot River Basin and are manufactured by Hydroscreen LLC, and other custom fabricators. The screen consists of a concrete screen box placed within the existing ditch, rotary drum screen angled to the path of flow, and an internal paddle wheel mechanical system to turn the drum. An example installations is shown in Figure 3-9.

Figure 3-9. Example of a drum screen set at an angle to flow in the ditch with a paddle wheel and gear system to turn it.

Drum screens have similar fish return and bypass flow requirements as for the Farmers screen in Alternative 1. This type of screen is limited to a maximum flow rate of approximately 14 cfs. The typical performance, maintenance and constructability for this type of screen is compared with other screen options in Table 3-2.

3.6.5 Fish Screen Alternatives Discussion

Each alternative would provide the amount of irrigation water allowed by the water right. Each alternative has varying degrees of fish protection, constructability, cost, and maintenance requirements. Relative characteristics of the three alternatives are compared in Table 3-2.

Fish screening performance for the three screens varies. The FCA screen is designed to meet all NMFS guidelines and is expected to provide excellent fish protection. The vertical flat panel and rotary drum screen screens generally meets NMFS guidelines, with the exception that the screen perforations are greater in size than recommended by NMFS. This limitation likely would only be of concern for small fry (less than 1/8").

The FCA screen has no moving parts, and as a result mechanical maintenance on the screen is lower than on the drum screen because there are fewer parts to maintain. The rotary drum screen has mechanical parts including a water wheel mechanical system that turns the drum and bushings that the drum rotates about. The vertical flat panel screen also has mechanical parts consisting of a water wheel mechanical system which moves the wipers.

Screen maintenance considerations for all screens involve periodic (daily to weekly) observations of the screen during the irrigation season to adjust flow rates, examine the screen for debris and to remove any accumulated debris. Management of fine sediment will likely be required for all designs. Fine sediments tend to accumulate below the screen surface in the FCA screen. A simple tool similar to a garden hoe can be used to clear the sediments out of the box by agitating the fines which will then discharge to the creek via the return pipe. Fine sediments tend to accumulate in the rotary drum and vertical flat panel screen entrances as the cross-sectional area of the ditch expands at the entrance to the screen. Accumulated fines must be periodically removed from the screen entrance by shoveling. Closing the ditch headgate once the irrigation season is over is recommended as it will reduce sediment accumulation for any of the screen alternatives.

Diversion structures, headgates and sluice gates also require periodic inspection and maintenance. Fine sediment may accumulate near the entrance to the headgate due to expansion of the channel and the upward slope of the cross vane arm that is designed to deliver water to the headgate. A sluice gate set lower than the headgate and connected to a sluice pipe is recommended to provide a means to flush the accumulated fine sediments out of the diversion inlet during high flows. Headgates and sluice gates require annual inspection and maintenance of moving parts.

Table 3-2. Relative comparison of fish screen alternatives.

	Alternative 1 **Horizontal Flat Panel Screen**	**Alternative 2** **Vertical Flat Panel Screen**	**Alternative 3** **Rotary Drum Screen**
Fish Screening Performance	Excellent	Good (chief concern: perforations larger than NMFS standard)	Good (chief concern: slot size larger than NMFS Standard)
Approach Velocity	< 0.4 ft/sec	< 0.4 ft/sec	< 0.4 ft/sec
Debris Maintenance	Low (scrub 1-2x per month to remove algae if present)	Medium (check weekly - remove debris)	Medium (check weekly - remove debris)
Screen Maintenance	Low (annual sediment flush)	Medium (periodically flush sediment, annual mechanical, replace brushes every 6 yrs)	Medium (periodically remove drum to flush sediment, annual mechanical, periodically replace bushings)
Constructability	Easy, ~2 weeks	Easy, ~2 weeks	Moderate, ~2 - 3 weeks

3.7 Summary of Restoration Strategies and Treatments

Table 3-3 provides a summary of potential restoration strategies for addressing limiting factors on Flint Creek. Ability to address site specific geomorphic, vegetation and aquatic habitat limiting factors is described for each restoration strategy.

Table 3-3. Summary of restoration strategies for addressing limiting factors on Flint Creek.

Restoration Strategy	Limiting Factors Addressed	Limitations
Conservation	Insufficient riparian buffers Lack of vegetation diversity	Conservations is suitable for floodplains with good connectivity to the stream and high natural recovery potential. Conservation does not directly address geomorphic limiting factors; however, conservation may improve riparian and aquatic habitat conditions in the long term. May provide opportunities for future restoration.
Revegetation and Wetlands	Bank erosion Insufficient riparian buffers Lack of vegetation diversity Lack of habitat diversity	Revegetation does not directly address limiting factors related to channel geometry such as channel entrenchment, straightened planform, or floodplain connection. Success is dependent upon routine maintenance and adaptively managing site conditions. Revegetation may improve aquatic habitat conditions in the long term.
Streambank Structures	Overwide riffles Shallow pools Bank erosion Lack of habitat diversity	Streambank structures do not directly address limiting factors related to channel geometry such as channel entrenchment, straightened channel planform, or floodplain connection. Success is dependent upon reach-scale stability and inclusion of vegetation components.
Irrigation and Fish Passage Improvements	Fish entrainment	Eliminate fish access to irrigation ditches Require routine operations and maintenance.
Channel Reconstruction	Straightened planform Altered pool development Bank erosion Shallow, infrequent pools Overwide riffles Lack of habitat diversity	Improvements to aquatic habitat are immediate. Success is dependent upon use in conjunction with other treatments including conservation, revegetation and streambank structures.

4 Conceptual Restoration Designs

4.1 Conceptual Design Criteria

This section provides specific restoration objectives to guide development of conceptual restoration design criteria. Limiting factors identified in Section 2 were used to link existing site conditions to objectives and conceptual design criteria aimed at achieving desired conditions. Objectives and conceptual design criteria are provided for categories of geomorphology, vegetation and aquatic habitat.

4.1.1 Geomorphic Objectives and Design Criteria

Geomorphic objectives provide guidance for addressing stream channel geometry and river processes. In addition, geomorphic objectives support aquatic habitat objectives and integrate with the vegetation objectives described in subsequent sections. Table 4-1 provides a summary of geomorphic objectives, limiting factors and conceptual design criteria. Addition detail is provided in the following sections.

Table 4-1. Summary of geomorphic objectives, limiting factors and conceptual design criteria.

Geomorphic Objective	Limiting Factor Addressed	Geomorphic Design Criteria
Improve pool development process	Altered pool development	Large wood and vegetation incorporated into bank structures and deepen pools
Reduce fine sediment supply	Bank Erosion	Address all banks with High and Very High BEHI scores
Reduce width to depth ratio of riffles	Over-widened riffles	Width to depth ratio less than 22

<u>Geomorphic Objective 1: Improve Pool Development Processes.</u> Pool development processes will be addressed by modifying channel morphology and adding woody debris to the channel.

> **Design Criteria for Geomorphic Objective 1:** Channel morphology will be modified to be an C stream type (Rosgen and Silvey 1996). Streambank treatments will include large wood to promote scour and pool development.

<u>Geomorphic Objective 2: Reduce Fine Sediment Supply.</u> Fine sediment supply will be reduced by reducing bank erosion rates and increasing sediment storage potential on the floodplain.

> **Design Criteria for Geomorphic Objective 2:** Design criteria for reducing fine sediment supply include addressing bank erosion mechanisms such as altered morphological conditions, sparse vegetation bank cover and land use such that bank erosion is limited to banks with lower than a High BEHI rating. In addition, floodplain roughness will be

increased, with the increase of woody vegetation, in order to provide hydraulic conditions that deposit and store sand on floodplain surfaces.

Geomorphic Objective 3: Reduce width to depth ratio of riffles. Width to depth ratios in riffles will be decreased by narrowing the channel and reconstructing the bank with a wood and brush fascine and a salvaged sod mat on top for quick revegetation and stabilization.

Design Criteria for Geomorphic Objective 3: Focus on riffles with highest width to depth ratios and reduce the width to depth ratio to around 22. These riffles could also incorporate a large wood structure below to promote spawning in the lower riffle and subsequent glide.

4.1.2 Vegetation Objectives and Design Criteria

Vegetation objectives provide guidance for addressing riparian conditions and ecological function. In addition, vegetation objectives support aquatic habitat objectives and integrate with the geomorphic objectives described in previous sections. Table 4-2 provides a summary of vegetation objectives, limiting factors and conceptual design criteria. Addition detail is provided in the following sections.

Table 4-2. Summary of vegetation objectives, limiting factors and conceptual design criteria.

Vegetation Objective	Limiting Factor Addressed	Vegetation Design Criteria
Preserve existing high quality riparian vegetation	Insufficient riparian buffers & Lack of woody vegetation and riparian diversity	Establish preservation areas for both during construction and grazing management
Restore diverse riparian vegetation communities	Lack of woody vegetation and riparian diversity	Floodplain is actively revegetated with diverse mix of native species, and planted stock is protected from browse and herbivory and maintained in the short-term.
Reduce invasive species	Lack of woody vegetation and riparian diversity	Site specific weed management integrated with revegetation efforts and management programs.
Increase woody vegetation on streambanks	Insufficient riparian buffers & lack of woody vegetation and riparian diversity	Streambanks are reconstructed at elevations that support conditions for desired vegetation communities. Streambanks are reconstructed using native, living plant material and biodegradable materials such as woody debris and coir.

Vegetation Objective 1: Conserve Existing High Quality Riparian Vegetation. Where present, existing high quality riparian vegetation will be conserved.

Design Criteria for Vegetation Objective 1. Design criteria for conserving existing high quality vegetation focus on identifying areas that currently support native, self-sustaining riparian vegetation communities. These areas are supported by existing site conditions and provide a range of desired ecological functions including streambank stability, overhanging vegetation, woody debris recruitment potential, and habitat corridors.

Vegetation Objective 2: Restore Diverse Riparian Vegetation Communities. Diverse riparian vegetation communities will be restored by creating the conditions necessary for development and maintenance of a diverse mosaic of native riparian vegetation communities.

Design Criteria for Vegetation Objective 2. Riparian vegetation communities require a relatively high ground water table, connectivity with the channel and a moderate degree of soil stability to establish. Active revegetation will be required to rapidly establish desired vegetation. Design criteria applicable to active revegetation include: planting of a diverse mix of native riparian species; seeding with a diverse mix of native riparian and upland species; protection of planted woody vegetation from browse and herbivory, primarily deer and beaver; and short-term maintenance of planted and seeded vegetation is conducted including weed control and supplemental irrigation as needed.

Vegetation Objective 3: Reduce Invasive Species. Invasive species, including noxious weeds, will be reduced or prevented by implementing weed control strategies specific to each project reach.

Design Criteria for Vegetation Objective 3. Actions implemented to achieve Vegetation Objective 2 will help prevent weed infestations and control weed densities long-term. Control of weeds in restored areas should be closely integrated with the grazing management plan. Design criteria to reduce invasive species also consider control or eradication of non-noxious weeds that may become invasive in restored riparian areas.

Vegetation Objective 4: Increase Woody Vegetation on Streambanks. Woody vegetation will be increased on streambanks by installing streambank structures that integrate living woody vegetation.

Design Criteria for Vegetation Objective 4. Design criteria for increasing woody vegetation on streambanks include integration of living woody vegetation in all streambank structures. Design criteria also call for the use of biodegradable materials in streambank structures such as woody material including brush, logs and rootwads or fabrics made from biodegradable fibers such as coir. To maximize desired ecological functions, streambank treatments should be designed to provide a stable growing environment for desired woody vegetation to establish along and within the channel margin.

4.1.3 Aquatic Habitat Objectives and Design Criteria

Aquatic habitat objectives provide guidance for addressing biological function and aquatic species life history needs. In addition, aquatic habitat objectives integrate with the vegetation and geomorphic objectives described in previous sections. Table 4-3 provides a summary of aquatic habitat objectives, limiting factors and conceptual design criteria. Addition detail is provided in the following sections.

Table 4-3. Summary of aquatic habitat objectives, limiting factors, and conceptual design criteria.

Aquatic Habitat Objective	Limiting Factor Addressed	Aquatic Habitat Design Criteria
Reduce fish entrainment	Fish entrainment	Construct a diversion structure that provides adequate water to the ditch and provides main stem fish passage Install a fish screen to prevent fish from accessing the irrigation ditch
Improve streambank cover	Lack of habitat diversity	Streambanks treatments include vegetation component
Increase pool frequency and enhance pool quality	Shallow, infrequent pools	Decrease pool to pool spacing by 50% Increase max depth in residual pools by 25% of current maximum depth
Maintain clean gravel substrate	Fine sediment accumulation	Gravel embedded with less than 20 percent fines Bankfull channel shear stress capable of mobilizing D_{50} particle size

Aquatic Habitat Objective 1: Eliminate Fish Entrainment. Fish entrainment will be eliminated with the addition of a fish screen to the diversion structure.

> **Design Criteria for Aquatic Habitat Objective 1**. Fish screen design should minimize maintenance and maximize efficiency at screening fish out of diversion structure.

Aquatic Habitat Objective 2: Improve Streambank Cover. The channel margins will offer streambank cover including woody vegetation and woody debris.

> **Design Criteria for Aquatic Habitat Objective 2:** Streambank treatments will include a woody vegetation component in order to develop streambank cover and increase shade.

Aquatic Habitat Objective 3: Increase Pool Frequency and Enhance Pool Quality. Pool frequency will be increased to be consistent with standards for properly functioning habitat for sustainable fish populations. Deep pools will provide suitable holding habitat and will provide woody debris for cover.

Design Criteria for Aquatic Habitat Objective 3: Proposed pool frequency is 70 to 100 pools per mile as derived from measured pool frequencies in properly functioning watersheds (USFS 1994). To accomplish this a decrease in pool to pool spacing by 50% is needed. Design criteria for pool quality are residual pool depth greater than 5 feet with good cover.

Aquatic Habitat Objective 4: Maintain Clean Gravel Substrate. Preferred substrate conditions will be provided by maintaining medium gravel mobility and flushing embedded fines from the interstitial spaces within the gravel.

Design Criteria for Aquatic Habitat Objective 4: Design criteria for maintaining clean gravel substrate is derived from hydraulic conditions required to mobilize D_{50} particles during bankfull discharge.

4.2 Conceptual Restoration Designs

This section presents conceptual restoration designs for the project area. Preliminary concepts were presented to and reviewed by the landowners and project stakeholders at an onsite meeting on June 16, 2017. Comments received from the landowners and project stakeholders were incorporated into the following conceptual restoration designs.

The conceptual restoration designs address the site-specific limiting factors and provide combinations of treatments that will satisfy project objectives. The concepts include plans that address fish entrainment, riparian habitat, streambank erosion and aquatic habitat as well as many other limiting factors. By organizing restoration treatments into these specific plans, proposed designs can be aligned with funding programs tailored to implementing specific types of restoration actions. The restoration plans can be implemented independently or in combination with elements from other plans. The four primary conceptual restoration plans are:

- **Irrigation Diversion Plan** – plan for addressing fish entrainment in the irrigation ditch located at the downstream end of the project area. This plan also addresses stream and floodplain conditions the lower segment of Flint Creek from the house downstream to the property line at the highway bridge.
- **Streambank Restoration Plan** – plan for addressing eroding streambanks and overwidened riffles in the upstream end of the project area.
- **Revegetation Plan** – plan for improving riparian habitat conditions on the Flint Creek floodplain through planting, fencing and grazing management.

- **Channel Reconstruction Plan** – comprehensive plan for improving aquatic habitat by restoring stream channel meander geometry and increasing stream length in the upstream end of the project area where Flint Creek has been channelized.

4.2.1 Irrigation Diversion Plan

The irrigation diversion plan and concept for the lower segment in the project area is shown in Figure 4-1. This conceptual design highlights the restoration activities proposed around the irrigation diversion site and the lower portion of Flint Creek down to the highway bridge. The existing diversion structure would be removed and replaced with a rock diversion structure consisting of boulders positioned in two u-shaped features pointing upstream. Small pools would be constructed on the downstream bend at the base of the U to aid aquatic organism passage and provide energy dissipation. The diversion structure would divert flow into the ditch and maintain 6-inch steps that would provide aquatic organism passage in Flint Creek at all flows. Additionally, the existing headgate would be replaced with a new headgate to meet the requirements for the fish screen. A sluice gate would be installed alongside the headgate to minimize sediment deposition in the forebay. A fish screen would be installed in the irrigation ditch downstream of the headgate. Diversion structures and fish screen alternatives are described in more detail in Section 3.6.

In addition to irrigation diversion improvements, there are opportunities to address streambank and floodplain conditions in the downstream end of the project area as part of the streambank restoration plan and revegetation plan. Large wood habitat structures are proposed to increase the quantity and quality of pool habitat in the reach. Two over widened riffles could be narrowed using vegetated wood and brush banks and sod mats, as described in Section 3.4.

On the south side of the irrigation diversion an existing depression could be enhanced to create an open water shallow wetland. The sod salvaged in this process could be transplanted for bank treatments throughout the project area. Revegetation opportunities are described in Section 4.2.3.

4.2.2 Streambank Restoration Plan

Figure 4-2 highlights the restoration activities proposed for the middle segment of the Corbett-Downs property reach on Flint Creek. To increase the quantity and quality of pool habitat in this portion of the reach 11 large wood habitat structures are proposed along with excavation of the channel adjacent to the structures to increase pool depth. These structures would provide cover for fish, increase bank stability, and direct flow toward the bed of the channel which will support natural pool forming processes currently missing in the reach. An over widened riffle would be narrowed and a large wood structure installed at the bottom to provide more connectivity between the two bends with pool habitat. Banks throughout this section that were identified in the bank erosion hazard analysis as significant contributors to sediment would be replaced with vegetated wood and brush structures as described in Section 3.4, thus reducing the overall sediment contribution to Flint Creek.

Figure 4-3 highlights the restoration activities proposed for the upper portion of the Corbett-Downs property reach on Flint Creek. To reduce sediment supply from a rapidly migrating bank the installation of 2 large wood habitat structures is recommended in conjunction with a constructed vegetated wood and brush bank. Fill would be required to narrow the channel slightly which will help maintain the pool depth for the bend. Downstream of the bend, 2 over widened riffles would be narrowed with a vegetated wood and brush fascine or vegetated soil lift with sod mats to help promote stability and revegetation efforts.

The streambank restoration plan includes 14 large wood structures and 2,330 feet of vegetated wood and brush structures. Materials needed for construction include approximately 500 trees, 4,000 cubic yards of streambed fill to narrow the channel, and 20,000 vegetative cuttings for the streambank structures.

4.2.3 Revegetation Plan

Figure 4-4 and Figure 4-5 depict the revegetation plan and grazing recommendations for the project reach. The revegetation plan includes approximately 6,000 plants in 31 planting units encompassing approximately 8 acres. Planting units vary in size from 0.05 acres to 0.85 acres. Planting units were placed throughout the area with the goals of increasing connectivity for habitat between existing riparian vegetation communities and increasing the overall quantity and diversity of woody vegetation in the riparian. These planting units would replace existing pasture grasses with woody vegetation using individual containerized plants that would need protection from browse for at least 3 years. Planting units would be enclosed in 8-foot high metal wire fencing to limit browse by cattle and wildlife. Preservation areas were identified to highlight where existing vegetation communities are thriving and the planting units were placed to help increase connectivity between the preservation areas.

Recommendations for grazing include dividing the Corbett-Downs property into segments that are surrounded by existing fencing and proposed fencing. Grazing activities are recommended for each segment. In continuous grazing areas, no limit is placed on the duration or amount of grazing. In rotational grazing areas, access should be limited to 5 days of grazing followed by a 30 day period where the area is allowed to recover without grazing. In exclosure areas, no grazing should be conducted. Exclosure areas are sensitive to grazing and consist of the wetted channel and wetlands. Revegetation treatments are described in more detail in Section 3.3.

4.2.4 Channel Reconstruction Plan

Figure 4-6 presents an alternative concept for channel reconstruction in the upstream segment of the project area where Flint Creek appears to have been channelized. Channel reconstruction would increase channel length by 800 feet and reduce the stream gradient from 0.60 percent to 0.35 percent. Three meander bends would be reconstructed and riffle-pool morphology would be established. The former channel would be converted to wetland habitat using material excavated from the new channel. Earthen plugs would be placed intermittently in the former channel to reduce avulsion risk. The details of new channel construction are described in general terms in Section 3.5.

The channel reconstruction plan includes 2,650 feet of new channel, 10 large wood structures and 2,650 feet of vegetated wood and brush structures. Materials needed for construction include approximately 700 trees, 1,200 cubic yards of streambed fill for riffle construction, and 26,000 vegetative cuttings for the streambank structures. Excavation of the new channel is estimated to be approximately 14,000 cubic yards.

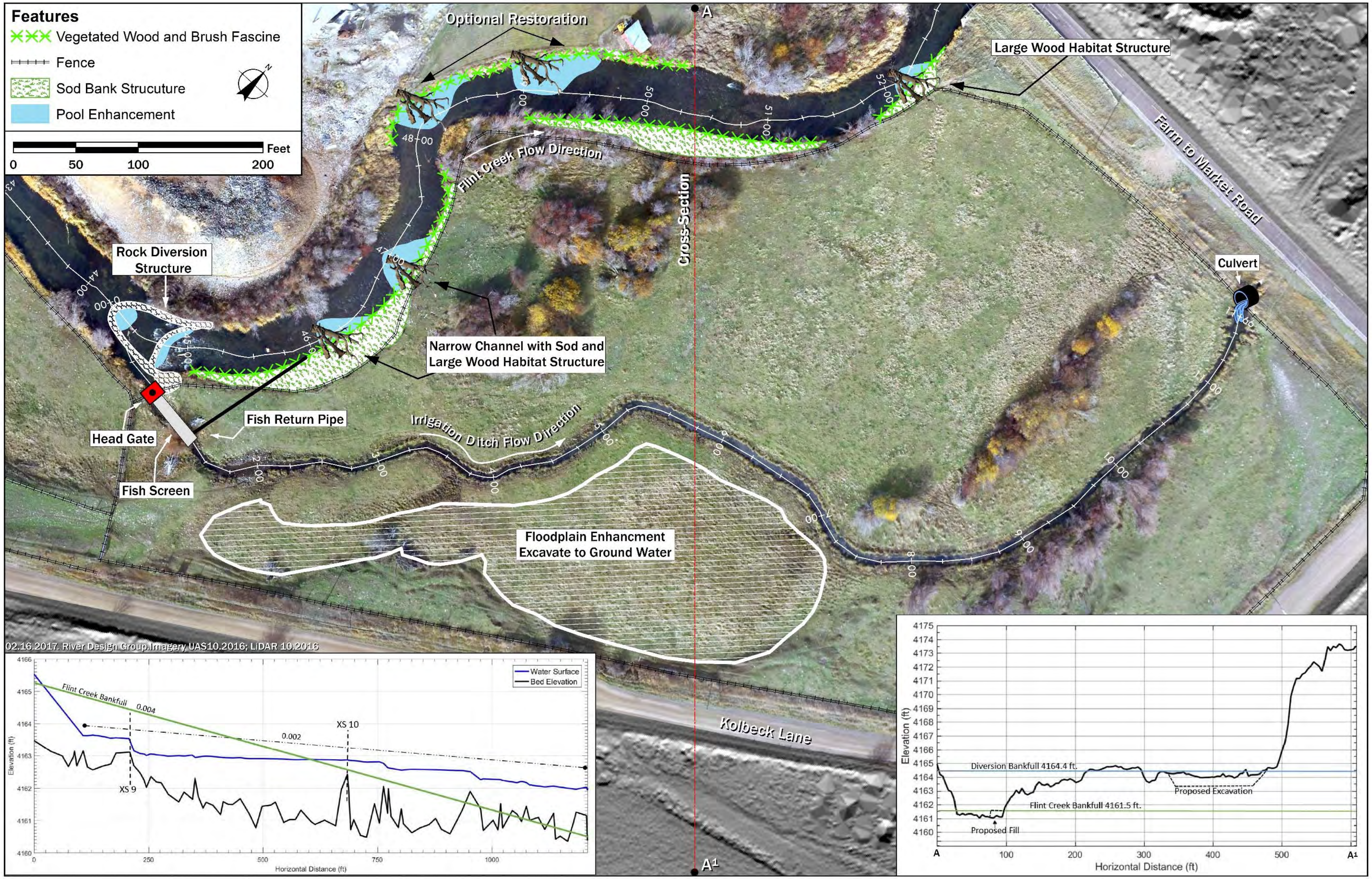

Figure 4-1. Conceptual irrigation diversion plan and conceptual design for the fish screen and lower project site on Flint Creek.

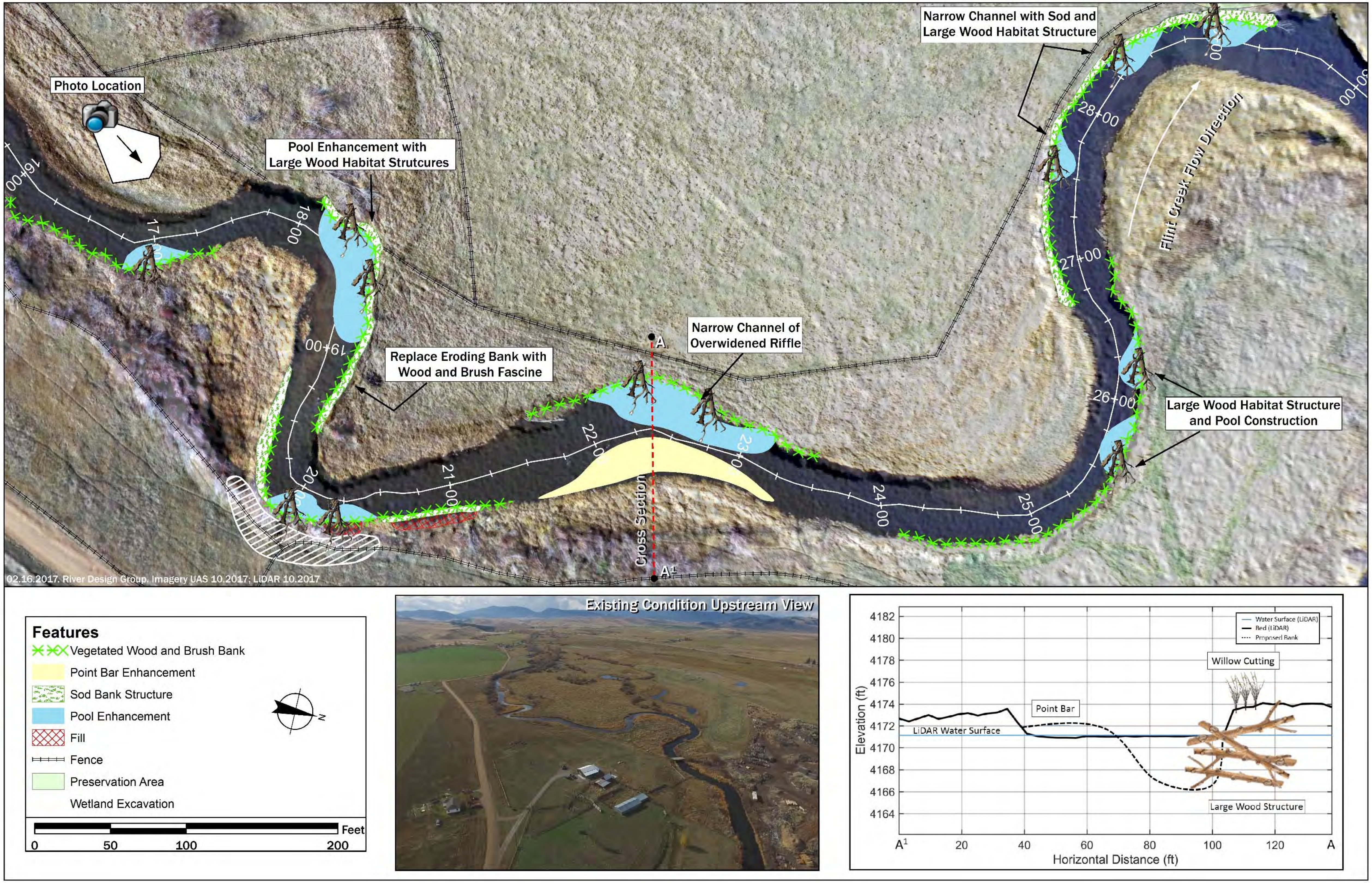

Figure 4-2. Conceptual streambank restoration plan and conceptual design for the downstream portion of the upper site for the Flint Creek.

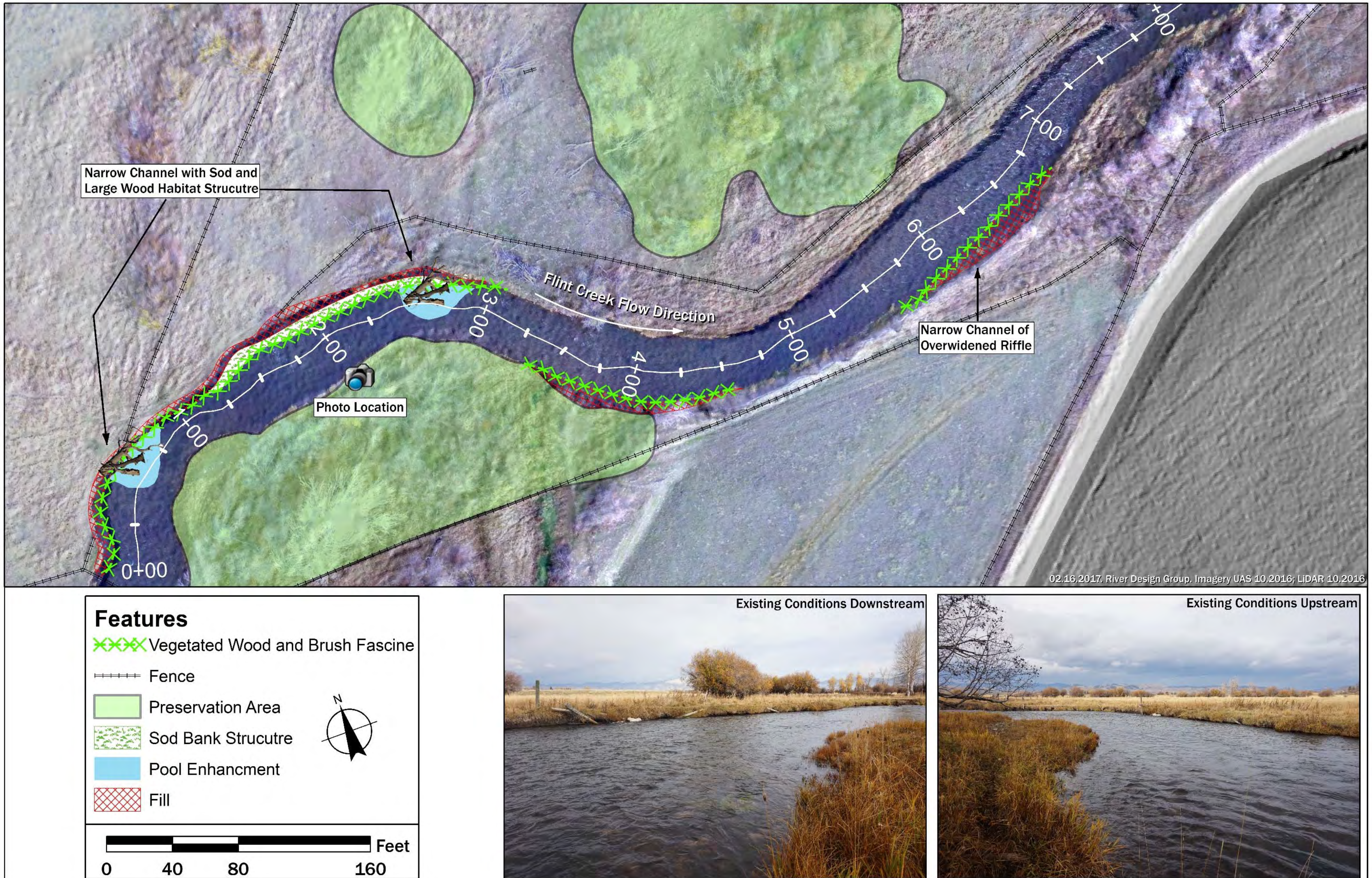

Figure 4-3. Conceptual streambank restoration plan and conceptual design for the upstream portion of the upper site for the Flint Creek.

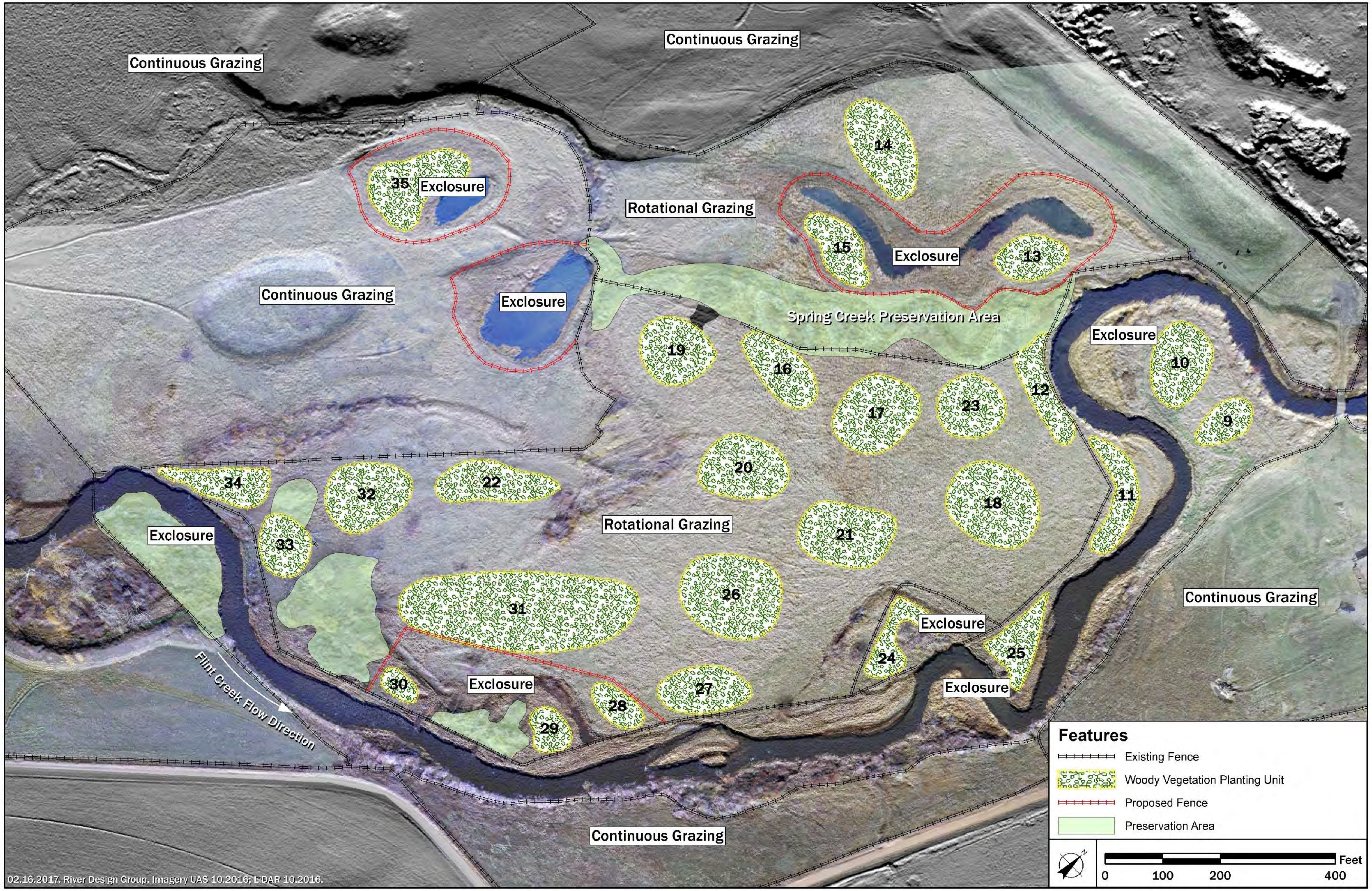

Figure 4-4. Conceptual revegetation and grazing plan for the upstream portion of the project site on Flint Creek.

Figure 4-5. Conceptual revegetation and grazing plan for the downstream portion of the project site on Flint Creek.

Figure 4-6. Alternative concept for a channel reconstruction plan for the upstream portion of the project site on Flint Creek.

5 Design and Implementation Considerations

This section provides guidance for project design and implementation phases.

5.1 Design Considerations

This section describes design considerations including data collection needs and permitting requirements.

5.1.1 Data Collection Needs

The conceptual restoration design was based on LiDAR and a field survey to characterize existing conditions. Additional data collection will be required to address project feasibility. Recommended data collection needs include:

- **Channel bathymetry –** supplement LiDAR topography with channel topography below water surface for further modeling, specifically around the fish screen site.
- **Subsurface investigations** – excavate representative soil pits at proposed excavation locations in order to characterize soils and sample for contamination.
- **Wetland delineation** – identify jurisdictional wetlands in the project area.
- **Diversion structure final survey –** Detailed survey around existing structure and diversion on downstream landowner's property.

5.1.2 Permitting

Flint Creek restoration work will require preparation of a joint permit application in compliance with the following environmental regulations:

- Federal Clean Water Act Section 404 and 401
- State of Montana Stream Protection Act 124
- State of Montana Natural Streambed and Land Preservation Act 310
- Endangered Species Act Section 7 Consultation

Additional permit applications that will be required include:

- National Environmental Policy Act (preparation of an Environmental Impact Statement or an Environmental Assessment)
- Montana State Historic Preservation Office (SHPO) to demonstrate regulatory compliance with the National Historic Preservation Act Section 106 (cultural resources investigations)
- EPA/Montana DEQ to demonstrate compliance with the Clean Water Act National Pollution Discharge Elimination System (NPDES) permit program (stormwater pollution prevention plan)
- Granite County to demonstrate compliance with the National Flood Insurance Program (floodplain development permit/no rise certification)

Other permit applications may be required depending on final project scope and local regulations.

5.2 Implementation Considerations

This section describes a conceptual approach for implementing the project design.

5.2.1 Construction Access and Staging

Two staging areas have been identified in the project reach to allow for the storage of equipment and materials for the construction phase of the project (Figure 5-1). Both access routes to the staging areas are on the Corbett-Downs property and will require removal of a small portion of fencing and a temporary gate installed. The lower staging area would be utilized for the installation of the fish screen, floodplain enhancement, and bank structure construction from station 44+00 to 53+00. The Upper staging area will be utilized for the bank treatments and revegetation efforts from station 00+00 to 32+00. After project completion, these sites will be reclaimed and any damage to fencing will be repaired or replaced in coordination with the landowner.

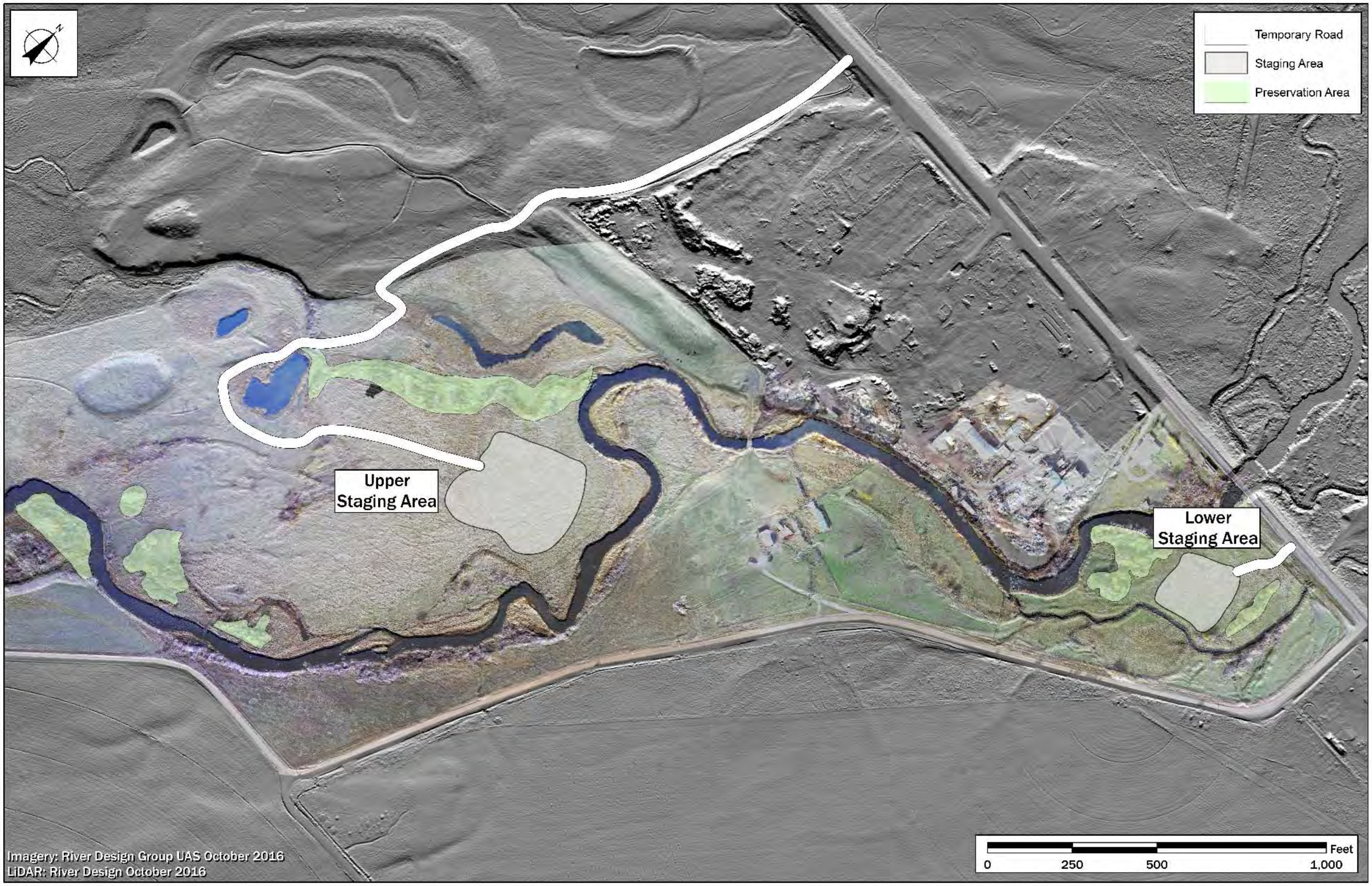

Figure 5-1. Staging areas and access roads for proposed construction efforts.

5.2.2 Water Management

Construction of the streambank structures will require heavy equipment in the channel. Construction should be timed with the lowest flows for the project site, which typically occur in late July and August. Dewatering work areas may be necessary at some sites. Concentrating flow to one side of the channel may be an effective alternative to dewatering the channel depending on the flows during construction. Fish salvage operations may be required if dewatering work site is required. Fish salvage operations will need to be coordinated with Montana Fish, Wildlife and Parks and completed by qualified biologists. During the final design phase specifics regarding water management strategies should be finalized based on the expected flows during construction period and permit requirements.

5.2.3 Construction Materials

Sourcing and staging of construction materials may need to occur in advance of implementation. Such materials may include logs, brush and containerized plants. Containerized plant sources may need to be identified and procured up to a year or more before expected planting to ensure appropriate species and quantities are available. Due to timing considerations, it may be necessary to designate these materials as owner-supplied items provided to the construction contractor.

5.2.4 Contracting

Restoration is a specialized construction practice requiring knowledge of water management, fish salvage operations, streambank structure installation, precision grading, planting and use of native materials. Submittal of contractor qualifications demonstrating knowledge and experience with restoration projects should be an important consideration in the bid process. Moreover, it may be necessary to procure multiple contractors responsible for various portions of the work based on qualifications such as revegetation and stream bank structure experience.

5.2.5 Cost Estimate

Conceptual implementation cost estimates were prepared and provided to the project partners. Estimates include costs for construction implementation, design, construction oversight, monitoring. Estimates were prepared for each of the four plans described in Section 4. Estimates are not included in this report.

5.3 Monitoring and Adaptive Management

Monitoring the effectiveness of restoration efforts is an important phase to ensure the project is achieving intended objectives. Standard monitoring plans include repeat surveys of established cross sections, longitudinal profile, and establishing photo points. The use of unmanned aerial systems (UAS) for river surveying has been tested and established in the literature as a valid technique for monitoring surveys utilizing structure from motion photogrammetry (Javernick et al. 2014; Tamminga et al. 2014; Tamminga et al. 2014; Stegman 2015; Qin 2014; Westoby 2012). Repeat aerial surveys could be conducted as part of project monitoring. For each survey a 3D surface and high-resolution orthophoto would be created for comparison with the as-built survey and orthophoto. The timing of the monitoring surveys can be flexible within the post-construction period to allow for surveys to be conducted on years with flows greater than a 2-year recurrence interval, if desired. Surface to surface comparison could be conducted to monitor geomorphic change in the project reach between time periods. Additionally, the high resolution orthophotos can be used to track the extent and relative health of the planting units.

The flexibility built into this plan will allow for surveys to be conducted in conjunction with any maintenance that may need to occur. During the design phase, project partners should consider how monitoring observations will be used to determine maintenance needs and project success. Routine maintenance of restoration projects typically includes: weed management, supplemental irrigation, supplemental seeding, and minor structure repair.

6 References

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APPENDIX A

HYDROLOGY ANALYSIS

Watershed Characteristics

The Flint Creek watershed is located within Granite and Deer Creek Counties and is surrounded by a series of mountain ranges: The Flint Creek mountains to the east, the Anaconda Range to the south, and John Long peaks to the west. The basin is comprised of two large valleys, the Philipsburg valley and Drummond valley (connected by a narrow canyon) and its total drainage area is 352 sq-mi. Additional watershed characteristics (Table A-1) and a map of the watershed (Figure A-1) are given below.

Flint Creek originates at Georgetown Lake and reaches its confluence, after flowing 36 miles, with the Clark Fork River at Drummond. Primary tributaries of Flint Creek include Fred Burr Creek, Boulder Creek, and Lower Willow Creek. Fred Burr Creek, which has an annual average flow of approximately 7,000 ac-ft per year, flows into Flint Creek in the Philipsburg Valley, while Boulder and Lower Willow Creeks enter Flint Creek in the Drummond Valley. There are two managed reservoirs within the watershed, one at Georgetown Lake, which has a capacity of 31,000 ac-ft and serves hydroelectric purposes, and Lower Willow Creek Reservoir, which has a capacity of 4,800 ac-ft and is utilized for consumptive use by agriculture (Watershed Consulting, LLC, 2015). Flow within upper Flint Creek is controlled by the dam at Georgetown Lake. The flow is augmented seasonally from a trans-basin diversion in the East Fork of Rock Creek and a trans-basin diversion in Trout Creek.

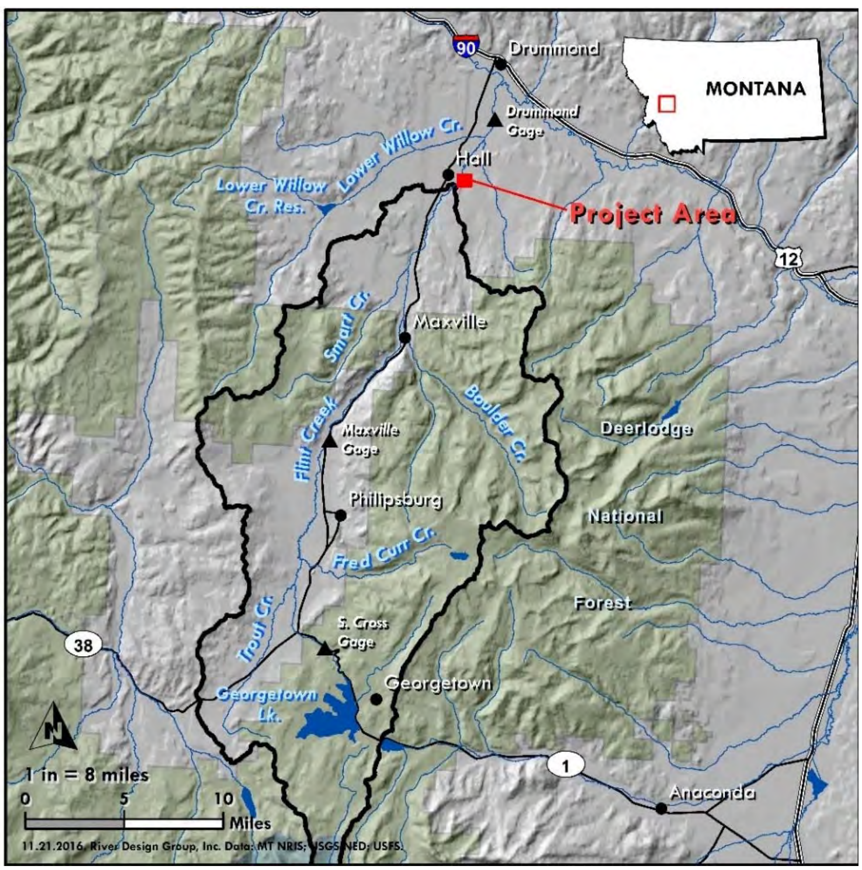

Figure A-1. Flint Creek watershed.

Table A-1. Flint Creek watershed characteristics.

Parameter	Description	Value
Drainage Area	Total area that contributes flow to the beginning of the study reach	351.5 mi^2
Precipitation	Mean annual precipitation	22.9 in
Temperature	Mean annual temperature	38.3 F
Mean Elevation	Average elevation of watershed	6213.3 ft
Max Elevation	Maximum watershed elevation	9829 ft
Min Elevation	Minimum watershed elevation	4182 ft
% Above 6000	Percent of area above 6000 ft in elevation	54.8%
Mean Slope	Mean basin slope computed from 30 m DEM	22.1 ft/ft
>30% Slope	Percent area with slopes greater than 30% from 30 m DEM	26.9%
>50% Slope	Percent area with slopes greater than 50% from 30 m DEM	6.5%
Forest Cover	Percentage of area covered by forest	60.4%
Cultivation	Percentage of area covered by cultivated land from NLCD 2001	7%
Irrigation	Percentage of area irrigated based on Montana Final Land Unit (FLU)	5%
Wetlands	Percentage of area covered by wetlands from NLCD 2001	0%
Lakes	Percentage of area covered by lakes, pond, and reservoirs	1%

Source: USGS StreamStats 4.0

In-stream hydrologic patterns within the basin are largely influenced by irrigation practices and flow releases from Georgetown Lake (Montana DEQ, 2012). As result, flows in Flint Creek and its tributaries can vary significantly over the water year. Flint Creek typically experiences peak flow in June, followed by a slow and gradual decline into the fall months, with a plateau in the late summer months and slight increase in the fall (after discontinuation of irrigation) (Montana DEQ, 2012). This prolonged decline can be attributed to the management of Georgetown Lake, inputs from the East Fork and Lower Willow Creek Reservoirs, and seasonal irrigational practices (Montana DEQ, 2012). Discharge within Flint Creek's tributaries typically reaches a peak in June, which is followed by a steady decline in flow into September. The four highest recorded discharges at Flint Creek near Maxville were likely triggered by rain-on-snow events and ranged from 900 to 1,680 cfs (Montana DEQ, 2012).

Available Data

Hydrologic data available for the basin includes flow data from stream gaging stations operated by the United States Geological Survey (USGS) and DNRC (Department of Natural Resources and Conservation). The USGS stations are situated on Flint Creek, while the DNRC stations are located on canals and diversions (to measure irrigation withdrawals). There are 11 total operational gaging stations located within the basin that have either been maintained in the past and have since been decommissioned, or remain operational (Table A-2).

Table A-2. Flint Creek watershed stream gages.

Name	Number	Drainage Area (Square Miles)	Agency	Period of Record (Years)
Flint Creek near Southern Cross	12325500	53	USGS	1940-2016 (76)
Flint Creek Main Canal below Headgate	76E 02000	--	DNRC	1961-1980, 1982-2016 (53)
Flint Creek Main Canal below County Bridge	76GJ02089	--	DNRC	1961-1980, 1982-2016 (53)
Marshal Canal below Headgate	76GJ04000	--	DNRC	1961-1980, 1982-2016 (53)
Trout Creek below Marshal Canal Diversion	76GJ05000	--	DNRC	1961-1980, 1982-2016 (53)
Fred Burr Creek near Philipsburg	12327100	15.7	USGS	1994-1996 (2)
Flint Creek at Maxville	12329500	208	USGS	1942-2016 (74)
Boulder Creek at Maxville	12330000	71	USGS	1940-2016 (76)
Allendale Canal below Headgate	76GJ08000	--	DNRC	1961-2016 (55)
Allendale Canal above Tail End	76GJ08080	--	DNRC	1961-1985, 1987-2016 (53)
Flint Creek near Drummond	12331500	490	USGS	1991-2002, 2003-2004 (12)

Source: Montana DEQ, 2012

A graphical summary of the available data from the USGS Flint Creek gages is given below in Figures A-2 A-3 and A-4.

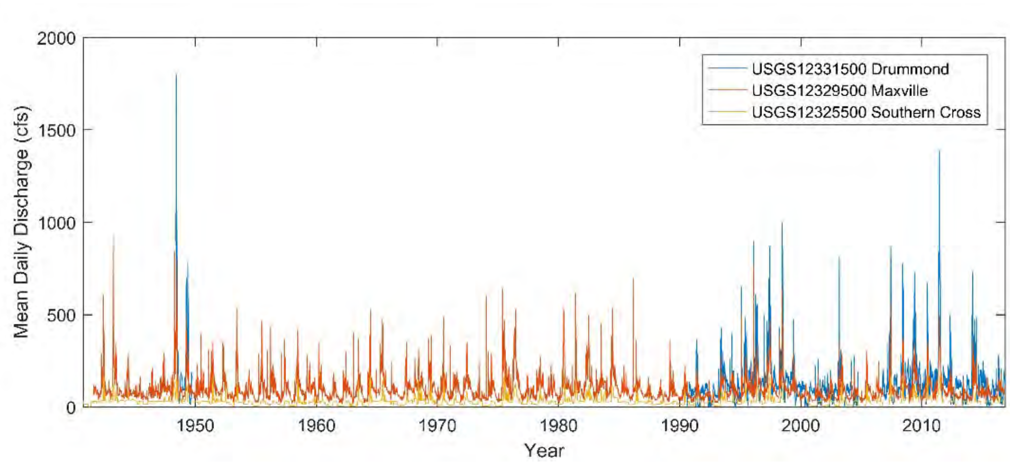

Figure A-2. Mean daily discharge for all three Flint Creek USGS gages.

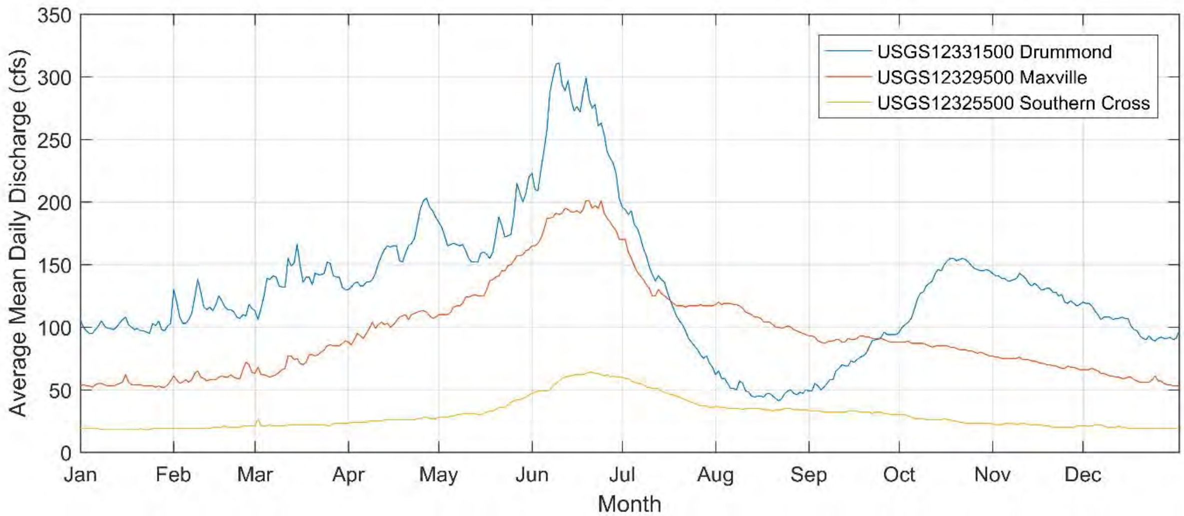

Figure A-3. Average mean daily discharge for three Flint Creek USGS gages that are still active. These values were obtained by averaging the daily mean flow values over the period of record (Drummond: 1991-2002, 2003-2004; Maxville: 1942-2016; Southern Cross: 1940-2016).

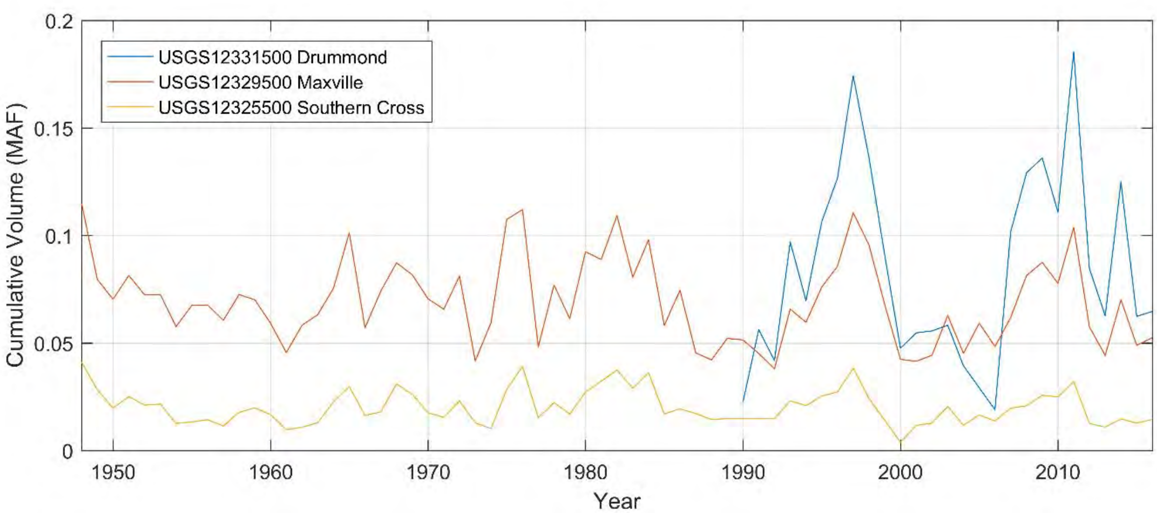

Figure A-4. Cumulative volume in million acre feet for the water years of record for the 3 active USGS gages.

Flood Frequency Analysis

Methods for determining flood frequency for unregulated systems include unit hydrographs, rainfall-runoff models, analysis of peak flows at gaged sites, and calculating flood-frequency data at ungaged sites based on drainage-basin and climatic characteristics. Options for determining flood frequency for regulated systems include reservoir routing and analysis of peak flows at gaged sites. Methods used in this analysis include analysis of peak flows at gaged sites; calculation of flood-frequency data at ungaged sites based on drainage-basin and climatic characteristics.

PeakFQ was utilized to conduct a USGS 17B flood frequency analysis for both the Maxville and Drummond gages on Flint Creek (Sando et al. 2016). The results from this analysis are summarized in Table A-3 and Figures A-4 and A-5. There is less uncertainty in the results from the upstream Maxville gage given the 74 years of record, compared to the Drummond gage with only 12 years of record.

Table A-3. Flood frequency analysis results (cfs).

Recurrence Interval (years)	USGS Gage Maxville	USGS Gage Drummond
1.25	264	310
1.5	327	412
2	410	550
2.33	450	617
5	637	932
10	803	1210
25	1030	1570
50	1200	1850
100	1390	2130
200	1580	2410
500	1850	2790

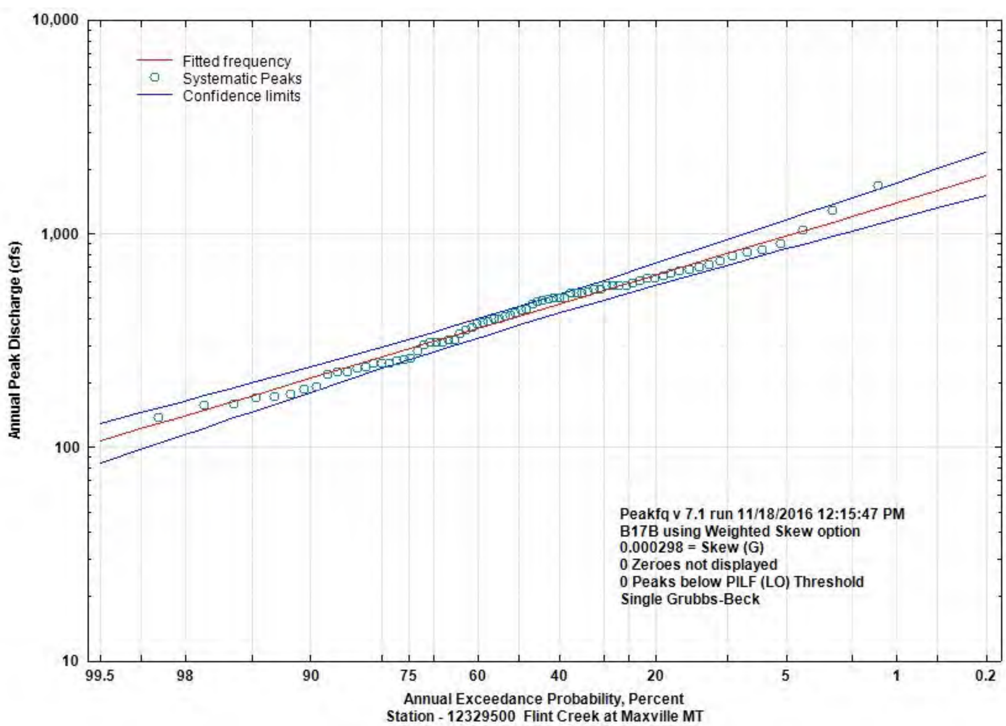

Figure A-5. Flood frequency analysis for Maxville gage conducted with USGS PeakFQ.

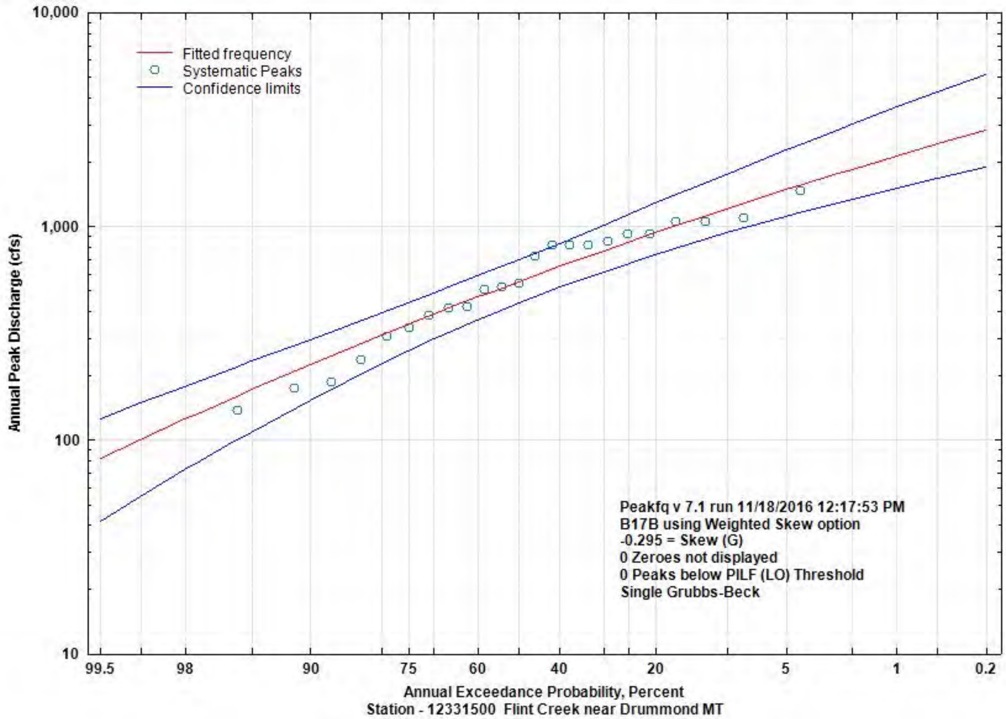

Figure A-6. Flood frequency analysis for Drummond gage conducted with USGS PeakFQ.

Bankfull Discharge Analysis

Bankfull discharge is the discharge that does the most work in shaping and maintaining stream channel geometry (Dunne and Leopold 1978; Rosgen 1996). Bankfull stage is determined in the field based on channel features such as point bar and floodplain elevations, vegetation, and other depositional features. It is often approximated by a 1.2-1.8 year return interval flood discharge.

Channel cross sections, longitudinal profiles and bankfull indicators were surveyed through the reach on Flint Creek. The reach is located upstream of the of the USGS gage "Flint Creek near Drummond, MT" (#12331500) and downstream of the USGS gage “Flint Creek at Maxville, MT” (#12329500). The bankfull elevation at each of four surveyed riffle cross sections were used to calculate conveyance area and wetted perimeter for the bankfull channel. Hydraulic relationships were used to estimate bankfull flow as a function of conveyance area, wetted perimeter, slope and roughness. Five separate methods were used to calculate bankfull discharge.

- Estimation using the USGS regional curve and drainage area (Lawlor 2004)
- Calculation using the friction factor/relative roughness equation (Rosgen, Leopold, and Silvey 1998; Rosgen and Silvey 2005)
- Manning’s equation with n estimated with the Strickler Equation (Chow 1959; Yen 1991)
- Manning’s equation with *n* estimated with Limerinos Equation (Limerinos 1970)
- Manning’s equation with *n* estimated with Jarret Equation (Jarret 1985)

The average bankfull discharge for the four reference cross sections were calculated. See Table A-3 for the estimated bankfull discharge estimations from multiple calculation methods. Additional analysis to determine bankfull for design purposes will be completed during the preliminary design phase.

Table A-4. Bankfull discharge (cfs) estimated for the Flint Creek study area.

Method	XS 2	XS 5	XS 6	XS7	Mean	Std. Dev.	Std. Err.
Regional Curve	674	674	674	674	674	NA	NA
Relative Roughness	481	471	401	353	427	61	30
Strickler Equation	382	380	349	297	352	40	20
Limerinos Equation	500	490	418	368	444	63	31
Jarret Equation	270	261	243	214	247	25	12

Low Flow Analysis

Low flow conditions present a hazard to aquatic species through increased water temperature, decreased dissolved oxygen, and can present a physical barrier for fish passage. To characterize the extent and frequency of low flow events on Flint Creek 7-day annual low flow statistics were calculated from the Drummond USGS Gage with 26 years of record. 7-day annual low flow statistics are based on an annual series of the smallest values of mean discharge computed over any 7 consecutive days during the annual period. A log Pearson type III probability distribution is fit to the annual series of 7 day minimums (Risley 2008). The results from this analysis are shown in Figure A-6 and Table A-5. Figure A-6 shows the probability of exceedance for the annual 7-day low flow event. Table A-5 shows the probability of non-exceedance which was then converted into recurrence interval in year. The 7-day low flow 10-year event calculated from the Drummond gage is 4.8 cfs. This is strikingly low compared to the regional curve estimation of the 7-day low flow 10-year event of 23.4 cfs (McCarthy 2016). This is likely caused by the extensive irrigation that occurs in the Flint Creek watershed.

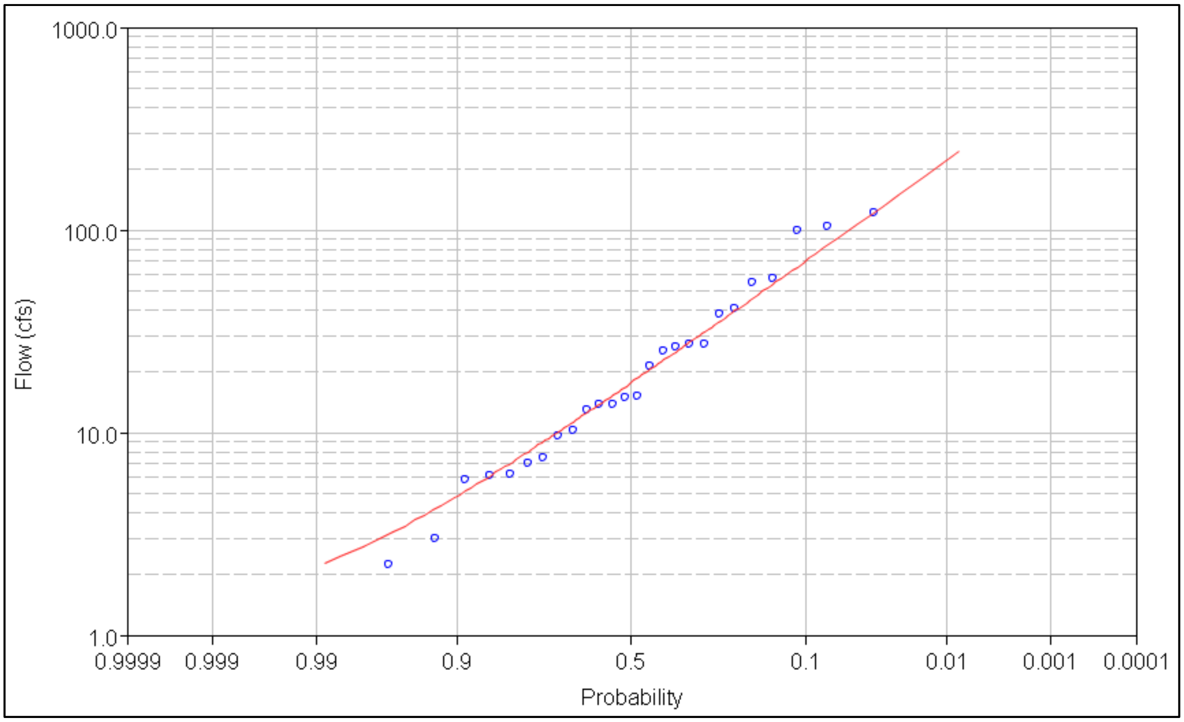

Figure A-7. 7-Day average low flow probability of exceedance analysis.

Table A-5. 7-Day average low flow analysis for USGS Drummond gage

Probability of Non-exceedance	Recurrence Interval (year)	Discharge (cfs)
0.992	1.01	245.3
0.985	1.02	182.4
0.975	1.03	151.5
0.97	1.03	131.9
0.96	1.04	117.9
0.95	1.05	107.2
0.945	1.06	98.7
0.9	1.11	68.7
0.85	1.18	53.5
0.8	1.25	42.4
0.75	1.33	35.8
0.7	1.43	30.7
0.6	1.67	22.8
0.500	2.00	17.7
0.4	2.50	13.5
0.3	3.33	10.3
0.25	4.00	8.7
0.2	5.00	7.4
0.15	6.67	6.2
0.1	10.00	4.8
0.05	20.00	3.5
0.025	40.00	2.7
0.02	50.00	2.4
0.01	100.00	2.3

Flow Duration Curve

A flow duration curve depicts statistically the percent of time in which the discharge of a river is above a given value. Figure A-8 and Table A-6 depict the results from the creation of a flow duration curve for the Drummond USGS gage, downstream of the Corbett property. This data will be used to help guide the design of the fish screen in the preliminary and final design stages of the project. This will ensure the diversion can be used during dry conditions which often fall during the irrigation season.

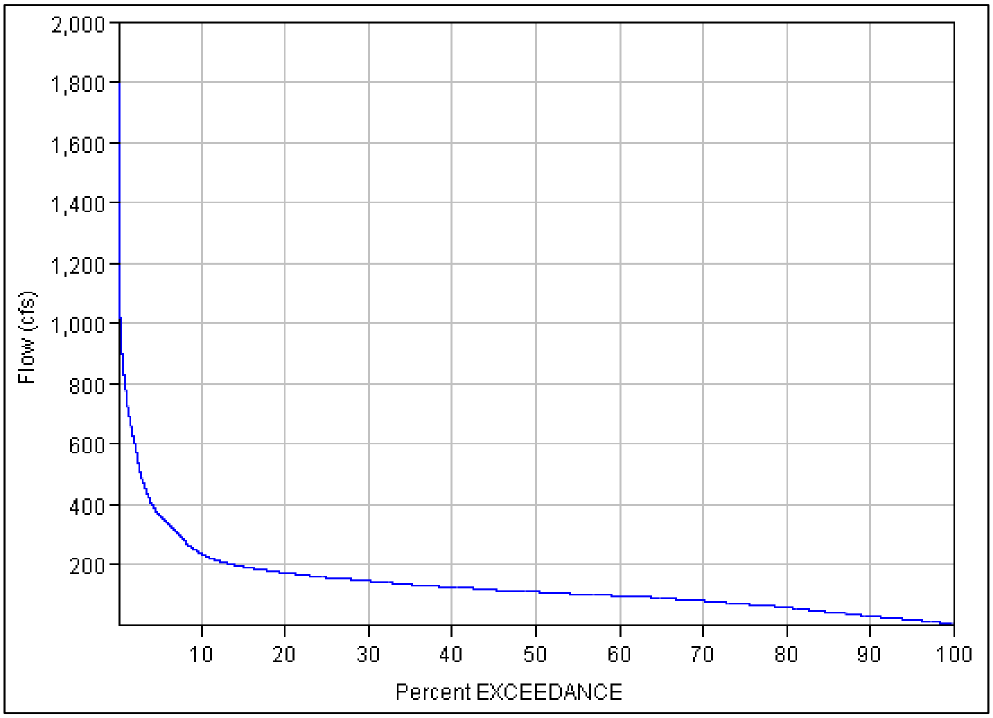

Figure A-8. Flow duration curve for the USGS Drummond gage downstream of the Corbett property.

Table A-6. Flow duration curve for USGS Drummond gage

Percent Exceedance	Discharge (cfs)
0.01	1800
0.05	1300
0.1	1130
0.5	856
1	734
2	588
5	361
10	232
15	191
20	171
25	155
30	144
40	122
50	108
60	94.8
70	78
75	67
80	55.2
85	40.5
90	27.1
95	15
98	7
99	4.4
99.5	3.7
99.75	2.7
99.9	2
99.99	0.6

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APPENDIX B
GEOMORPHIC DATA SUMMARY

Introduction

Flint Creek is a highly-impaired system from anthropogenic impacts including mining, grazing, channelization, and flow alteration from both dams and diversion structures. These impacts have led to a degradation of channel form and geometry in a number of ways including reducing bank stability and decreasing the peak and reoccurrence of channel forming flows. In order to identify the major limiting factors for the system, an inventory of existing impaired and reference conditions was conducted. Due to the extent of degradation in the study area reference conditions were not found at the project site, nor were conditions immediately upstream and downstream found to be suitable reference sites.

Survey efforts were conducted on October 25-26, 2016 by Ryan Richardson (Fluvial Geomorphologist RDG) and Josh Lenderman (Professional Land Surveyor RDG). Weather during the field work was largely overcast with scattered showers, temperature hovering around 40-50˚ F. Flow was moderately high for that time of year with a measured discharge of 121 cfs. Field work coincided with spawning of *Salmo trutta,* common name brown trout, within the reach. Redds were found concentrated from 29+00 to 32+00 and freshly constructed. Efforts were made to reduce disturbance to these sites by limiting wading through these areas and not establishing cross sections or pebble counts in the immediate area.

The purpose of the provided appendix is to present the analysis conducted from the geomorphic assessment phase of the design process that aims to characterize existing conditions. Existing conditions, from a geomorphic view, include an inventory of the longitudinal profile, channel dimensions, bank stability, particle size, aquatic habitat, and sediment supply for the reach. The methods used incorporate traditional field techniques in conjunction with emerging data collection methodology including the incorporation of UAS/LiDAR technology for imagery and topographic data. The following sections showcase the results from the geomorphic analysis.

Methods

Rosgen Level II surveys (geomorphic surveys) were conducted to characterize typical, impaired, and reference channel conditions. Real Time Kinematic Global Positioning System (RTK GPS) was used to complete each geomorphic survey (Figure B-2). Survey data collection followed USFS procedures (Harrelson et al. 1994) and included channel cross-sections and profiles. Data were collected to characterize terrace, floodplain, bankfull, water surface, and thalweg features. Additional features were also collected if deemed important for characterizing the reach. Channel thalweg measurements were generally collected at changes in the channel bed elevation or habitat features. Water surface measurements were collected at changes in the water surface slope and corresponding habitat features. Grain size was characterized using Wolman pebble counts, in both riffle and pool features (Wolman 1954).

The deployment of a small Unmanned Aerial System (sUAS) was conducted on the project site. A total of three flights took place on October 25th, 2016 ranging from 14-17 minute operating time. These flights collected video of the main study site for project overview and review during the conceptual design phase, video of the downstream reach for in efforts to find a reference reach, and repeat overlapping aerial images for the creation of a high-resolution mosaic of the project reach. All of these flights were conducted by Ryan Richardson, FAA Remote Pilot #3920066, in accordance with the FAA rules and regulations regarding commercial sUAS activity.

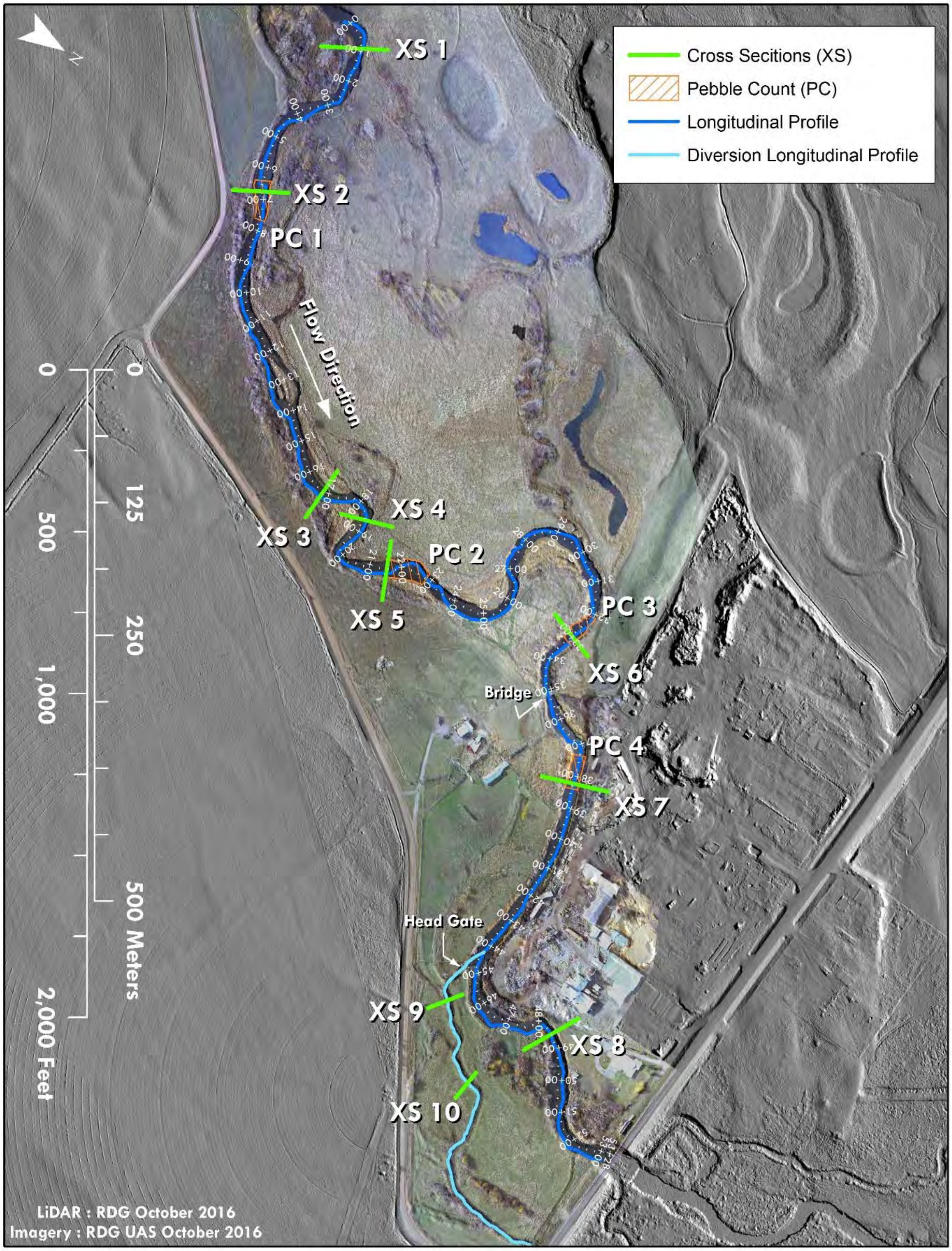

Figure B-1. Overview map of the Flint Creek Assessment project area and data collection locations.

PROJECT DATUM

PROJECT COORDINATES ARE BASED ON THE FOLLOWING:

HORIZONTAL PROJECTION:	MONTANA STATE PLANE
HORIZONTAL DATUM:	NAD 83 (CORS96 2002.00)
UNITS:	US SURVEY FEET
VERTICAL DATUM:	NAVD88 GEOID 09

POINT NUMBER	EASTING	NORTHING	ELEVATION	DESCRIPTION
001	873179.1'	1044013.4'	4168.4'	5/8" Rebar with a 2" aluminum cap marked "RDG"
002	873195.4'	1043994.3'	4169.1'	5/8" Rebar with a 2" aluminum cap marked "RDG"

Figure B-2. Survey control plan for the Flint Creek Assessment project area.

Longitudinal Profile

Flint Creek Assessment Reach

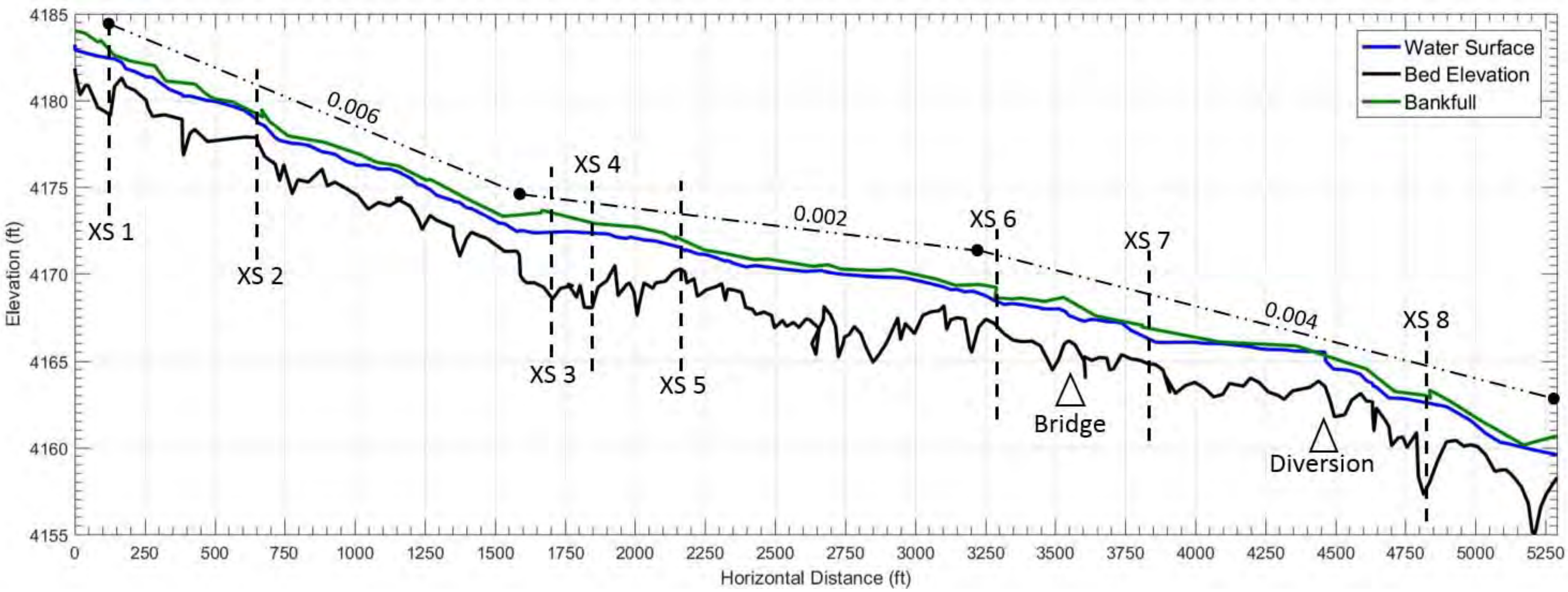

Figure B-3. Flint Creek Assessment project reach longitudinal profile. North American Datum 1983.

Table B-1. Longitudinal profile summary data for Flint Creek	
Metric	**Value**
Bed Slope (ft/ft)	0.004
Water Surface Slope (ft/ft)	0.004
Bankfull Slope (ft/ft)	0.004
Sinuosity	1.5

Longitudinal Profile

Flint Creek Diversion

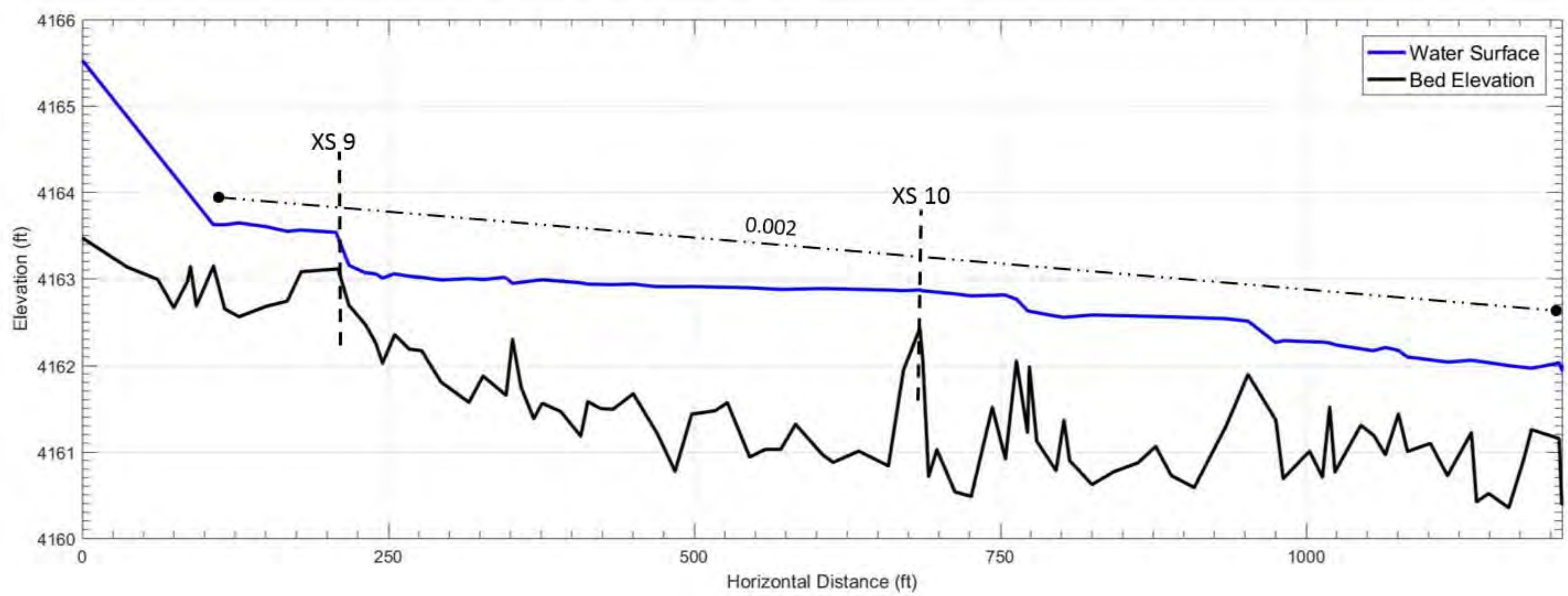

Figure B-4. Flint Creek Assessment diversion longitudinal profile. North American Datum 1983.

Table B-2. Longitudinal profile summary data for diversion	
Metric	**Value**
Bed Slope (ft/ft)	0.002
Water Surface Slope (ft/ft)	0.001
Sinuosity	1.3

Cross Sections

Table B-3. Summary of channel cross section metrics measured in Flint Creek.

Metric	XS 1 Pool	XS 2 Riffle	XS 3 Pool	XS 4 Pool	XS 5 Riffle	XS 6 Riffle	XS 7 Riffle	XS 8 Pool	Mean Riffle	Mean Pool
Bankfull Width (ft)	46.0	51.8	49.3	41.7	61.0	49.6	42.4	35.7	51.2	43.2
Mean Depth (ft)	2.3	1.8	2.3	3.0	1.6	1.7	1.7	3.6	1.7	2.8
Max Depth (ft)	3.7	2.4	4.3	4.6	2.2	2.2	2.5	5.4	2.3	4.5
Bankfull Area (ft^2)	99.1	90.6	113.7	123.4	95.2	83.7	72.6	127.5	85.6	115.9
Width/Depth Ratio	20.4	29.6	21.2	14.1	38.6	29.3	24.7	10.0	30.5	16.4
Hydraulic Radius	2.0	1.7	2.2	2.8	1.5	1.6	1.7	3.3	1.6	2.6
Bankfull Elevation	4183.5	4179.1	4173.7	4172.9	4172.2	4169.2	4167.0	4163.8	NA	NA
Station Location	01+00	06+75	16+75	18+50	21+50	33+00	38+25	48+50	NA	NA

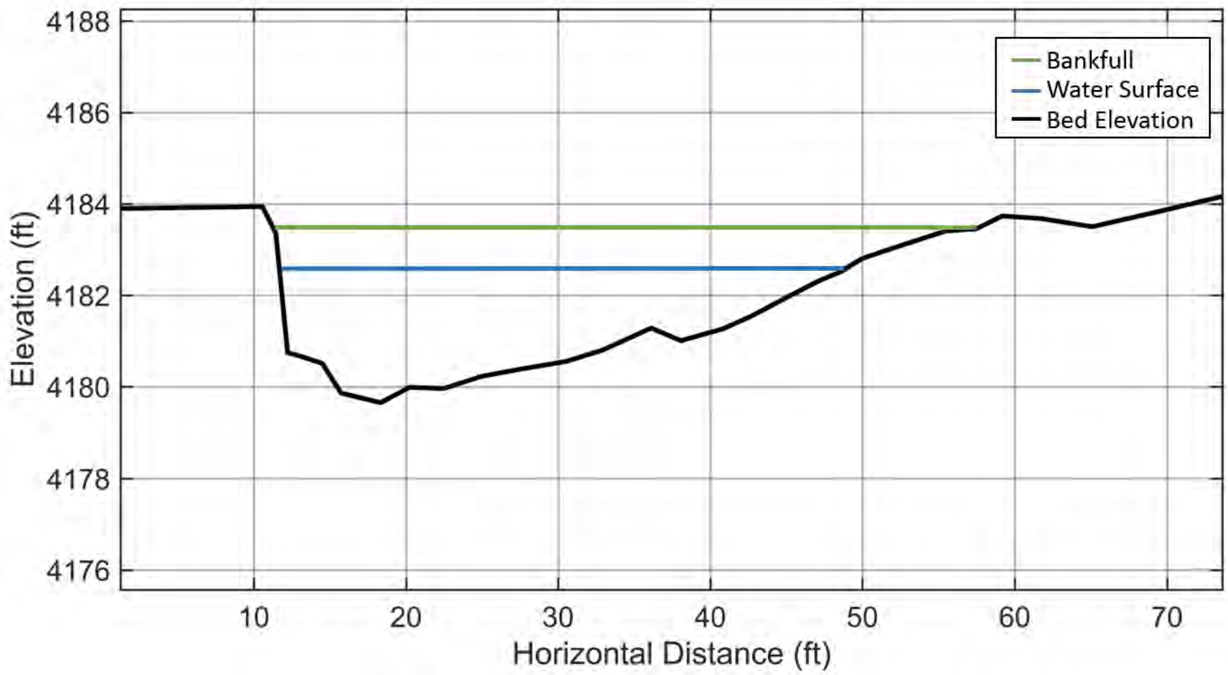

Figure B-5. Cross section 1 in the Flint Creek project reach (Longitudinal Profile Station 01+00).

Figure B-6. Looking upstream at cross section 1 in the Flint Creek Assessment reach (left). Looking downstream at cross section 1 in the Flint Creek Assessment reach (right).

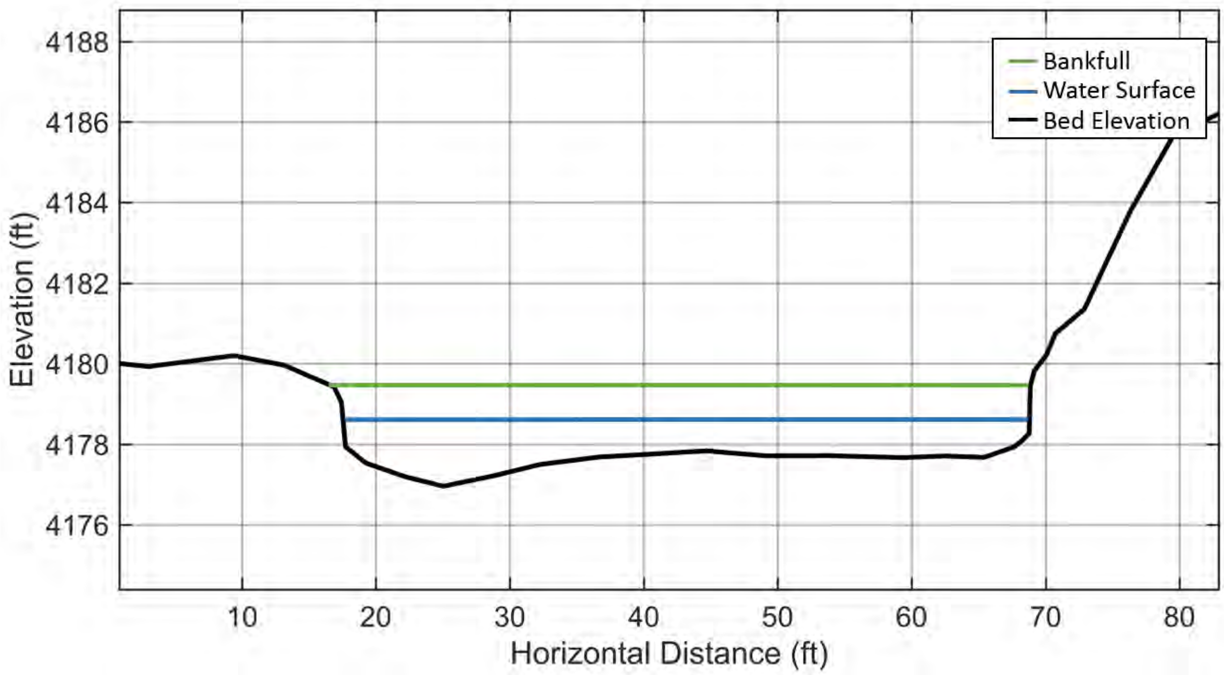

Figure B-7. Cross section 2 in the Flint Creek project reach (Longitudinal Profile Station 06+75).

Figure B-8. Looking downstream at cross section 2 in the Flint Creek Assessment reach (left). Looking upstream at cross section 1 in the Flint Creek Assessment reach (right).

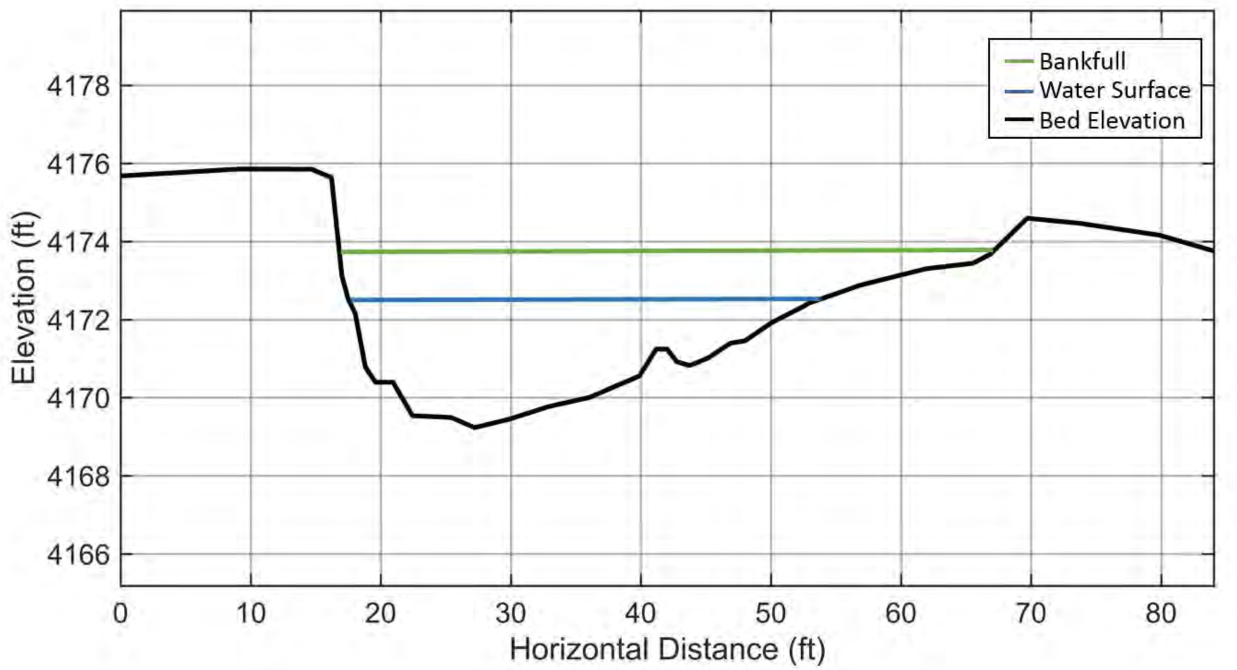

Figure B-9. Cross section 3 in the Flint Creek project reach (Longitudinal Profile Station 16+75).

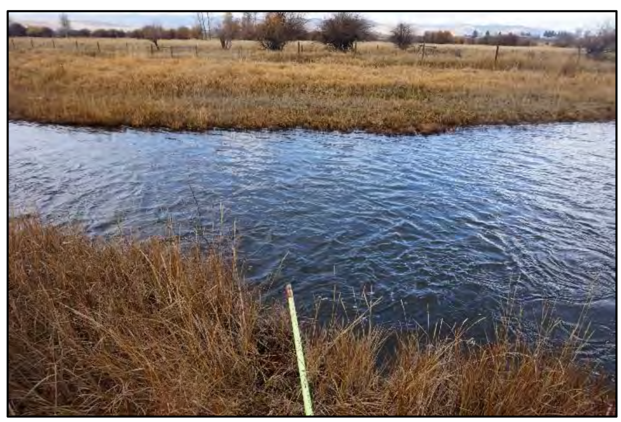

Figure B-10. Looking downstream at cross section 3 in the Flint Creek Assessment reach (left). Looking at cross section 3 from the right bank in the Flint Creek Assessment reach (right).

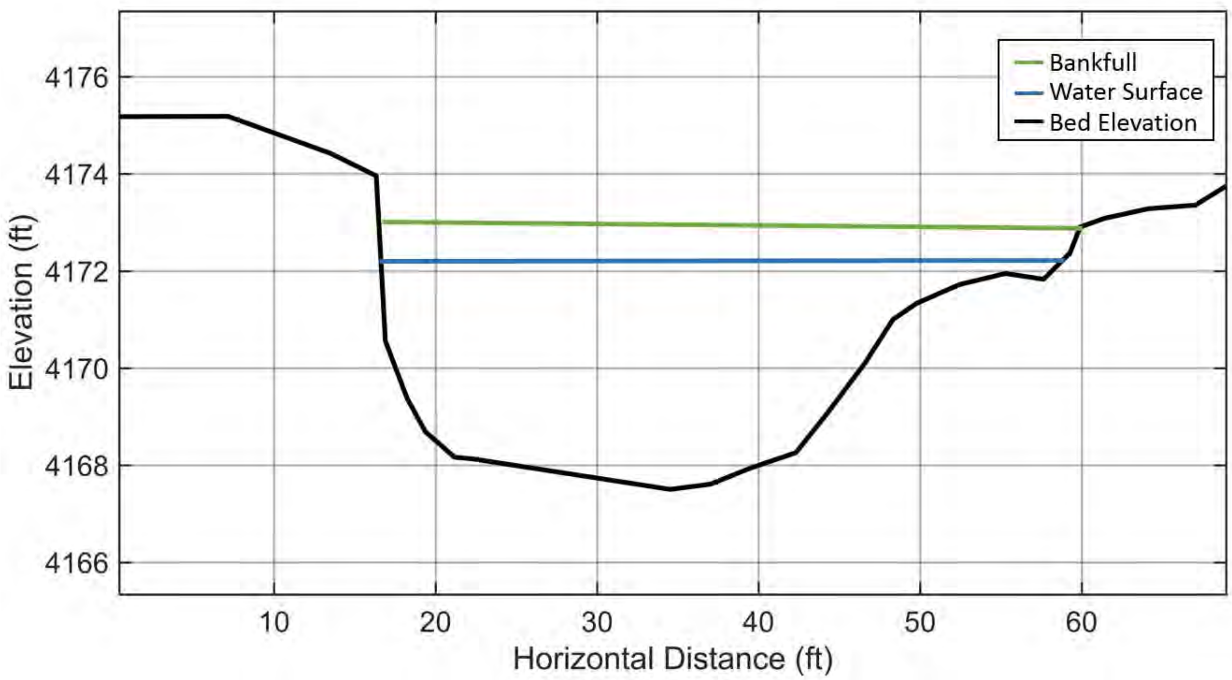

Figure B-11. Cross section 4 in the Flint Creek project reach (Longitudinal Profile Station 18+50).

Figure B-12. Looking upstream at cross section 4 in the Flint Creek Assessment reach.

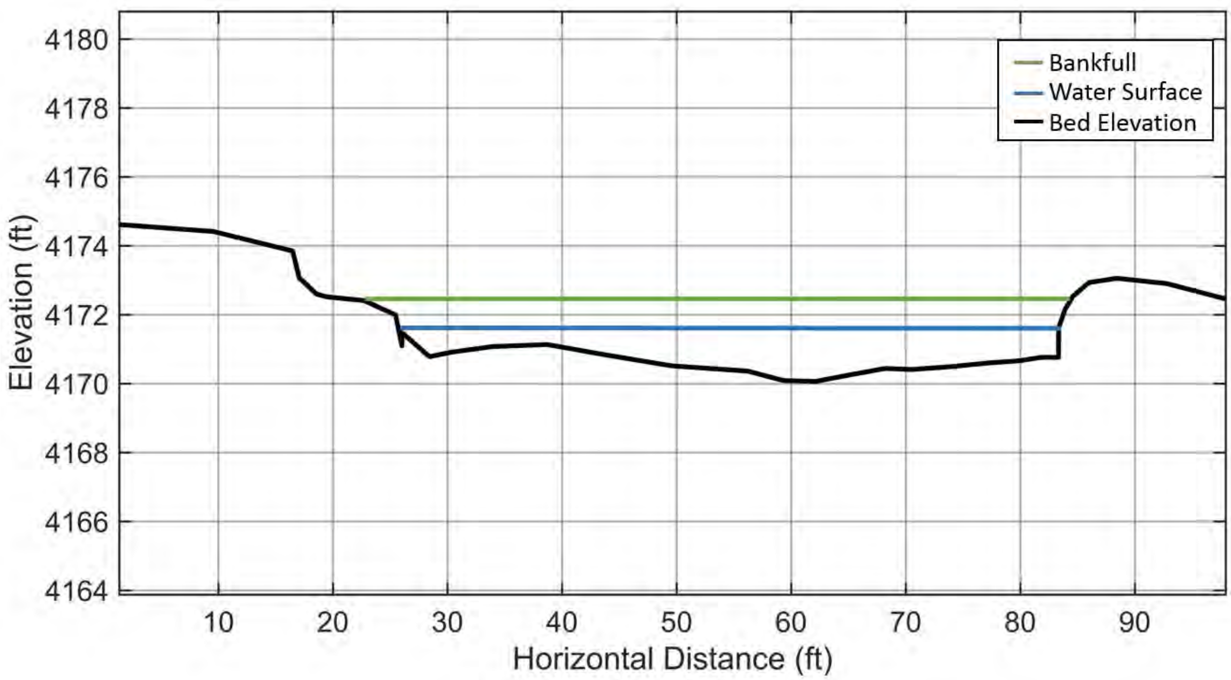

Figure B-13. Cross section 5 in the Flint Creek project reach (Longitudinal Profile Station 21+50).

Figure B-14. Looking downstream at cross section 5 in the Flint Creek Assessment reach (left). Looking upstream at cross section 5 in the Flint Creek Assessment reach (right).

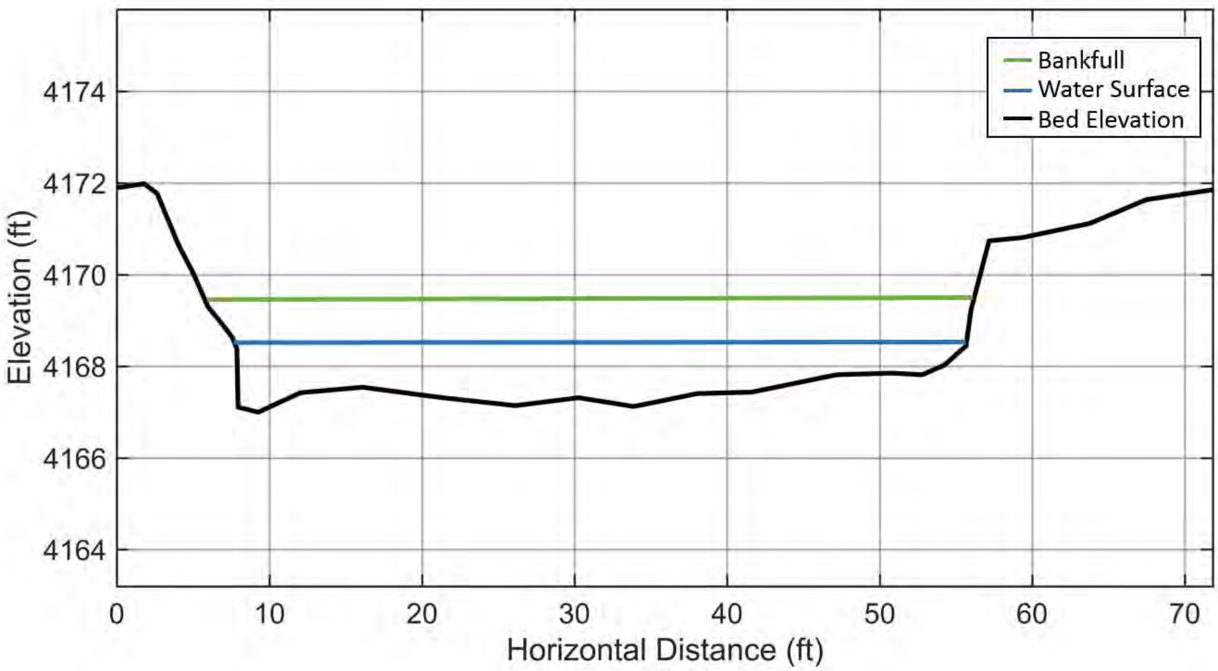

Figure B-15. Cross section 6 in the Flint Creek project reach (Longitudinal Profile Station 33+00).

Figure B-16. Looking at cross section 6 from the left bank in the Flint Creek Assessment reach (left). Looking downstream at cross section 6 in the Flint Creek Assessment reach (right).

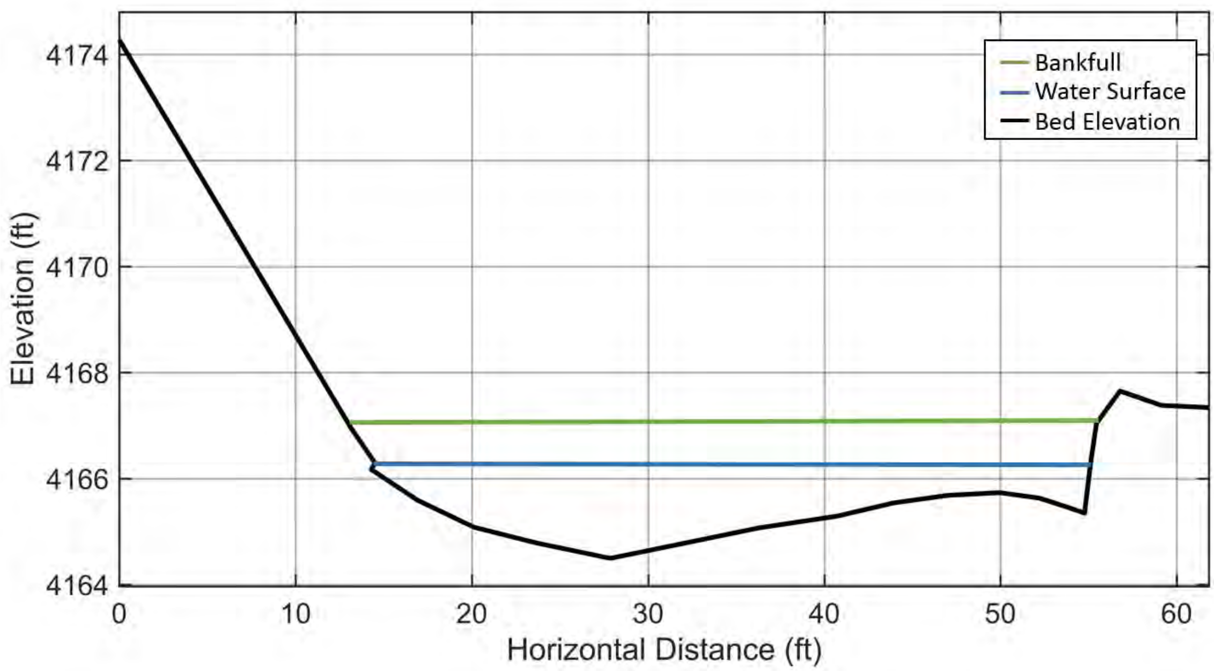

Figure B-17. Cross section 7 in the Flint Creek project reach (Longitudinal Profile Station 38+25).

Figure B-18. Looking downstream at cross section 7 in the Flint Creek Assessment reach (left). Looking upstream at cross section 7 in the Flint Creek Assessment reach (right).

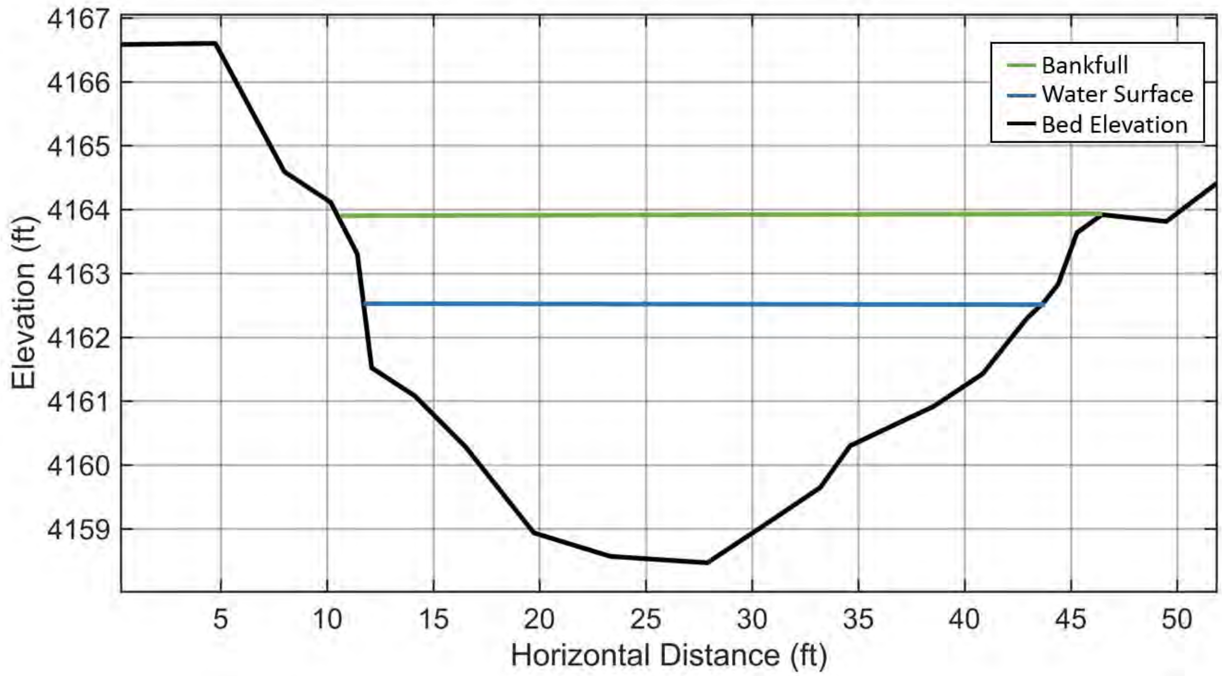

Figure B-19. Cross section 8 in the Flint Creek project reach (Longitudinal Profile Station 48+50).

Figure B-20. Looking downstream from cross section 8 in the Flint Creek Assessment reach (left). Looking at cross section 8 from the right bank in the Flint Creek Assessment reach (right).

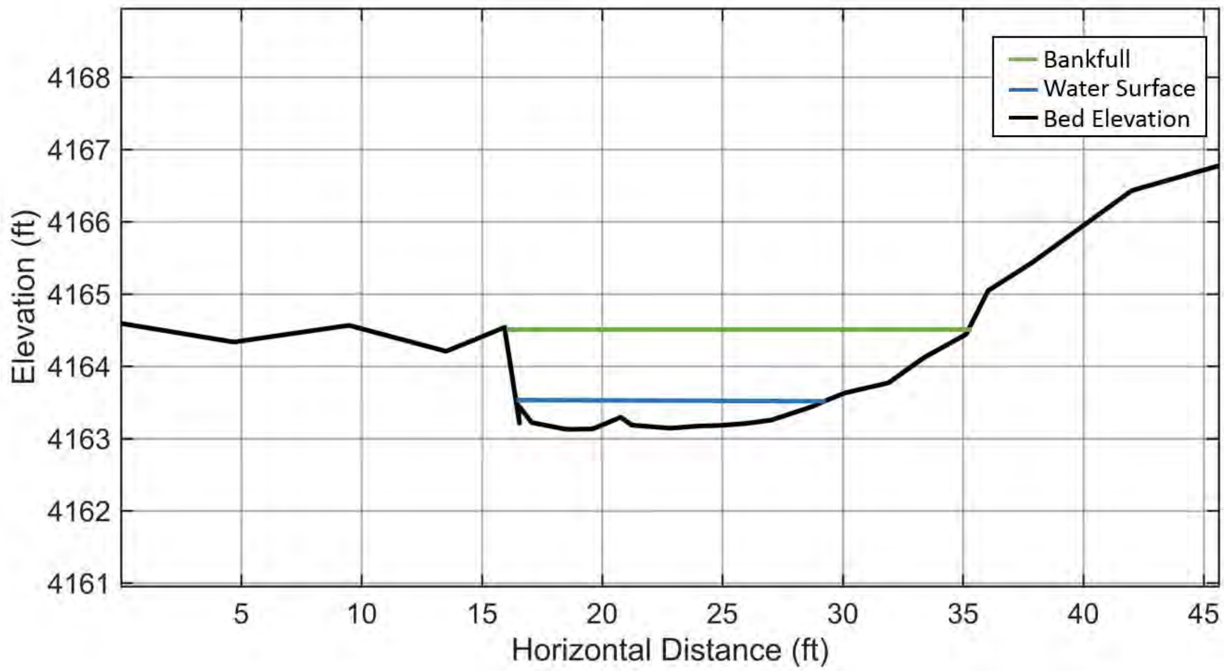

Figure B-21. Cross section 9 in the Flint Creek diversion.

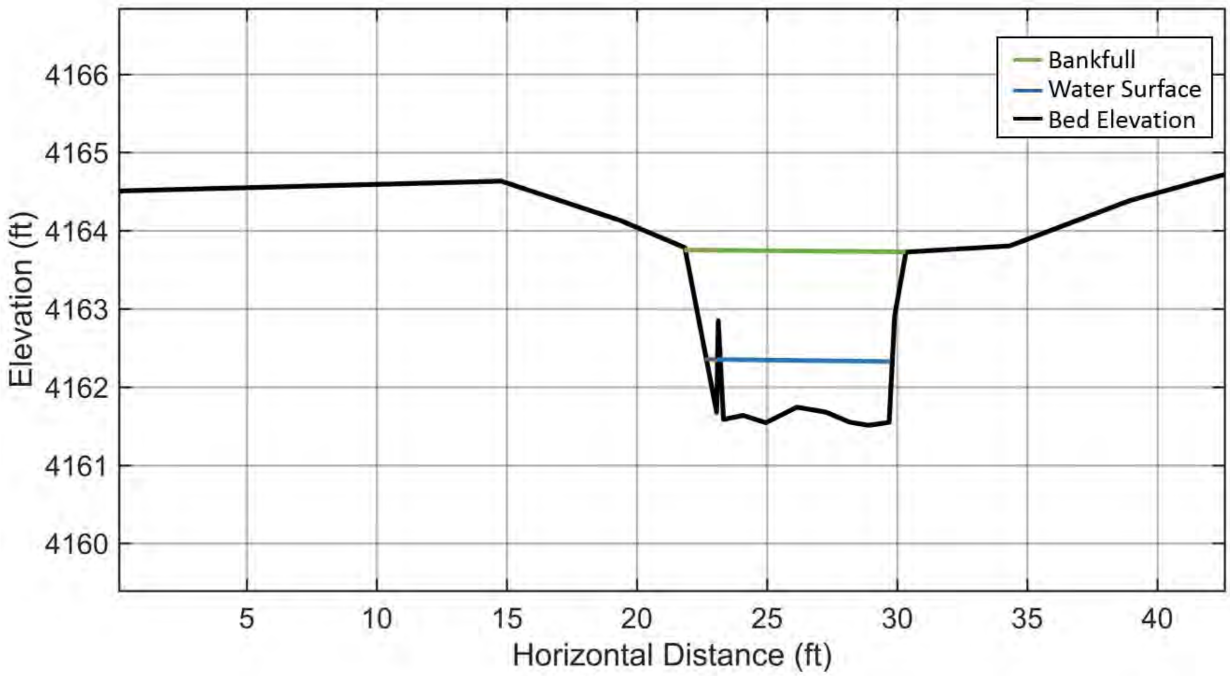

Figure B-22. Cross section 10 in the Flint Creek diversion.

Wolman Pebble Count

Table B-4. Pebble count results

Size Class	XS 2 (mm)	XS 5 (mm)	XS 6 (mm)	XS 7 (mm)	Mean (mm)
D_{16}	18	16	24	14	18
D_{35}	42	39	40	46	42
D_{50}	59	55	55	67	59
D_{65}	75	71	71	86	76
D_{84}	100	94	115	116	106
D_{95}	122	128	168	155	143

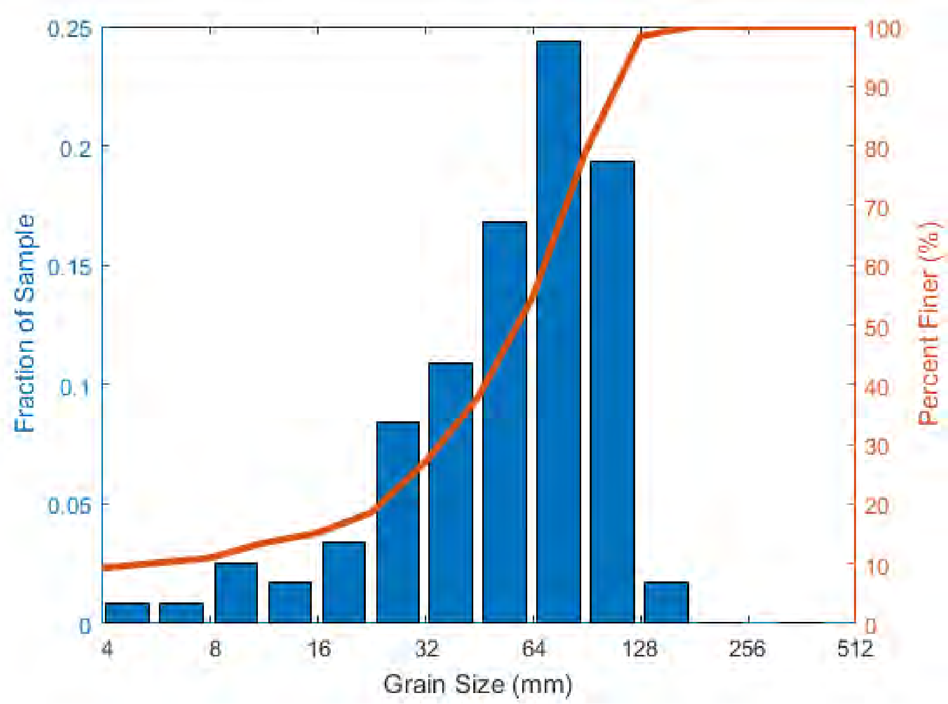

Figure B-23. Pebble count results from cross section 2 (XS 2). Histogram shows the fraction of sample for grain size classes, while the line indicates the cumulative grain size distribution.

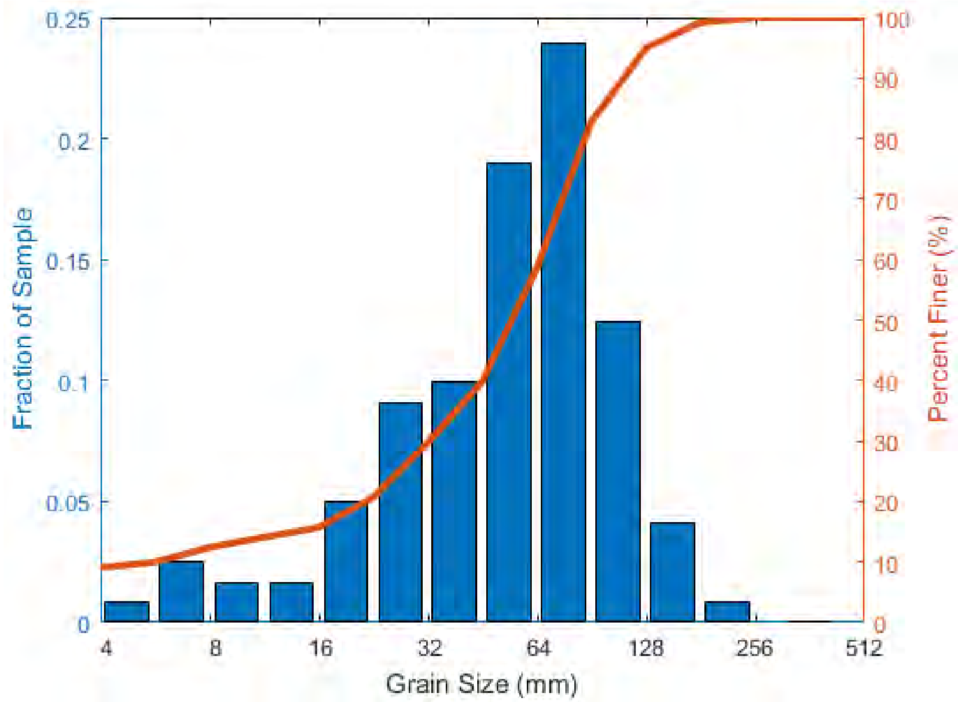

Figure B-24. Pebble count results from cross section 5 (XS 5). Histogram shows the fraction of sample for grain size classes, while the line indicates the cumulative grain size distribution.

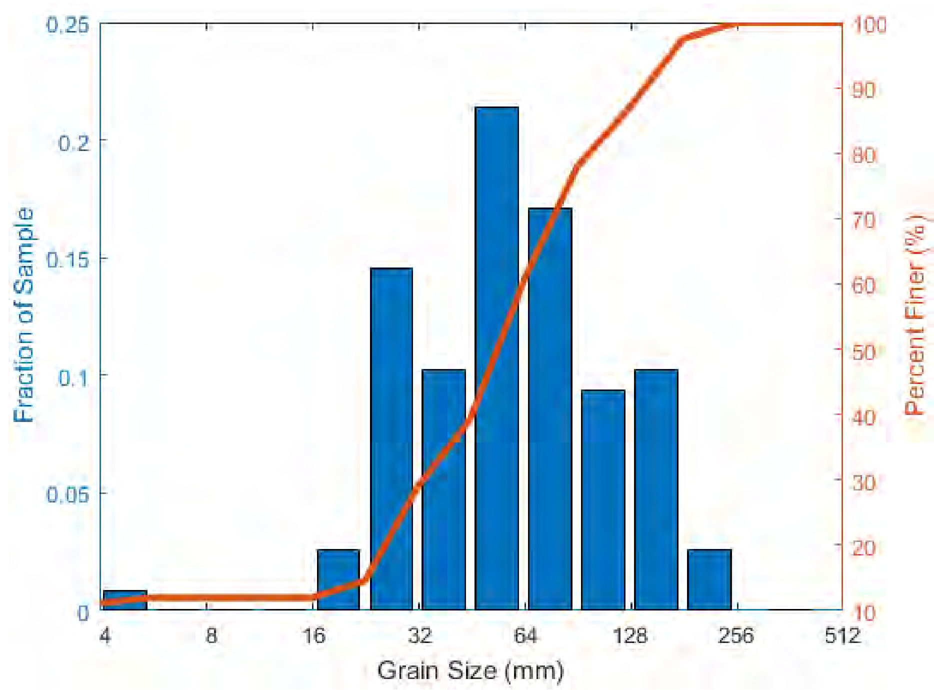

Figure B-25. Pebble count results from cross section 6 (XS 6). Histogram shows the fraction of sample for grain size classes, while the line indicates the cumulative grain size distribution.

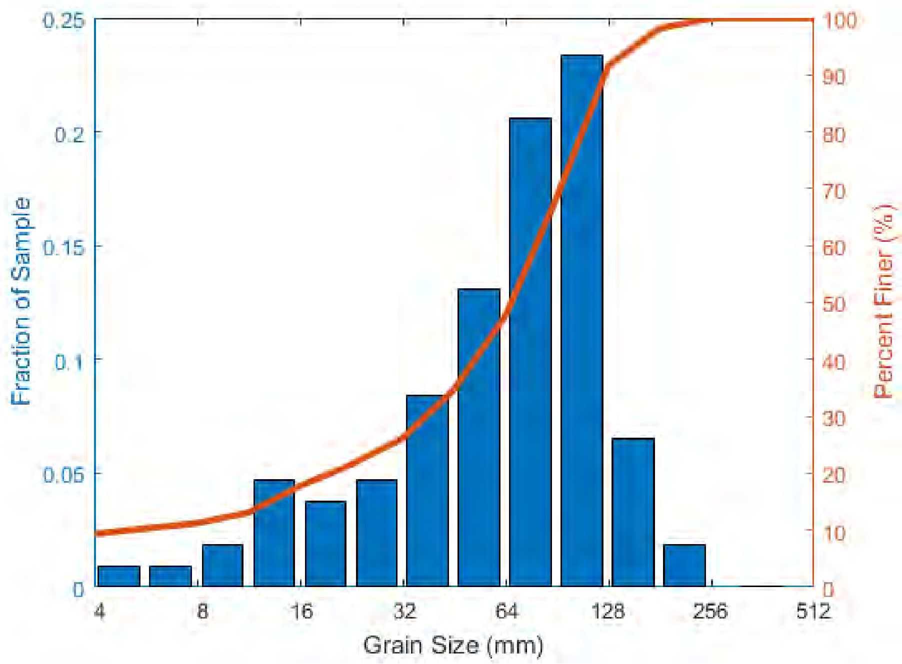

Figure B-26. Pebble count results from cross section 7 (XS 7). Histogram shows the fraction of sample for grain size classes, while the line indicates the cumulative grain size distribution.

Bank Erosion Sediment Yield

A comprehensive inventory of instream sediment sources was completed for assessment reach in Flint Creek. The survey focused on identifying, mapping, and characterizing reach-averaged sediment loading, and mapping discrete major sources of sediment contributions to the primary channel. A modified Bank Erosion Hazard Index (BEHI) (Rogen 2001) was used to evaluate streambank erosion related sources of sediment. The BEHI procedure integrates multiple factors which have a direct impact on streambank stability, including:

- Ratio of streambank height to bankfull stage (i.e. bank height ratio);
- Ratio of riparian vegetation rooting depth to streambank height;
- Degree of rooting density;
- Composition of streambank soils;
- Streambank angle;
- Bank material stratigraphy; and
- Bank surface protection afforded by coarse wood and vegetation.

A BEHI score was then assigned to the major bank types in the reach. These scores were used to estimate bank migration rates from empirically derived curves from the Blackfoot River in Montana, which has similar geophysiographic characteristics to the Flint Creek watershed. Bank heights and lengths coupled with migration rates and average estimate of density allowed for sediment yield to be calculated in tons/year.

Table B-5. BEHI Results Summary

BEHI Score	Bank Length (ft)	Bank Height (ft)	Erosion Rate (ft/yr)	Sediment Volume (ft^3)	Sediment Yield (tons/yr)
Very Low	1205	0.6	0.17	123	62
Low	2966	1.4	0.17	706	353
Medium	3394	3.25	0.23	2537	1269
High	2282	4	0.31	2830	1415
Very High	614	5.5	0.39	1317	659
Extreme	286	9	0.47	1211	606
Rip-Rap	635	NA	NA	NA	NA
Total	**11382**			**8724**	**4363**

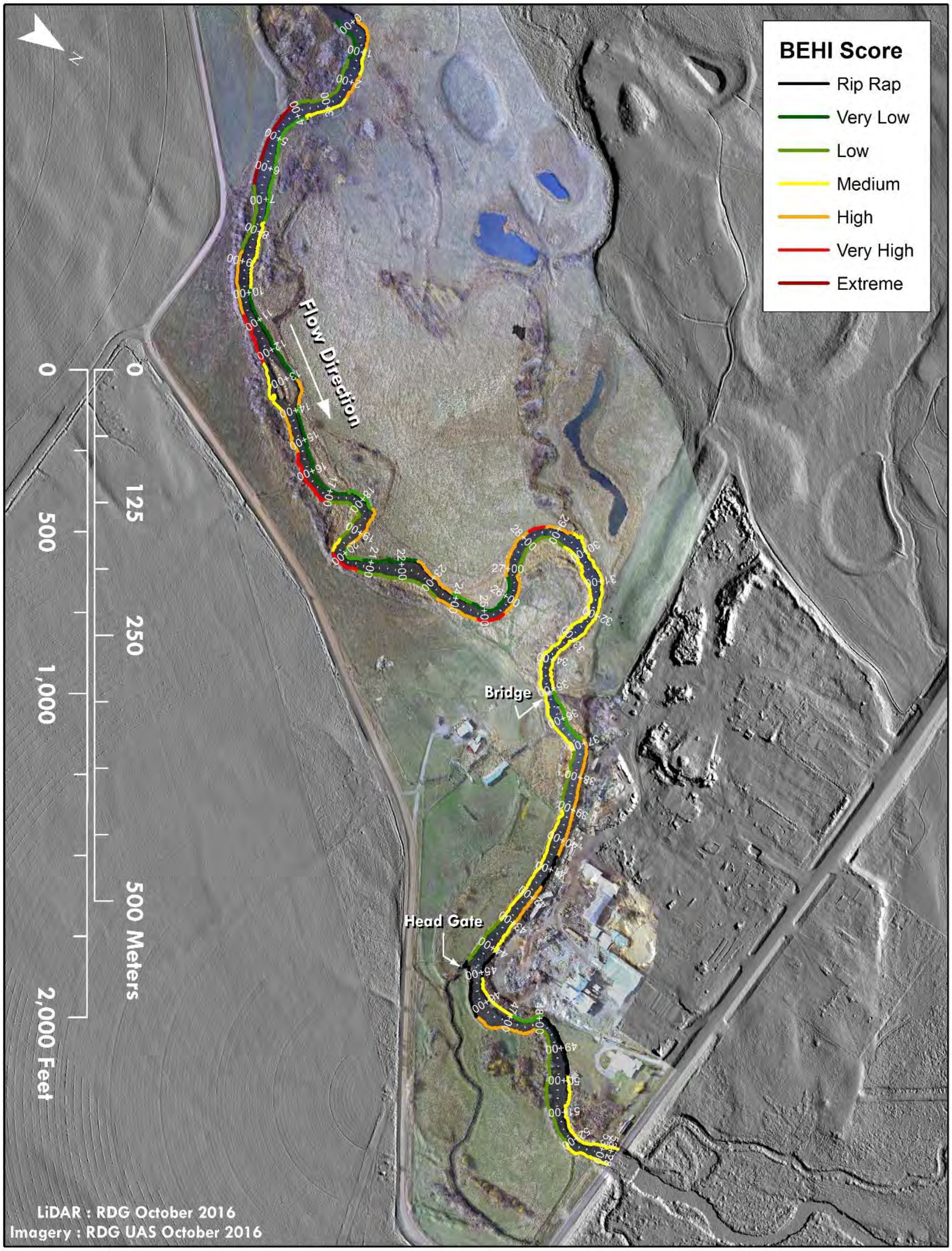

Figure B-27. Map of the results from the BEHI field analysis of the Flint Creek Assessment reach.

Floodplain Connectivity

Floodplain and stream connectivity is vital to the maintenance of stable channels and productive riparian ecosystems. River channels convey one- to two-year flow events (i.e. bankfull), and larger over-bank flows are often dissipated over floodplain surfaces adjacent to channels. When forced to convey large flows within the bankfull channel margin, channels can exhibit incision, bank erosion, and eventually widening. Floodplains disperse stream energy over a much larger area than what is available within the bankfull channel margin. Benefits of connected floodplains include flood water storage and attenuation, slowing of stream velocities, and reduction of bank erosion. In addition, over-bank flows deliver nutrients and fine sediment to floodplain areas, which helps sustain riparian vegetation communities and provide natural seed recruitment opportunities.

Floodplain connection in the Flint Creek Assessment reach was analyzed using available Light Detection and Ranging (LiDAR) data in a Geographic Information System (GIS). The LiDAR data was flown in October of 2016, just prior to field work campaign. First, stream centerlines were digitized using a combination of LiDAR data and high resolution aerial imagery. LiDAR elevations were then sampled to the stream centerlines, with the value representing water surface elevations. A mean bankfull height above water surface of 1.2 ft was added to the water surface, and the elevations were written to cross-sections across the floodplain areas, drawn perpendicular to stream flow. A bankfull surface across the floodplain was then created from the cross-sections by interpolation using Delaunay triangulation. Finally, the bankfull surface was compared with the bare earth LiDAR data model, resulting in a continuous surface across floodplain areas which display elevations relative to bankfull. The results from this analysis should not be used in place of, or compared to, Federal Emergency Management Agency flood study results.

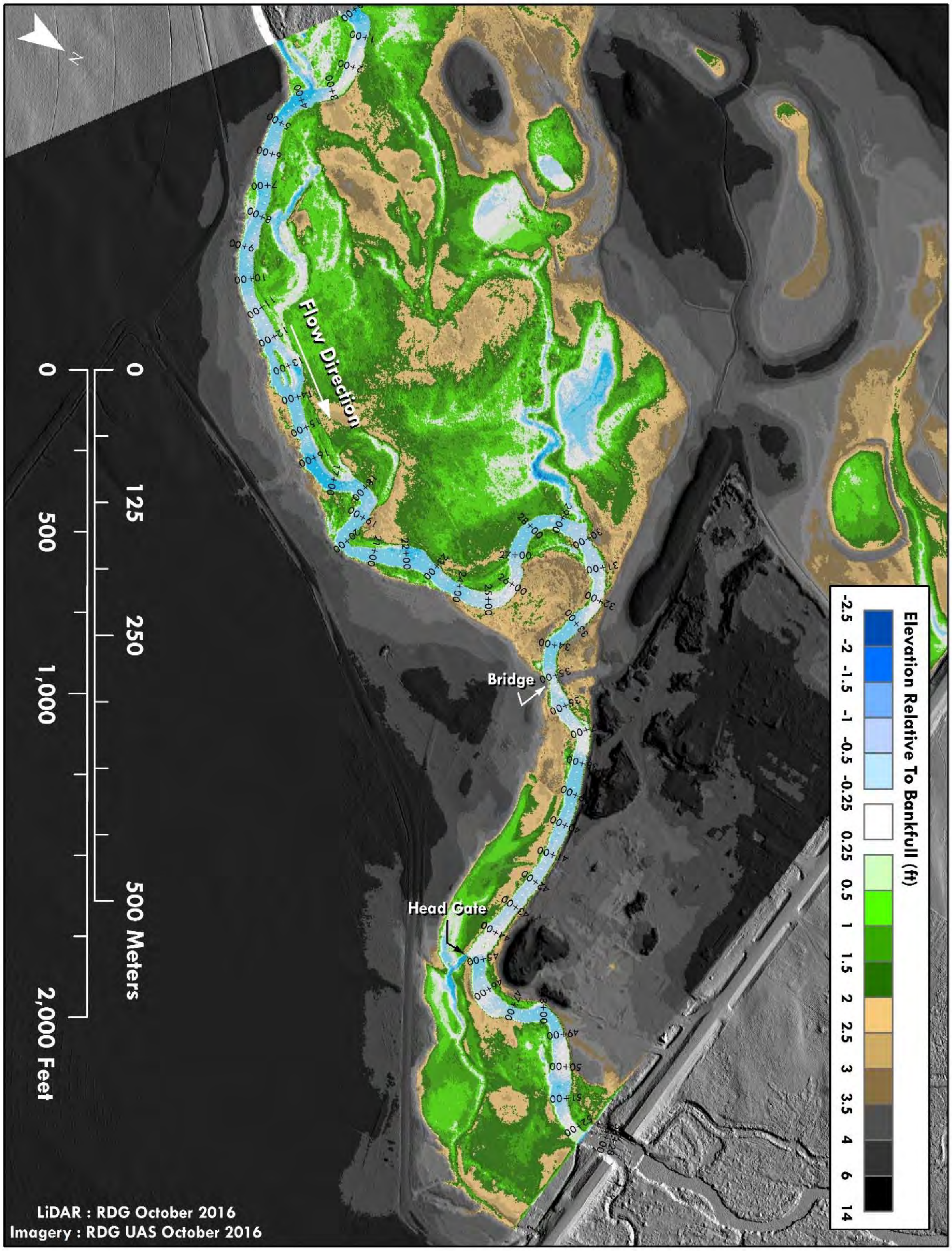

Figure B-28. Map of floodplain connectivity of the Flint Creek Assessment reach derived from the LiDAR collected in October, 2016.

Channel Migration Analysis

An initial remote sensing effort to analyze the historical channel migration identified key problem areas (excessive bank erosion) and stable portions of the channel. This analysis utilized NAIP imagery from 2004 and 2015 both with one meter pixel resolution. The workflow was based on the National Center for Earth-Surface Dynamics channel planform statistics toolbox v 2.0. The tools perform three primary functions: 1) Interpolation of the centerline of two bank lines that have been digitized from an aerial photograph, with width and local radius of curvature saved in a text file; 2) Estimation of the mean lateral normal distances at even increments between river channel centerlines at two points in time; and 3) Generation of a polygon adjacent to the channel banks that corresponds with a particular centerline point (NCED 2012). The results from this analysis are used to estimate meander migration rates and identify reach bank stability. Maps produced show the rate of migration with a color ramp where red indicates rapid migration and green indicates slow to no migration (Figure B-29).

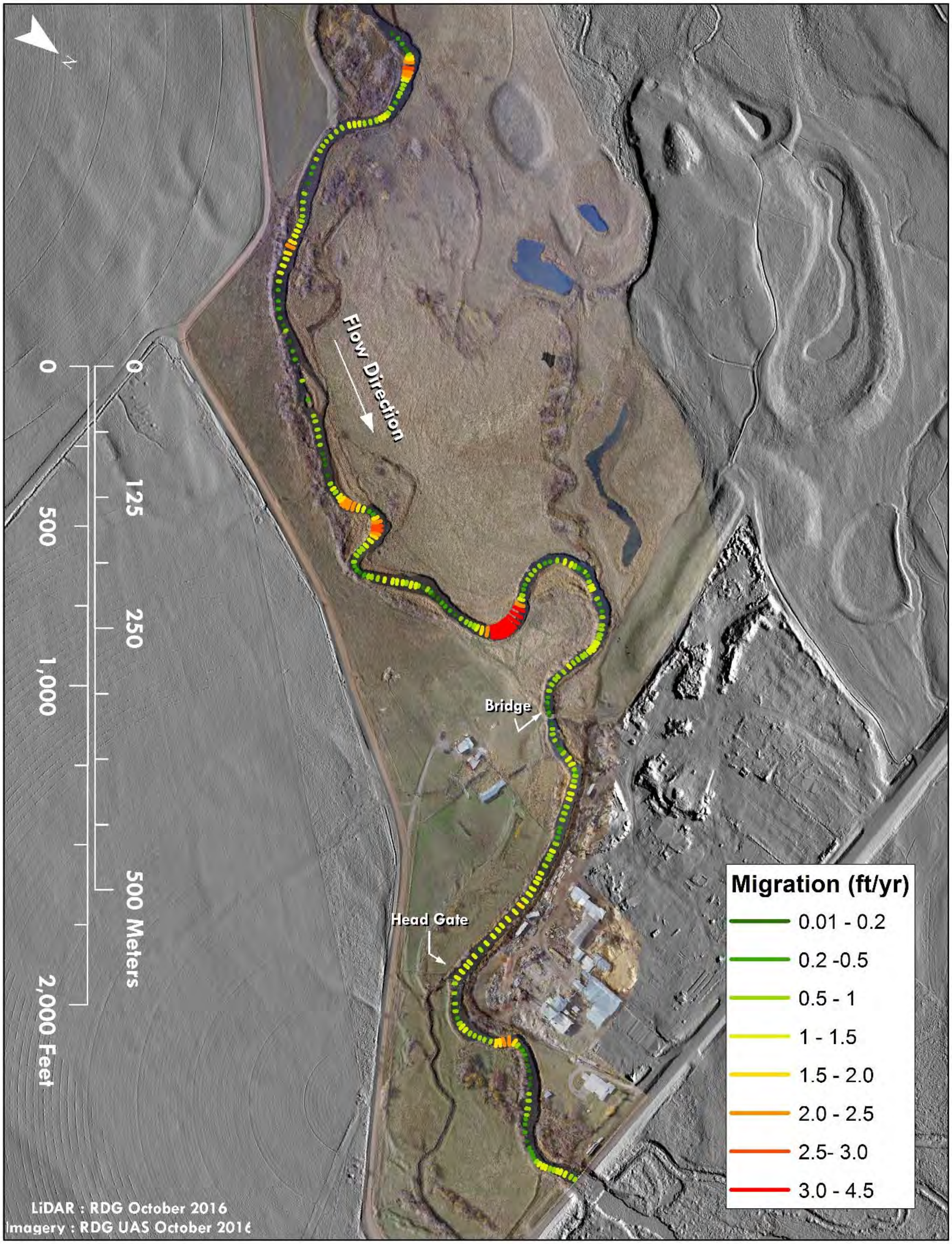

Figure B-299. Map of channel migration rates calculated from aerial photos over a 10-year span.

APPENDIX C

CONCEPT-LEVEL COST ESTIMATE

Cost Narrative

This appendix summarizes concept-level project implementation costs for the conceptual designs presented in the document. Cost estimates are provided for each restoration plan including the Diversion-Fish Screen Plan, Streambank Restoration Plan, Revegetation Plan and Channel Reconstruction Plan. Cost estimates include a summary of quantities and unit costs for construction items as well as lump sum estimates for design, construction oversight, monitoring, maintenance and contingencies as a percentage of the construction cost. Additional information related to general assumptions and the basis for unit pricing are described in the following sections.

General Assumptions

The following general assumptions apply to the concept-level cost estimates:

- Project conceptual designs represent a combination of restoration strategies applied to a site with limited availability of site-specific data. Although conceptual designs were reviewed and refined collaboratively by the project stakeholders, supplemental data collection and engineering may result in subsequent modifications of the quantities used in the concept-level cost estimates.
- Cost estimates were prepared using local cost data from completed restoration projects as well as industry standards for heavy civil construction.
- Costs are presented in 2017 dollars. Depending on the timing of implementation, inflation/escalation may need to be applied to the cost estimates. Typical rates for inflation/escalation are 3 to 4 percent per year.
- Design, construction oversight, monitoring and maintenance costs were estimated as a percentage of the construction cost.
- Design costs include planning, data collection, analysis, engineering design, environmental compliance and bid document support.
- Construction oversight includes survey control, construction staking, oversight and as-built documentation.
- Monitoring costs include 3 surveys over a 6-year span for evaluating project effectiveness and maintenance needs.
- Maintenance costs include irrigation, fence repairs, browse protector maintenance, and minor repairs to project elements from erosion or scour. Maintenance costs assume that maintenance will be considered for up to five years.
- Contingencies ranging from 15 to 25 percent were applied to construction costs to address uncertainty. Contingencies vary by project based on risk, complexity, land ownership and data gaps.

Basis for Unit Pricing

The basis for unit pricing for each construction item is based on the following:

- Mobilization and demobilization were assumed to be $5 per mile per piece of equipment delivered to the site. This item does not include markups, insurance, bonding, site preparation, development of site access and staging areas, site facilities, site reclamation, and other miscellaneous construction administration costs.
- River access, work area isolation and turbidity BMPs are presented as a lump sum item. This item includes construction of in-river access, activation/deactivation of temporary bypass channels, construction of berms/cofferdams, pumping, dewatering, turbidity management, and fish salvage operations.
- Equipment rates include fuel and operator. The following equipment rates were used:
    - Excavator - $175 per hour
    - Bulldozer - $150 per hour
    - Loader - $150 per hour
    - Dump Truck - $80 per hour
    - Skid Steer - $75 per hour
    - Labor - $65 per hour
- The unit cost for acquiring trees is based on cost data from local restoration projects. Tree costs can vary significantly based on the tree source, haul distance and size of trees specified. For these projects, it was assumed that restoration treatments will use a range of tree sizes comprised mostly of brush and small to medium sized logs.
- Tree quantities assume 7 trees per large wood structure and two trees per 10 linear feet of vegetated brush bank structure.
- The unit cost for acquiring rock is based on cost data from local restoration projects. Rock costs can vary significantly based on the rock source, haul distance and rock gradation specified. For these projects, it was assumed that restoration treatments will use large gravel and cobble structure foundations and boulders for diversion structures. Haul distances are assumed to be reasonable.
- Rock quantities assume 0.3 cubic yard per linear foot of vegetated brush bank structure foundations and 30 cubic yards of rock for large wood structure backfill/ballast.
- The unit cost for earthwork encompasses a combination of activities including excavation, backfill, hauling and grading. Earthwork costs are based on earthwork cost data from the local restoration projects.
- The unit cost for streambank structures is based on cost data from local restoration projects. Unit costs include costs for vegetative cutting acquisition, fascine assembly, equipment, labor and installation. Unit costs do not include costs for purchasing/delivery of wood and rock.

- The unit cost for large wood structures is based on cost data from local restoration projects. Unit costs include costs for equipment, labor and installation. Unit costs do not include costs for purchasing/delivery of wood and rock.
- The unit cost for planting is based on cost data from local restoration projects. Planting costs include all materials, equipment and labor for installation of plants, and weed mats. Plant sizes were assumed to be one gallon containerized stock. Weed mats were assumed to be 3-feet by 3-feet polyethylene mats.
- The unit cost for fencing and gates is based on cost data from local restoration projects. Fencing costs include all materials, equipment and labor for installation of wildlife fencing and gates. Fence material was assumed to be 8-foot high graduated welded wire fence. Fence posts were assumed to be 12-feet high by 4-inch diameter treated timber. Gates were assumed to be 10-foot vehicle access gates.
- The unit cost for broadcast seeding is based on cost data from local restoration projects. Seed mixes are assumed to be riparian, wetland and upland seed mixes.

Concept Level Project Cost Estimate					
Flint Creek - Corbett-Downs Property near Hall, MT					
Plan: Irrigation Diversion and Fish Screen					
	Construction Cost Items	**Quantity**	**Units**	**Unit Cost**	**Cost**
1	Mobilization and Demobilization	1	Lump Sum	$ 3,000	$ 3,000
2	Site Prep, River Access, Work Area Isolation, BMPs, Reclamation	8	Hours	$ 240	$ 1,920
3	Remove Existing Diversion Structure and Salvage Boulders	2	Hours	$ 240	$ 480
4	Furnish Boulders for Diversion Structure	115	Boulders	$ 25	$ 2,875
5	Furnish Non-woven Geotextile Filter Fabric for Diversion Structure	1	Roll	$ 425	$ 425
6	Furnish New Headgate, Sluice Gate and Piping	1	Lump Sum	$ 9,500	$ 9,500
7	Furnish Fish Screen	1	Lump Sum	$ 40,000	$ 40,000
8	Furnish Pit Run for Screen and Pipe Bedding	20	Cubic Yards	$ 15	$ 300
9	Install Diversion Structure	24	Hours	$ 240	$ 5,760
10	Install Headgate, Sluice Gate and Piping	16	Hours	$ 240	$ 3,840
11	Install Fish Screen	8	Hours	$ 240	$ 1,920
			CONSTRUCTION SUBTOTAL		**$ 70,020**
	Other Costs				
1	Design				**$ 20,000**
2	Construction Oversight				**$ 10,000**
3	Monitoring				**$ 5,000**
4	Contingency		**15% of Construction Subtotal**		**$ 10,503**
			GRAND TOTAL		**$ 115,523**

Concept Level Project Cost Estimate					
Flint Creek - Corbett-Downs Property near Hall, MT					
Plan: Streambank Restoration					
	Construction Cost Items	**Quantity**	**Units**	**Unit Cost**	**Cost**
1	Mobilization and Demobilization	1	Lump Sum	$ 6,000	$ 6,000
2	Site Prep, River Access, BMPs, Reclamation	24	Hours	$ 240	$ 5,760
3	Furnish Logs and Brush for Streambank Structures	564	Trees	$ 500	$ 282,000
4	Furnish Willow Cuttings for Streambank Structures	23,300	Cuttings	$ 1.00	$ 23,300
5	Furnish Pit Run for Streambank Fill	972	Cubic Yards	$ 15	$ 14,580
6	Sod Salvage and Placement	4,400	Square Feet	$ 1.50	$ 6,600
7	Install Large Wood Structures	14	Structures	$ 2,000	$ 28,000
8	Install Vegetated Brush Bank Structures	2,330	Linear Feet	$ 30	$ 69,900
			CONSTRUCTION SUBTOTAL		**$ 436,140**
	Other Costs				
1	Design				**$ 15,000**
2	Construction Oversight				**$ 25,000**
3	Monitoring				**$ 15,000**
4	Contingency		**15% of Construction Subtotal**		**$ 65,421**
			GRAND TOTAL		**$ 556,561**

Concept Level Project Cost Estimate					
Flint Creek - Corbett-Downs Property near Hall, MT					
Plan: Streambank Restoration					
	Construction Cost Items	**Quantity**	**Units**	**Unit Cost**	**Cost**
1	Mobilization and Demobilization	1	Lump Sum	$ 3,000	$ 3,000
2	Site Prep, Access, Reclamation	8	Hours	$ 195	$ 1,560
3	Furnish and Install Containerized Plants and Weed Mats	6,050	Plants	$ 20	$ 121,000
4	Furnish and Install Wildlife Exclosure Fencing	14,000	Linear Feet	$ 8	$ 112,000
5	Seeding	8.4	Acres	$ 350	$ 2,940
			CONSTRUCTION SUBTOTAL		**$ 240,500**
	Other Costs				
1	Design				**$ 10,000**
2	Construction Oversight				**$ 5,000**
3	Monitoring				**$ 15,000**
4	Contingency		**15% of Construction Subtotal**		**$ 36,075**
			GRAND TOTAL		**$ 306,575**

Concept Level Project Cost Estimate					
Flint Creek - Corbett-Downs Property near Hall, MT					
Plan: Channel Reconstruction					
	Construction Cost Items	**Quantity**	**Units**	**Unit Cost**	**Cost**
1	Mobilization and Demobilization	1	Lump Sum	$ 10,500	$ 10,500
2	Site Prep, River Access, BMPs, Channel Activation, Reclamation	30	Hours	$ 240	$ 7,200
3	Furnish Logs and Brush for Streambank Structures	675	Trees	$ 500	$ 337,500
4	Furnish Willow Cuttings for Streambank Structures	26,500	Cuttings	$ 1.00	$ 26,500
5	Furnish Cobble for Streambed Fill	1,231	Cubic Yards	$ 35	$ 43,102
5	Furnish Pit Run for Streambank Fill	548	Cubic Yards	$ 15	$ 8,213
6	Excavate New Channel and Backfill Old Channel	13,800	Cubic Yards	$ 9	$ 124,200
7	Riffle Construction	665	Linear Feet	$ 15	$ 9,975
8	Sod Salvage and Placement	10,000	Square Feet	$ 1.50	$ 15,000
9	Install Large Wood Structures	10	Structures	$ 2,000	$ 20,000
10	Install Vegetated Brush Bank Structures	2,650	Linear Feet	$ 30	$ 79,500
11	Install Floodplain Roughness in Former Channel	1.50	Acres	$ 2,500	$ 3,750
			CONSTRUCTION SUBTOTAL		**$ 685,439**
	Other Costs				
1	Design				**$ 40,000**
2	Construction Oversight				**$ 30,000**
3	Monitoring				**$ 30,000**
4	Contingency		**15% of Construction Subtotal**		**$ 102,816**
			GRAND TOTAL		**$ 888,255**

RIVER DESIGN GROUP

Date:	March 23, 2018
To:	Beau Downing, Montana Natural Resource Damage Program Casey Hackathorn, Trout Unlimited Rob Roberts, Trout Unlimited
From:	Matt Daniels, P.E. River Design Group, Inc.
Subject:	Assessment and Conceptual Restoration Design Summary Lower Flint Creek – Rue, Johnson, Slaughter and Corbett/Downs Properties

1. Introduction and Background

The State of Montana Natural Resource Damage Program (NRDP) has identified the Flint Creek Watershed as a priority area for restoration (NRDP 2012). River Design Group, Inc. (RDG) was contracted by NRDP to complete an assessment and develop conceptual restoration designs for approximately 242 acres along a three-mile segment of lower Flint Creek upstream of Hall, Montana (Figure 1). This memorandum summarizes results of the assessment and identifies potential conservation and restoration opportunities the Rue, Johnson, Slaughter and Corbett-Downs properties along lower Flint Creek.

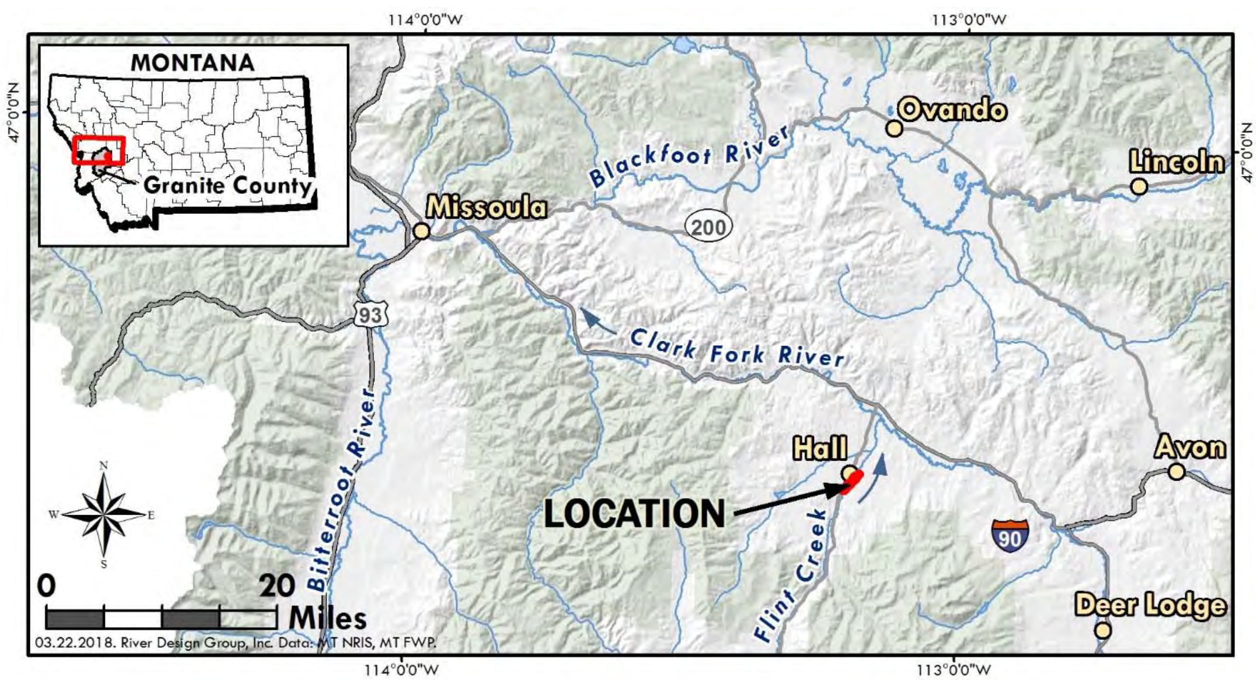

Figure 1. Project vicinity map for Lower Flint Creek restoration.

The Final Upper Clark Fork Basin Aquatic and Terrestrial Resources Plan (NRDP 2012) outlines key objectives for lower Flint Creek as outlined below:

- Improve water quantity through flow augmentation (e.g., water right purchases, water leases, and irrigation efficiency improvements);
- Reduce fish entrainment at irrigation diversions;
- Improve fish passage throughout the reach; and
- Riparian habitat improvements including fencing/protection, woody shrub and tree plantings, and off-site watering.

In addition, landowners have identified objectives that coincide with NRDP's overarching goals for Flint Creek as outlined below:

- Improve fish habitat;
- Improve terrestrial habitat for waterfowl and other wildlife; and
- Maintain a functional ranch operations and grazing leases.

2. Site Assessment and Summary of Existing Conditions

In 2016 and 2017, vegetation and geomorphic field assessments were completed for the project area. Results of the assessments were used to characterize existing conditions and identify impairments affecting stream and floodplain function. The potential condition for lower Flint Creek in the study area is a meandering, riffle-pool stream type with a connected floodplain that supports emergent wetland, willow and cottonwood vegetation communities. Limiting factors influencing the potential condition include:

- Geomorphic Limiting Factors
  - Altered flow regime from impoundments and irrigation management
  - Low channel sinuosity from channel manipulation
  - High bank erosion rates from lack of stability
  - Over-widened riffles and shallow pools
- Vegetation Limiting Factors
  - Insufficient wetland and riparian buffers from ranch operations and grazing
  - Lack of woody vegetation and riparian diversity
  - Competition from pasture grasses, noxious weeds and non-native species
- Aquatic Habitat Limiting Factors
  - Fish entrainment in irrigation ditches
  - Over-wide riffles and shallow pools
  - Gravel substrate embedded with fine sediment
  - Lack of instream cover, habitat diversity and complexity

3. Conservation and Restoration Opportunities

Conservation and restoration opportunities were identified to address the limiting factors identified in the assessment. Opportunities were categorized into four restoration plan alternatives that could be implemented independently or jointly in multiple phases based on funding availability and landowner objectives. The four restoration plans are:

- Phase 1 – Grazing Management Plan
- Phase 2 – Revegetation Plan
- Phase 3 – Channel Restoration Plan
- Phase 4 – Fish Entrainment Plan

Restoration plans are described in more detail in the following sections.

3.1. Grazing Management Plan

The grazing management plan includes recommendations for fencing and off-channel stock water locations. The grazing management plan represents a conceptual layout and is subject to revision based on stakeholder and landowner input. The plan addresses protection of sensitive riparian and wetland areas from grazing to allow native plant communities to become established. Fence locations were established based on the estimated channel migration zone, which represents a corridor that the stream channel is likely to occupy over the long term. By allowing native vegetation to become established in the floodplain and along the streambanks, stream channel stability will improve, and bank erosion will be reduced to more natural rates.

The grazing management plan identifies areas for continuous grazing, rotational grazing and grazing exclusion. In continuous grazing areas, no limit is placed on the duration or amount of grazing. In rotational grazing areas, access should be limited to 5 days of grazing followed by a 30-day period where the area can recover without grazing. In exclosure areas, no grazing should be conducted. Exclosure areas are sensitive to grazing and consist of the streambanks, channel migration zone and wetlands.

The grazing management plan is a passive restoration approach that, if implemented as a stand-alone plan, only partially addresses the range of limiting factors identified in the assessment. Other limiting factors such as competition from pasture grasses and streambank stability would need to be addressed with comprehensive revegetation and streambank strategies as described in other plans in the following sections.

The budgetary cost estimate range for the grazing management plan is $68,000 to $103,000. Costs include implementation (materials, equipment and labor), design, maintenance and a contingency. The estimated length of fence per the conceptual layout is 15,500 linear feet. The proposed fence type is four-strand barbed wire livestock fencing with 6-foot timber posts. The top and bottom strands of the livestock fence would be smooth wire for wildlife passage.

The conceptual grazing management plan is presented in Figures 2 through 4. Plans are presented on three figures from upstream to downstream.

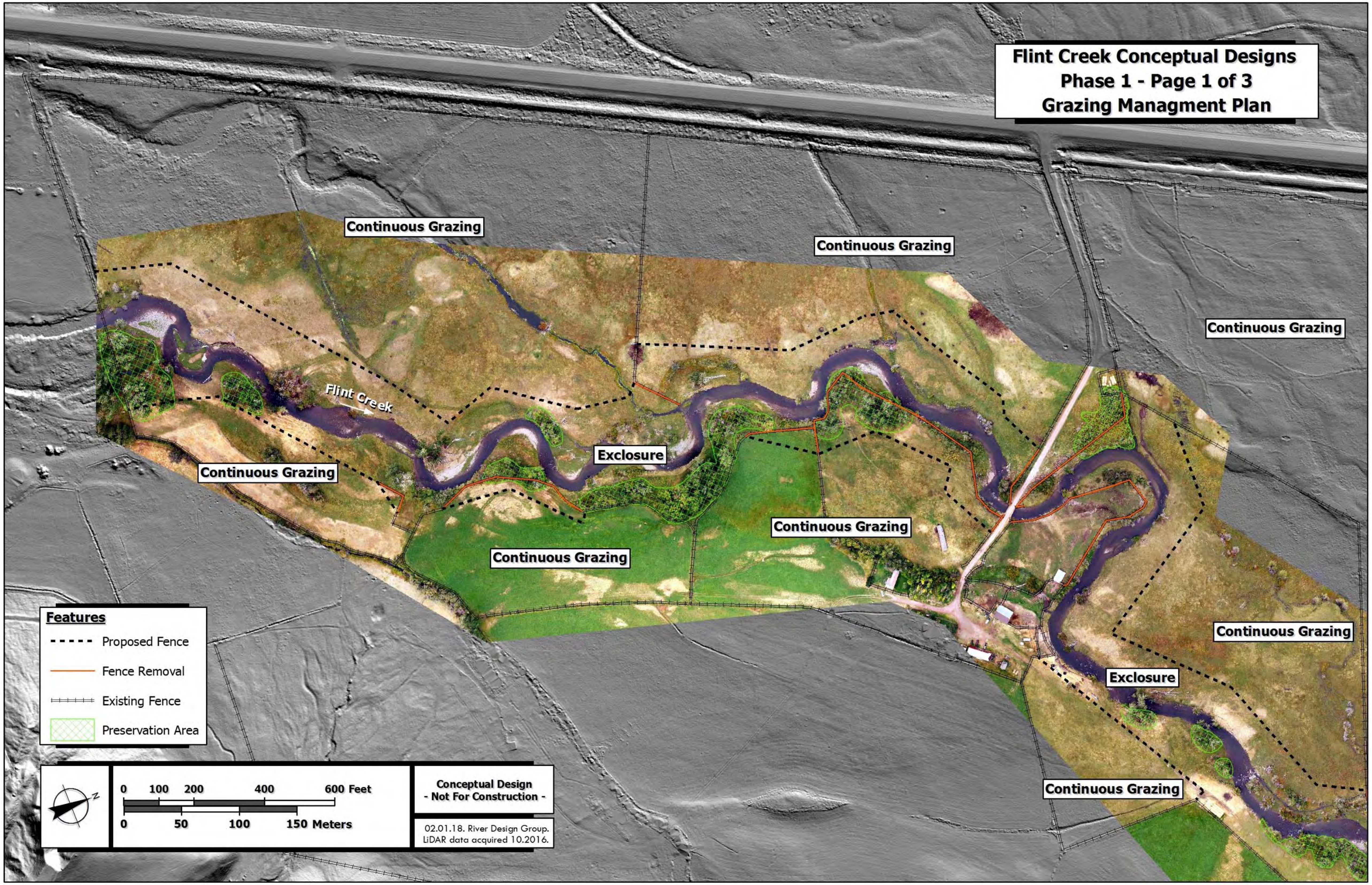

Figure 2. Conceptual grazing management plan for the lower Flint Creek project area.