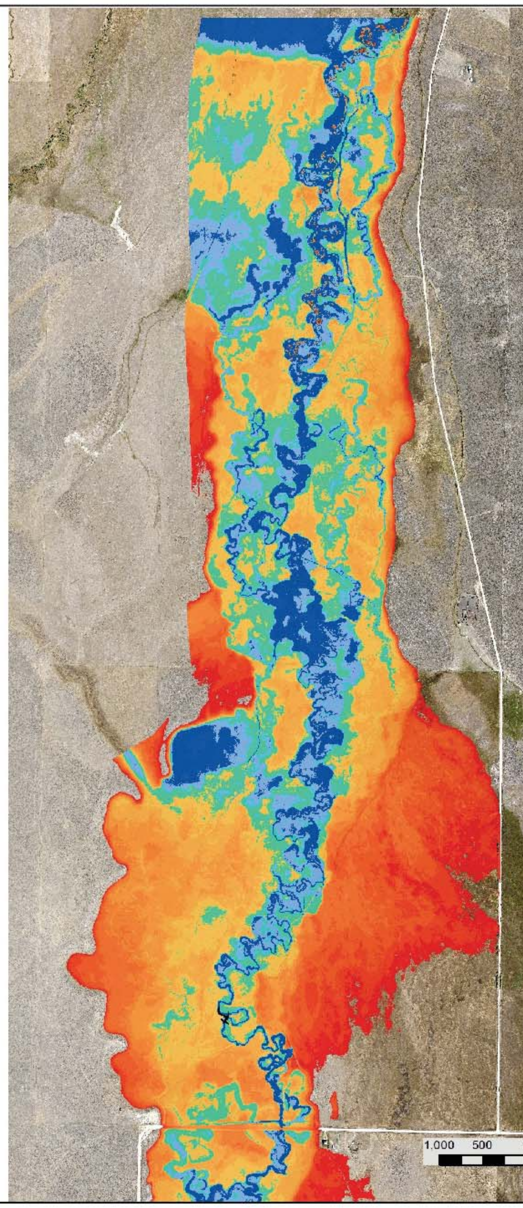
# LONG CREEK INCISED CHANNEL RESTORATION PROJECT
# DESIGN REPORT AND COST ESTIMATE

***PREPARED FOR***: The Nature Conservancy MONTANA OFFICE Helena, MT

November 20, 2015




***PREPARED BY:*** GILLILAN ASSOCIATES
MARKET-BASED CONSERVATION SOLUTIONS

***IN ASSOCIATION WITH:***

Applied Geomorphology, Inc.
Allied Engineering Services, Inc.
KESTREL AERIAL SERVICES
DTM CONSULTING MAPPING SPECIALISTS
MILLER RECREATIONAL

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# 1 Executive Summary

Scott Gillilan (Gillilan Associates), in collaboration with Karin Boyd, (Applied Geomorphology), Tony Thatcher (DTM), Ed Spotts and Jason Miller, (MRD), Kestrel Aviation and Allied Engineering were retained in the summer of 2015 by The Nature Conservancy of Montana (TNC) to develop a restoration project on a TNC owned parcel of Long Creek in the Centennial Valley. Long Creek has an existing small population of fluvial arctic grayling and was identified by past investigations to be in poor functional condition from the confluence with the Red Rock River upstream through the TNC-owned property. The lack of functionality includes: 1) channel incision ranging between 2 to 4.25 feet which has detached the floodplain from normal runoff events; 2) high rates of bank erosion and fine sediment export; 3) partial dewatering resulting in poor low flow habitat conditions for fish; 4) absence of low-water habitat diversity and; 5) absence of recruiting young or existing mature streamside woody vegetation.

The guiding image for the current proposed phase of Long Creek restoration project is as follows:

> *Utilizing deformable channel grade controls, re-create a floodplain hydroperiod where both overland and side-channel flow occurs during the typical annual peak runoff through the receding limb of the hydrograph. This will result in significant increases in seasonal and perennial wetlands through local groundwater table rise and longer periods of surface flow on the floodplain creating both natural and assisted riparian shrub establishment. The diminishment of channel energy in the currently incised channel thread will result in a reduction in bank erosion and channel narrowing that will enhance instream habitat. Incidental shallow alluvial aquifer recharge will expand the area of riparian and wetland habitat types and support later season base flow. The combined project benefits will provide better habitat for arctic grayling. The life of the structures is projected to be 7-10 years at which point the channel, banks and valley floor will be suitable for natural recolonization of beaver.*

The project builds on the design criteria and success of a similar project undertaken by TNC and the downstream neighbor, the J-Bar-L ranch in 2014. In the J-Bar-L reach, 7 hardened riffle and sod structures reconnected approximately 2 miles of incised channel with its floodplain, including runoff activation of 7,000 feet of formerly abandoned side channels.

Specific design criteria for the current project include:

- Sufficient raising of both runoff and low-flow water elevations through the installation of armored riffles to achieve frequent floodplain connectivity;
- Utilization of solely site-sourced construction materials which include a level of plasticity for long-term deformation;
- Construction of armored riffle structures capable of long term deformation while preserving elements of grade control into the future;

- Strategic re-activation of abandoned side channels and depressional areas during runoff discharges above flows of approximately 6 cubic feet per second (cfs);
- Provision of fish and aquatic species passage at baseflow conditions;
- Riparian grazing management.

The current project also expands on the J-Bar-L pilot project including a more comprehensive monitoring plan consisting of upstream and downstream continuous surface discharge monitoring and recording groundwater piezometer transects. Significantly, the design was also guided by the acquisition of low cost photogrammetric aerial photography for the creation of digital elevation models and utilizing those to create floodplain inundation maps with a GIS platform. This mapping allowed us to pinpoint locations for low head riffle structures with the highest potential to create overbank flow and floodplain interaction during normal runoff periods and model future landscape conditions.

The project will include construction of 9 armored riffle and sod grade controls over approximately 3.7 miles of channel. Average spacing between controls is 2,133 feet which due to the low channel slope, (average = 0.25%), average backwater lengths behind each structure will be approximately 500 feet. This spacing will result in heterogeneous channel conditions ranging from backwatered to the current riffle pool morphology. As the channel aggrades following project completion the extent of backwatered channel will progressively decrease as backwatered areas convert to a pool/riffle morphology.

Average structure dimensions are 14.2 feet wide x 2.2 feet high and 40 feet in plan length. Upstream riffle slope will be approximately 3:1 and downstream slope averaging 12:1. They will be built with native pit-run gravel cores and surfaced with an armor layer 12 inches thick composed of 3-8 inch screened cobble. The materials will be excavated from an existing gravel pit on TNC property. Native donor wetland sod from banklines that will be submerged upstream of the structures will be utilized to build the downstream right and left banks of the structure; (average 290 sq ft of donor sod utilized per structure). The channel width over the crest of the riffle will be approximately 5 feet to insure sufficient water depths for fish passage. The banks will be low enough that they will allow for regular overtopping events during runoff without concentrating channel energy in the passage channel.

## 2 Introduction

The following report describes the results of a field and office assessment of specific alternatives and designs to reconnect Long Creek to its historic floodplain from North Valley Road upstream for 6.7 miles (Figure 1). **Please note that the project implemented for 2016 will only extend over the 3.7 miles of stream on TNC-owned property**. The downstream landowner, Matador Ranch, has been in conversation with TNC regarding a similar project on their property and it is hoped that the success of the J-Bar-L and TNC projects will lead to their interest in restoring their reach of Long Creek similarly in the future.

This report assumes the reader has a general understanding of The Nature Conservancy's (TNC) mission to enhance hydrologic resiliency and aquatic habitat in the upper Missouri River and Centennial Valley and past efforts undertaken in the valley by a host of project partners including the Centennial Valley Grayling Working Group. Summaries of these programs can be accessed from TNC as well as the regional FWP fisheries biologists including Matt Jaeger.

### 2.1 Restoration Need

The need for ecological restoration in the project area is based primarily on identified degraded geomorphic conditions that have reduced the ecological potential of Long Creek. Recognized contributing factors to degradation in the system include the following:

- Aggravated levels of sediment production from chronic bankline erosion
- Reduced levels of sediment capture on stable surfaces
- Degraded riparian communities with little natural recruitment
- Elevated water temperatures
- Invasive plant species including non-native pasture grasses
- Incision and associated lowering of the floodplain water table
- Loss of beavers as agents of floodplain complexity and resilience
- Altered flow regimes due to irrigation withdrawal
- Non-native fish

The objective of this project is to identify means of restoring the project area to a dynamically stable system that has a markedly improved level of aquatic and terrestrial ecological potential.

### 2.2 Review of Project Guiding Image

A guiding image represents a conceptualization of restoration project outcomes in the short- and long-term. Our guiding image is the re-establishment of a self-maintaining floodplain environment characterized by frequently active distributary and sheet flow areas that result in an improved ecological condition and resiliency relative to present conditions. Through these processes, we expect to maximize the ecological potential of both the river and floodplain over a period of several years and in so doing provide a higher degree of hydrologic and ecologic resiliency with respect to anticipated climatic changes that may include increased periods of drought and/or unusually large runoff events.

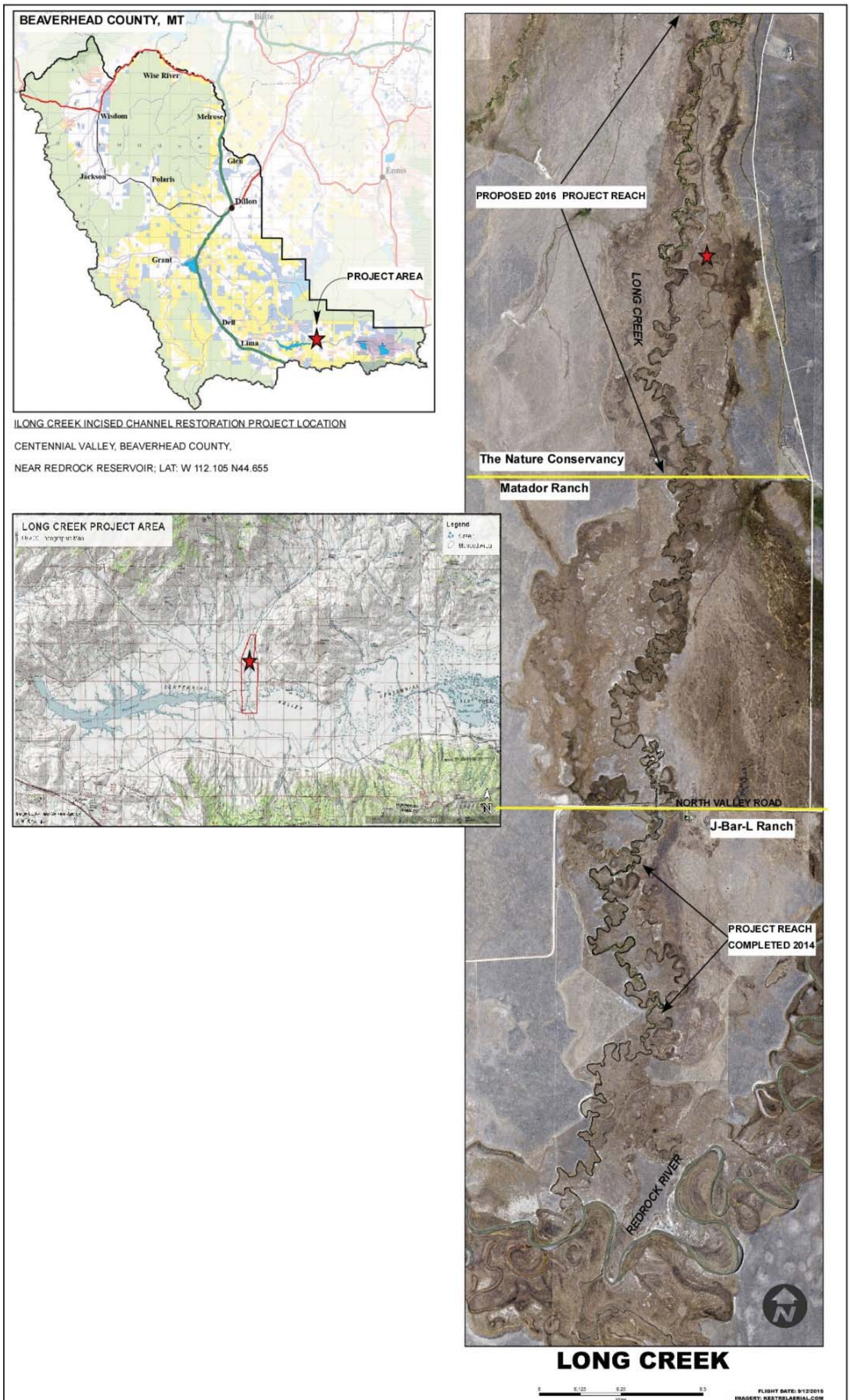



**Figure 1 Project area location map.**

The specific guiding image for Long Creek is to induce aggradation by elevating channel grade and a long-term trajectory that includes natural channel behavior expected in a freestone channel with connectivity to its floodplain. This includes the potential evolution of an anastamosed channel type with channel dimensions matched to lower conveyance requirements due to split and floodplain flow. Reduction in channel energy in the described condition will result in a gradually aggrading channel that through reductions in stream power will begin to develop an inset floodplain surface and more stable banks composed of accreting barforms progressively supporting a vigorous riparian community of wetland vegetation and shrubs. This will result in bank consolidation and less erosion and sediment export to the Red Rock River.

The guiding image for the floodplain is the re-establishment of a temporally and spatially diverse hydroperiod that will result in a significant expansion of seasonal and perennial wetland area and the natural recruitment of woody riparian vegetation that increases habitat diversity and floodplain resiliency. We also anticipate that the increase in frequency of overbank flow conveyance and elevation of the streambed will result in an elevation of the alluvial floodplain aquifer through recharge. Re-charging the shallow aquifer may also result in a net increase in base flow through return flows from groundwater.

In order to achieve these guiding images, the following restoration objectives apply:

1. Selectively modify flow routing on the floodplain surface to restore inundation at selected peak, ephemeral and perennial flow conditions;

2. Significantly expand the density and extent of riparian and wetland vegetation on the floodplain through more frequent inundation and establishment of natural vegetative recruitment tied to fluvial disturbance such as sediment deposition and scour;

3. Temporally improve fisheries habitat for all life stages and seasons. For example, during bankfull+ flows the project will significantly increase the quantity of velocity refugia over shallower and rougher surfaces. At minimum flow periods a progressively narrowing main channel will provide more favorable depth profiles.

4. Establish vegetative, fluvial and alluvial aquifer baseline conditions through: establishing community level vegetative transects related to other wetland/vegetation/soil mapping; monumented and surveyed channel cross-sections and; groundwater recording wells.

Note that the existing guiding image and objective does not specifically address a bank-by-bank treatment approach and instead assumes that changed hydrologic/hydraulic channel conditions will unfold in multiple years of systemic process driven changes. For example, virtually every outside channel bend is currently vertical and erosive and it is likely that some ongoing channel adjustments such as lateral migration or channel widening will continue, albeit at a greatly reduced rate assuming a “normal” hydrologic regime.

## 2.3 Report Structure

The following report is divided into Sections 3-7. ***Section 3*** consists of a discussion of general ***project area geomorphology, channel processes and hydrology***. This includes an analysis of key historic conditions compared to current conditions including known and likely historic impacts, current stability, and projected evolutionary channel trends. ***Section 4*** describes the alternatives analysis and project design process. **Section 5** discusses the ***preliminary project monitoring plan***. ***Section 6*** discusses likely ***project costs*** and ***Section 7*** consists of ***a summary of project benchmarks and future recommended actions for project continuation.***

***Appendix A contains the current project design drawings.***

# 3 Project Area Geomorphology, Hydrology and Channel Processes

## 3.1 Summary of General Geologic and Geomorphic Setting in the Long Creek Valley

Long Creek is a tributary to the Red Rock River, and its confluence is located approximately 3.5 miles upstream of the upper end of Lima Reservoir in the Centennial Valley of Montana. Lower Long Creek flows southward through the southern portions of the Snowcrest Range and Gravelly Range into the east-west trending Centennial Valley. The Centennial valley is unglaciated, however glacial tills are found on the Centennial Mountains to the south. In the valley itself, large lakes appear to have at least intermittently filled the basin during the Pleistocene (Albanese, et al, 1995). As Long Creek flows into the Centennial Valley, it flows through alluvial fan deposits and into lake and windblown (eolian) deposits on the valley floor (Figure 2). As such, the project area transitions from alluvial fan sediments which range from coarse cobbles to fine silts, to extremely fine silt/clay lake deposits. These units interfinger on lower Long Creek, creating variable conditions in the stream bed and banks. In general, however, this portion of lowermost Long Creek is fine grained, with localized exposures of gravels in the bank (Figure 3). Sediment loading from the upper watershed is relatively coarse, however, with gravels commonly comprising the bed and point bars (Figure 4 and Figure 5).

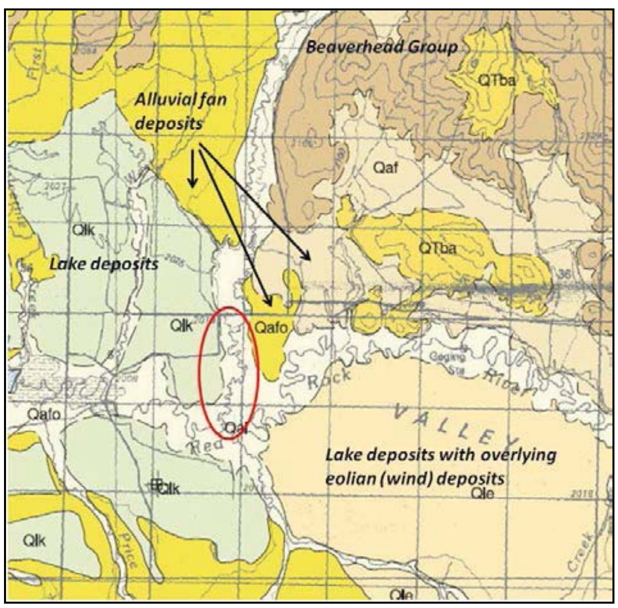



**Figure 2. Geologic map of central Centennial Valley with lower Long Creek circled.**

**Figure 3. High bank on Long Creek showing clay in bank toe and mid-bank gravels**

**Figure 4. Long Creek bed material (D50 approx. 0.75 inches).**

**Figure 5. Long Creek point bar showing gravel bedload.**

### 3.1.1 Inferred River and Floodplain State Change Between Pre-Settlement and Current Conditions

#### 3.1.1.1 Historic Valley, Floodplain and Valley Condition

Lower Long Creek is geomorphically similar to a myriad of small streams in southwest Montana. It flows within a single thread, it is entrenched, and its adjacent floodplain supports old channel courses that are currently accessible only during high water. The banks are predominantly fine-grained. We surmise that these conditions indicate a strong geomorphic influence of beaver prior to Anglo settlement, coupled with removal of beaver over the last ~150 years. These currently entrenched channels historically supported an anastomosing (multi-thread, sinuous) channel form, along with complex woody riparian and wetland corridor up to hundreds of feet wide established between the existing upland terraces. Subsequent removal of the grade controls and high water table provided by beaver dams resulted in downcutting and entrenchment. A 1951 air photo of lower Long Creek reach shows a complex mosaic of wet channels that is discreetly confined by the higher terrace surfaces (Figure 6). Although it is difficult to see the influences of irrigation in the photos, the 1951 photo appears to show broad floodplain access and more wet area than the more recent image. Historically, this corridor likely supported a wide range of wildlife using the area for cover, reproduction, forage, resting and travel between the valley mountain ranges.

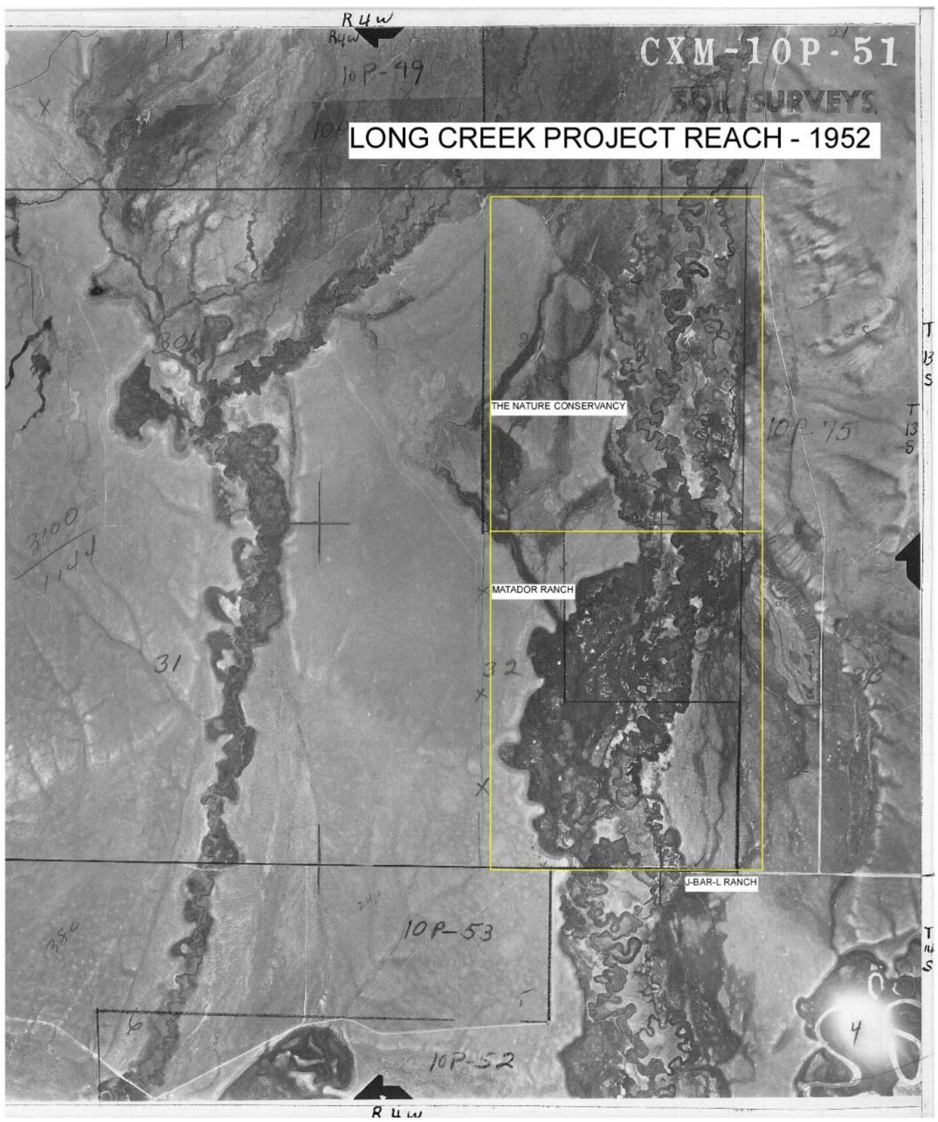



**Figure 6. Aerial photo of project area from 1952, which appears to indicate a higher degree of channel connectivity with the floodplain and willow population than current conditions.**

#### 3.1.1.2 Existing Valley, Floodplain and Channel Condition

As described previously, lower Long Creek is currently entrenched as it flows through a distal alluvial fan environment that interfingers with fine lake deposits of the Centennial Valley. The entrenchment is manifested by very high banks composed of erodible sediment, and a perched, poorly accessed floodplain. In general, there are four very distinct features of Long Creek on that are especially relevant to restoration concept development:

1. It is uniformly entrenched from the head of the TNC property to North Valley Road.
2. Willow populations are notably absent.
3. The rate of channel erosion as indicated by channel migration is relatively low, (despite relatively common occurrence of unvegetated outside banks).
4. The presence of an extensive network of numerous historic channels and depressional areas that are elevated 2-4 feet above the bed that are only inundated during large runoff events.

Typically, mature, gently sloping stream channels that flow through fine-grained valley bottom soils inundate extensive areas beyond the main channel. These may include multiple channels that flow during normal base flows, or low surfaces on the channel margin that are activated during flood events. Lower Long Creek does not commonly inundate either of these environments, due to its deep cross section and poor access to those features. In some locations on Long Creek, narrow floodplain benches have developed and accumulated recent sediment, indicating their inundation (Figure 7). However, these features are small, such that the "floodprone width" of the channel is narrow. This condition is fairly common on the valley floor of the Centennial and throughout the Upper Red Rock River and tributaries. Basically, a channel is considered to be entrenched when the floodprone width is narrow, such that relatively frequent floods inundate only minimal area beyond the channel banks. Entrenchment in these low gradient, fine-grained settings is commonly the result of incision, which is active channel downcutting to a lower elevation. Several types of geomorphic change can drive incision, including a reduction in sediment load, channel shortening, systemic base level lowering, or loss of grade controls. On lower Long Creek, the two most likely factors driving incision include a lowering of base level at Red Rock Creek, or a loss of internal grade controls, (eg. beaver dams), within the channel. A lack of evidence of incision on Red Rock Creek suggests that lower Long Creek downcutting was predominantly due to a loss of historic grade controls, and those grade controls were very likely formed by beaver dams.


**Figure 7. Deposition in Long Creek following a 2011 discharge of approximately 120 cfs. Note deposition line on inset floodplain surface.**

### 3.1.1.3 General Channel Form

The channel in the project reach is highly sinuous (2.68) and entrenched (Figure 8). In the Rosgen classification the channel is largely an $E_G$ (sinuous and entrenched). The average width is 18.6 feet and depth of 3.7 (W:D = 5.1; measured from top of banks), though there is variability including significantly overwide outside bends with widths of up to 30 feet. The average "bankfull" cross-section area is 66 sf. The majority of outside bend banks are erosive.

**Figure 8. Typical channel conditions in project area. Note only intermittent willow regeneration and lack of riparian canopy.**

More detailed channel geometry is presented in Appendix A plan sheets

### 3.1.1.4 Alterations to Vegetation

The project area has historically been under agricultural management (grazing and hay production). The TNC property has been rested from grazing for 3 years. We assume that in the pre-settlement condition the stream corridor was typically beaver mediated which included a mosaic of wetland, riparian and fluvial habitat types. The reaches of Long Creek above the project site and towards Divide may represent a partial reference condition, (presence of active beaver colonies and associated vegetative mosaics). Currently the project site is notable for the absence of riparian vegetation and wetlands.

#### 3.1.1.5 Alterations to Hydrology

Due to relatively pristine conditions in the upper watershed we believe that runoff period hydrology has not been altered by human activity. However, there are a number of historic and active irrigation diversion points above and in the project area that affect baseflow hydrology through withdrawal. In drier years and prior to TNC conversion of their Long Creek water rights to an instream flow lease it was not uncommon for Long Creek to effectively stop flowing below North Valley Road.

## 3.2 Hydrologic Setting and Site Hydrology

The watershed of Long Creek above the project site is approximately 44 sq. miles with an upper basin elevation of approximately 9,600 feet and an elevation of 6,624 feet at North Valley Road. NRCS SNOTEL Site Divide #448 at the upper end of the watershed is at an elevation of 7,800 feet indicates 24.5 inches of annual precipitation. The watershed area is split almost equally between N/NW and S/SE exposures.

Natural hydrology is affected by several irrigation diversions upstream and on the property.

### 3.2.1 Period of Records and Estimated Annual Peak Flow

April – October flows were monitored by MFWP on the TNC property over the years 2010-13 as part of an instream flow lease study. This short period of record included two average to above average precipitation years (2010-11) and two drought years (2012-13). Peak recorded discharges from 2010-13 were as follows: 75 cubic feet per second (cfs), 90+ cfs, 50 cfs, and 27 cfs. In 2015, another drought year, a qualitative estimate of peak flow was between 30-40 cfs. Using the 4 measured years, the average peak runoff is approximately 65 cfs.

### 3.2.2 Discussion of Base Flows

In all measured years except 2011 flows declined to less than 10 cfs by in the period between mid-June to mid-July, (and observationally true for 2014 as well). August – October base flows not including the high precipitation year of 2011 ranged between 1.3-4.7 cfs, (2011 range was 14.3 – 8.9 cfs). Flows from October through March are unknown but likely increase due to irrigation headgates being closed.

# 4 Project Design Process

## 4.1 Review of Incised Channel Restoration Alternatives and Selection of Chosen Grade Adjustment Strategy

There are effectively 3 strategies for restoration of incised channels (Fishenich and Morrow 2000 http://el.erdc.usace.army.mil/elpubs/pdf/sr09.pdf): 1) "allow the channel to establish a new equilibrium strategy on its own"; 2) "accelerate natural recovery within the Channel Evolution Model" which on shorter timescales results in the formation of a new floodplain inset relative to the historic floodplain; 3) "restore the hydraulic grade of the system to re-establish the hydrologic connection to the historic floodplain." These are reviewed below within context to the current project objectives and guiding image.

### 4.1.1 Allow Natural Recovery

While natural recovery timelines are subjectively assessed it is our belief, based on review of historic current and historic imagery, ground observation, and trends in other incised Centennial Valley streams imagery, that natural evolution to a stable and highly functional channel and floodplain on the project site would occur over multi-decadal scales. Further, this period will include ongoing if not accelerated rates of channel enlargement and straightening planform and high sediment export rates.

Given the guiding image for the recovery of connectivity to the historic floodplain which we believe has more spatial diversity with respect to restoration of broad-based ecological function, (for example, restoration of perennial and seasonal wetlands), natural recovery is less desirable. Further, one project purpose is to demonstrate feasible intervention in functionally degrading incised channels to short-circuit the period of high channel instability and sediment export downstream. We therefore are not considering natural recovery as a viable project alternative to do unknown but excessively long timelines.

### 4.1.2 Accelerate Natural Recovery

Accelerating natural recovery is generally considered an excellent restoration strategy provided the state of the natural recovery is already fairly advanced. In fluvial systems, this state includes: major grade and planform adjustments have already occurred and the new inset channel and floodplain surface area is largely balanced with the dominant discharge and flood regime. Accelerating the next stage of recovery typically involves the following:

- Stabilizing inset floodplain terrace toes (which are formerly eroding banks), providing a stable boundary between overbank flows and highly erodible fine sediment dominated terraces.

- Increasing floodplain conveyance by excavating larger inset floodplain surfaces.
- Enhancing stability and consolidation of forming inset floodplain surfaces. This can be accomplished by increasing roughness on these surfaces by vegetative or other means.

Based on current channel and floodplain geomorphology we concluded that the above strategies would not be effective based largely on our belief that the channel has not yet reached a balance between floodplain and channel flood conveyance and bedload. Specifically, within the project reach there is little indication that barforms are coalescing into stable inset floodplain surfaces and instead are largely directing channel energy into highly erodible fine sediment terraces/banks. Looked at from a channel energy perspective, we believe that peak flow channel and floodplain stream power exceeds the threshold for formation of stable surfaces – the total floodprone channel width still needs to significantly enlarge to reduce channel energy at peak discharges.

### 4.1.3 Selected Strategy - Restore Hydraulic Grade to Re-connect with Historic Floodplain

Restoring hydraulic grade is synonymous with "floodplain reconnection" and if feasible is considered the most desirable channel intervention (Fishenich and Morrow 2000, http://www.fws.gov/northeast/virginiafield/pdf/partners/priority_restoration_defintions.pdf, Pollack et al 2014, http://bioscience.oxfordjournals.org/content/early/2014/03/23/biosci.biu036.full) provided the existing floodplain still retains high functional potential, system hydrology is capable of supporting desired conditions, overbank flooding is not considered a risk to infrastructure or other uses and a project will not have unintended consequences to other riverine functions. Our preliminary investigation ascertained the project reach met the above criteria and therefore was not only feasible but also technically achievable and became our principal restoration strategy.

Restoring an incised channel to historic hydraulic grade typically follows one of two paths or a combination of them:

1. Divert and relocate principle incised channel thread onto the historic floodplain.
2. Raise the existing incised channel's hydraulic surface to interact at a designed level of overbank flood frequency.

Based on the successful demonstration project on Long Creek on the J-Bar-L we concluded the existing channel alignment sinuosity and depth of incision suggested that raising grade would return the largest in-channel and floodplain functional lift. We also concluded this strategy is far more economically viable than diversion and re-build.

## 4.2 Inundation Mapping Tool to Assess and Quantify Restoration Effected Areas

Kestrel Aerial photogrammetrically mapped Long Creek from the confluence with the Ruby River on the J-Bar-L to the northern end of the TNC property. These data were then converted into a digital elevation model (Figure 9).

### 4.2.1 Existing Conditions Inundation Map

DTM prepared an inundation surface map of existing channel conditions utilizing proprietary GIS-based mapping methods. An inundation map is essentially a color-coded topographic map with a color ramp assigned to a chosen increment above a base-level, which for this project is the channel bed (Figure 10). In Figure 10 one can see the relationship between channel bed elevations and the abandoned floodplain and side channels including the general observation that the channel bed is entrenched between 1.5 to 4 feet below the elevation of the formerly active floodplain, (floodplain prior to beaver extirpation and downcutting). The surface patterns have the signature of a formerly beaver-mediated, complex channel and ponded environment. The blue through light green shades indicate either active channels, disconnected floodplain channels or depressional areas at elevations between 2.75-3.5 feet above the channel bed is the floodplain area this project will hydrologically reconnect.

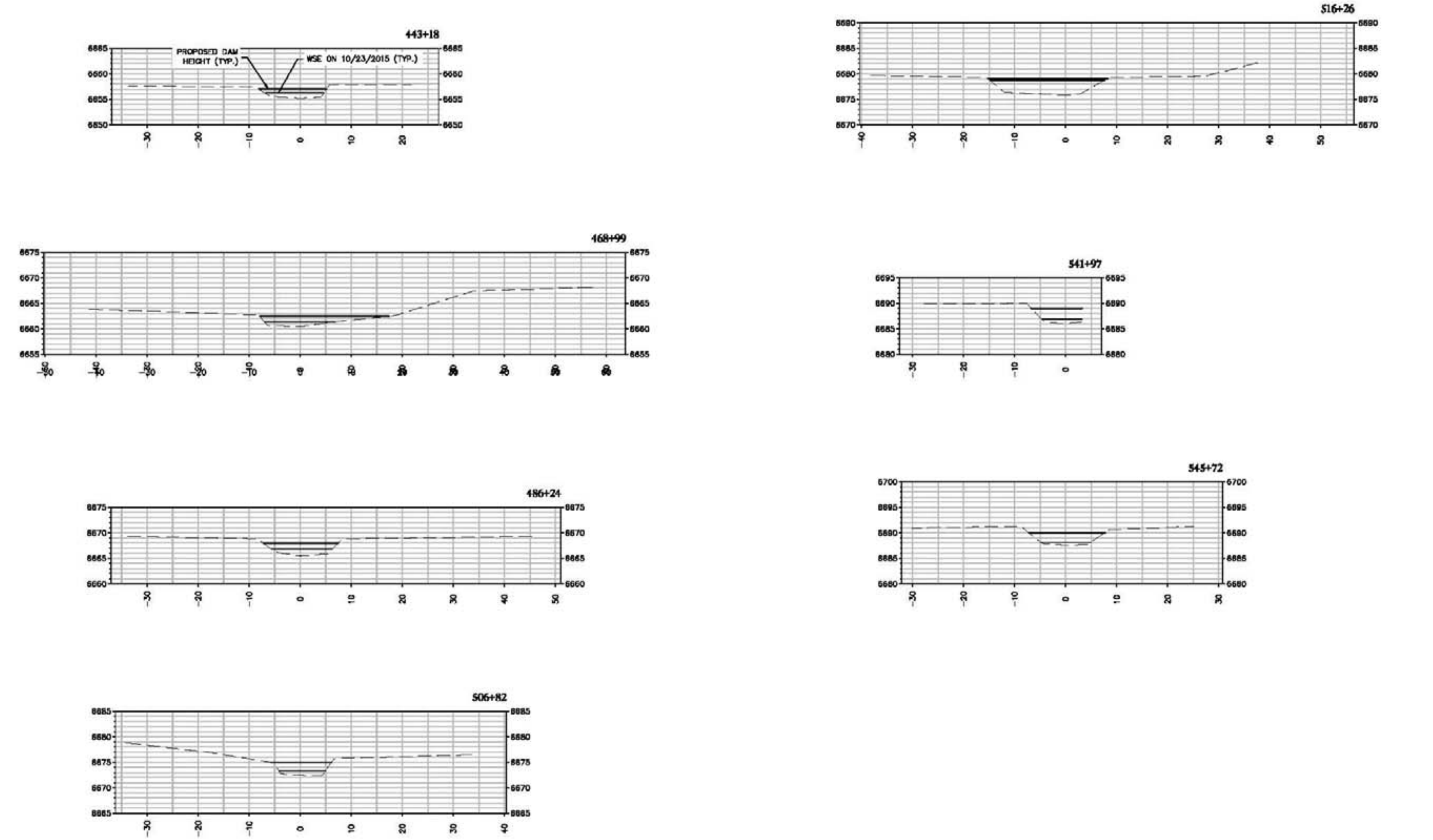
Figure 11 is an inundation map of the TNC project reach with the color ramp adjusted to amplify/display the target floodplain areas for reconnection (areas 1-3 feet above the channel bed). This imagery guided the specific design placement of grade control structures.

### 4.2.2 Riffle Structure Locations

In a GIS platform we used the inundation map to plot bed and low-water surface profiles and sections for detailed structure placement. Structures were located such that the baseflow backwater elevation would intersect within 0.5 -1 foot of the floodplain or invert of the detached floodplain channel to be reactivated. This will insure that runoff flows and receding limb flows will have a dramatically larger surface area to spread energy, infiltrate to shallow groundwater tables and create a temporary multi-channel thread habitat type.

### 4.2.3 Riffle Structure Design

Figure 12 is a photo series detailing the construction of a single armored riffle and sod grade control structure from the J-Bar-L Ranch pilot project. Average structure dimensions for the current project are 14.2 feet wide x 2.5 feet high and 38 feet long. Upstream riffle slope will be approximately 3:1 and downstream slope averaging 12:1. They will be built with a total of 168 CY native pit-run gravel and surfaced with 219 CY of a deformable armor layer 12 inches thick composed of 3-8 inch screened cobble. The materials will be excavated and hauled to the site from an existing gravel pit on TNC property. Native donor wetland sod from banks that will

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HORIZONTAL SCALE FEET 0 10 20
VERTICAL SCALE FEET 0 10 20

PROJECT ENGINEER:
DESIGNED BY:
DRAWN BY: JWJ
REVIEWED BY:

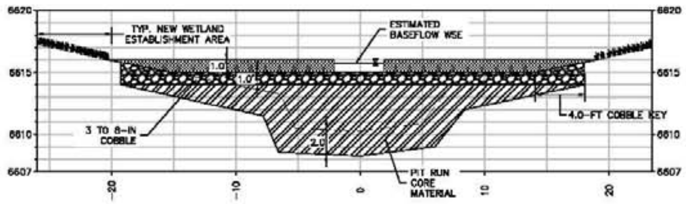
# LONG CREEK CROSS-SECTIONS
## BEAVERHEAD COUNTY, MT

GILLILAN ASSOCIATES
MARKET-BASED CONSERVATION SOLUTIONS

PROJECT #: 15-172
DATE: 11/18/15
CROSS-SECTIONS

SHEET XS-2

LONG CREEK CROSS-SECTIONS

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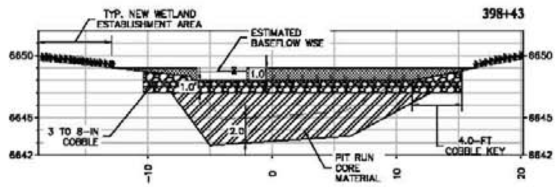


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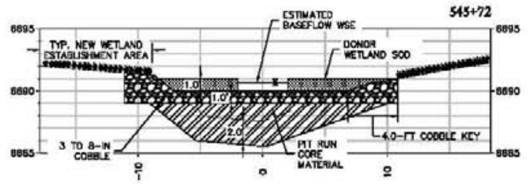


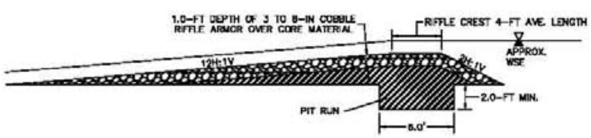

CROSS SECTION - STRUCTURE 545+72

RIFFLE PLUG NOTES:

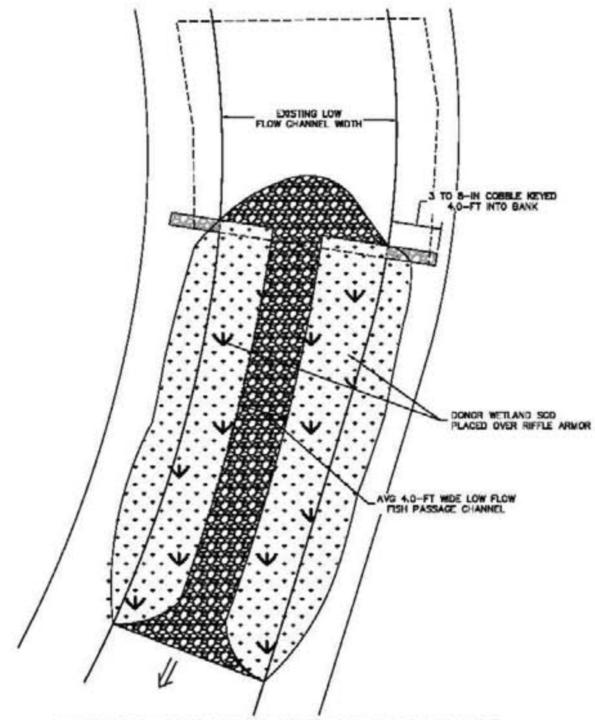
1. ESTIMATED ANNUAL SPRING FLOW = 25 YEAR STORM EVENT FLOW
2. DAM HEIGHT SET TO ALLOW MINIMUM OF 25 YEAR STORM EVENT TO PASS WITHIN EXISTING BANKS
3. END OF GRAVEL KEYWAY TO BE MINIMUM OF 12-IN ABOVE TOP OF DAM.

SOD RAMP NOTES:

1. MADE OF DONOR SOD MATS
2. SOD MATS TO BE MINIMUM OF 12-IN THICK
3. SOD MATS TO BE HARVESTED ONSITE FROM INUNDATED AREAS OR UPPER BANKS
4. SOD MATS TO BE INSTALLED PER SITE SUPERVISOR




TYPICAL RIFFLE GRADE CONTROL STRUCTURE SECTION DETAIL




TYPICAL RIFFLE GRADE CONTROL STRUCTURE PLAN DETAIL

EXAMPLE OF RIFFLE GRADE CONTROL STRUCTURE

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VERTICAL SCALE FEET 0 0 10

PROJECT ENGINEER:
DESIGNED BY:
DRAWN BY: JWJ
REVIEWED BY: PJS

# LONG CREEK
# DETAILS
## BEAVERHEAD COUNTY, MT

GILLILAN ASSOCIATES
MARKET-BASED CONSERVATION SOLUTIONS

ALLIED ENGINEERING SERVICES, INC.

PROJECT #: 15-172
DATE: 11/18/15
DETAILS

SHEET D-1

LONG CREEK DETAILS