GEOMORPHIC ASSESSMENT REPORT
TETON CREEK
TETON COUNTY, IDAHO

Prepared For

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INTRODUCTION

Biota Research and Consulting, Inc. (Biota) was retained by Friends of the Teton River to complete a geomorphic assessment of Teton Creek. The primary focus of the effort is to characterize geomorphic conditions within the fluvial system from Cemetery Road Bridge downstream to the vicinity of the Highway 33 Bridge. A secondary focus of the effort is to identify areas of concern, or hot spots, between the Idaho state line and the vicinity of the Highway 33 Bridge. This report presents methodologies and findings associated with geomorphic assessment, hydrologic conditions, sediment transport regime, hydraulic analyses, and management recommendations.

EXISTING CONDITIONS

Teton Creek flows westerly out of the Teton Mountain Range in western Wyoming. The creek enters Idaho in Teton County, and passes through the town of Driggs before reaching a confluence with the Teton River. The Restoration Reach of Teton Creek has a catchment of approximately 42 sq mi and has mean annual precipitation of 48.8 in, maximum elevation of about 11,400 ft, and mean basin elevation of about 8,560 ft.

The Teton Creek channel was altered during the 1980's by heavy equipment in an attempt to channelize seasonal high flows and protect adjacent development. Anthropogenic manipulation to the fluvial system resulted in the destabilization of Teton Creek, and the resulting fluvial impairment has migrated both upstream and downstream from the location of the original system manipulation. Fluvial system impairments have perpetuated severe bank erosion that threatened riparian lands, adjacent residential developments, and both public and private infrastructure.

Friends of the Teton River (FTR) initiated an effort in the mid-2000's to restore the degraded Teton Creek based upon project objectives of improved public health, safety, and welfare; protection of residential development and public infrastructure; flood control; recreational, aesthetic, and economic benefits to the local community; and the restoration of ecological values and processes. As a result of these efforts, a large scale restoration project was implemented in 2013 that involved reconstruction of more than 1 mile of the Teton Creek channel immediately upstream of the Cemetery Road Bridge. Subsequent efforts have investigated existing system impairment both upstream and downstream of that project area, and presented recommendations regarding fluvial system restoration.

HYDROLOGIC REGIME

The analysis and design of the 2013 Teton Creek restoration project involved quantification of the hydrologic regime of Teton Creek, and identification of peak flow return characteristics, flow duration, and the local bankfull discharge. Bankfull discharge is the flow rate and bankfull stage is the corresponding water surface elevation at which instream water escapes the active channel and inundates the floodplain (when incipient flooding occurs). There is natural variability in the recurrence interval of bankfull discharge between sites, but professional experience suggests that bankfull discharge has a typical recurrence interval of around 1.5 years in this region. Bankfull discharge is selected as the primary hydrologic parameter for fluvial assessment purposes because it can be identified and corroborated through field investigations, as opposed to potential alternate parameters of dominant discharge (e.g., the flow rate responsible for establishing the stable morphology) or effective discharge (e.g., the flow rate that transports the greatest fraction of the annual sediment load) that are primarily derived through analytical processes, without empirical corroboration.

Bankfull discharge in Teton Creek proximate to the Cemetery Road Bridge was determined to be 480 cfs (cubic feet per second) during the 2013 project. This estimation of bankfull discharge is considered an appropriate value for use during the subject Geomorphic Assessment effort, which considers the stream reach located between the Cemetery Road Bridge and the downstream Highway 33 Bridge. Quantification of peak flow return interval based upon hydrologic data from the period of record indicates that the bankfull discharge rate of 480 cfs has a recurrence interval of about 1.45 years in the Assessment Reach (Figure 1).

Flow duration characteristics within the Teton Creek project area inform analysis of sediment transport capacity, channel and floodplain hydraulic conditions, and the temporal duration of hydrologic support for stream bank and floodplain vegetation. A flow duration curve developed from modeled mean daily discharge records spanning 1972-2003 (modeled by Dr. Rob Van Kirk during previous investigations) depicts the probability (percent of time) that a given mean daily discharge rate will be exceeded during a given year (Figure 2). The flow duration curve indicates that a mean daily discharge of 480 cfs occurs about 3.3% of the time, or for about 12 days, during an average year.

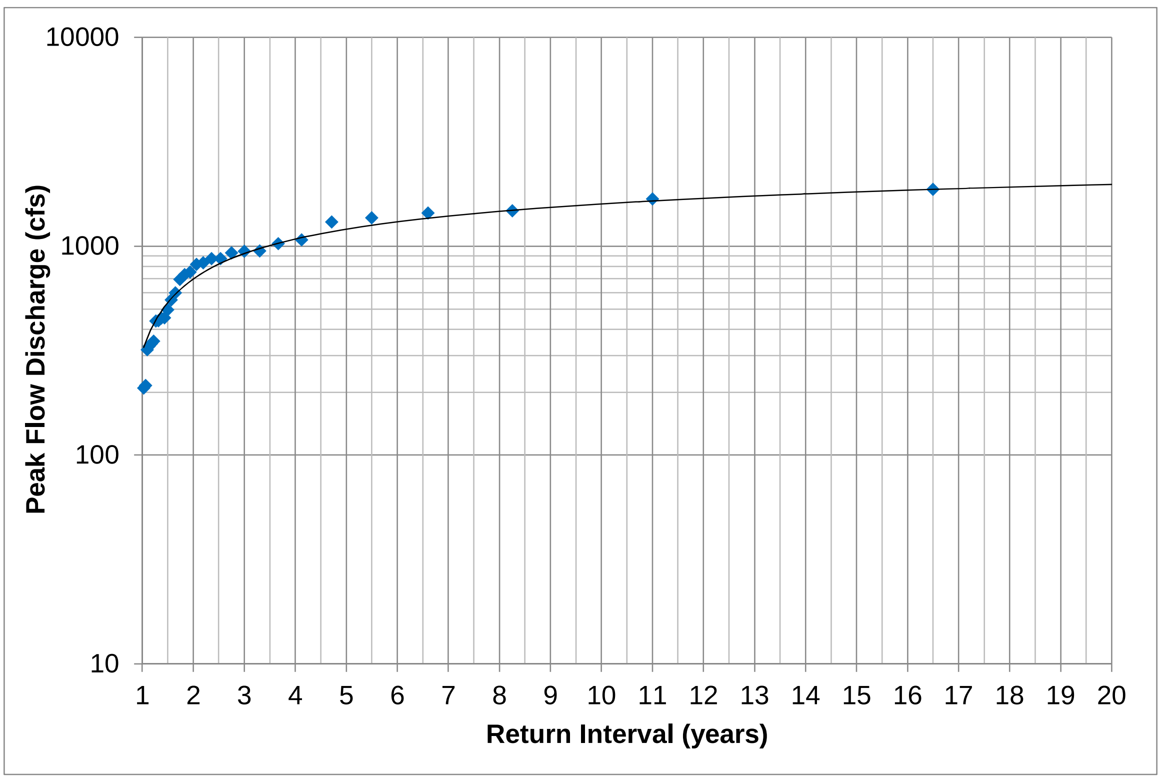

Figure 1. Peak flow recurrence intervals within the Teton Creek Geomorphic Assessment project area.

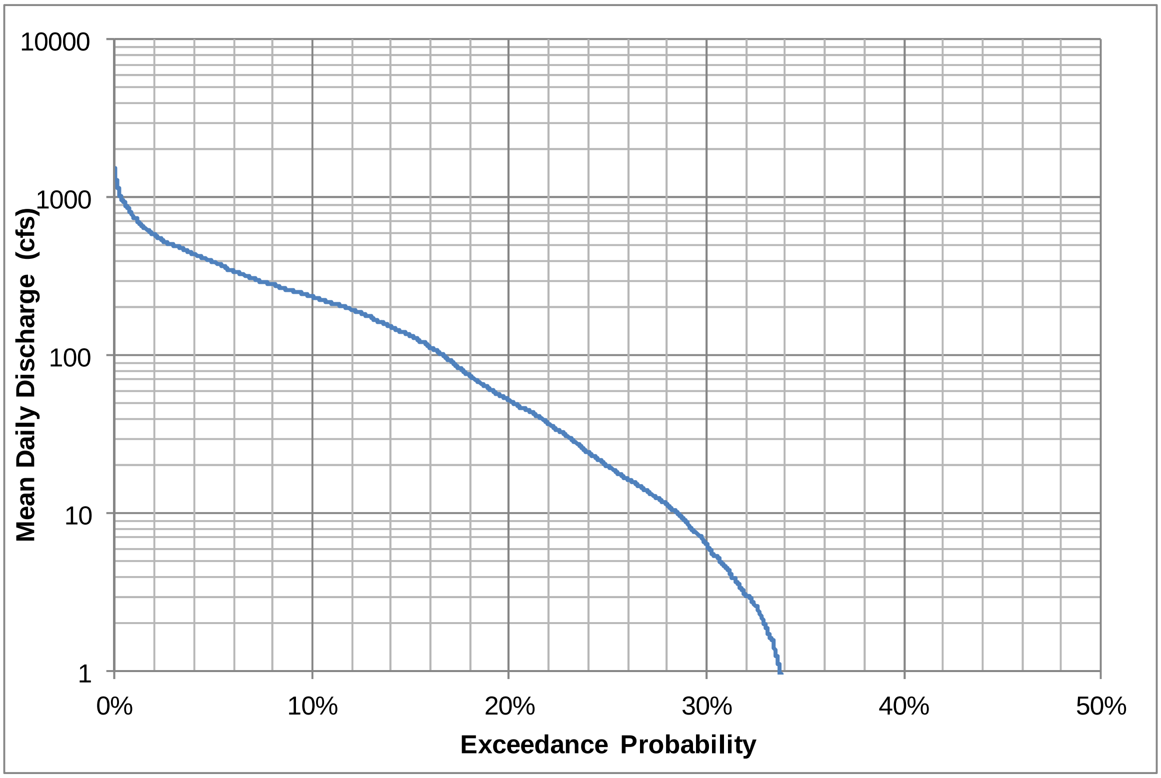

Figure 2. Mean daily discharge flow duration curve within the Teton Creek Geomorphic Assessment area.

SEDIMENT TRANSPORT REGIME

The Teton Creek geomorphic Assessment Reach is located near the downstream extent of the inactive Teton Creek alluvial fan. The fan is considered inactive because it is no longer building through sediment deposition on the fan surface. Functional channel conditions typically associated with this valley type setting include a single channel stream with moderate entrenchment, moderate width/depth ratio, and moderate sinuosity. A functional fluvial system is generally defined as having capacity to convey surface water flows and to transport the supplied sediment load without demonstrating significant changes in channel dimension (cross sectional geometry), pattern (alignment), or profile (reach-wide slope). Examples of functional fluvial systems proximate to Teton Creek have riparian vegetation communities consisting of cottonwood, conifer, and woody understory comprised of species adapted to non-cohesive, well-drained, coarse-grained alluvium substrate.

Quantification of sediment transport regime is integral to assessing geomorphic conditions because the process of sediment movement influences channel form. Excess sediment transport can result in channel incision, bank failure, and xerification of the riparian area. Conversely, insufficient sediment transport can result in channel aggradation, reduced slope, lateral migration, increased avulsion potential, and loss of riparian lands.

The sediment transport regime in Teton Creek proximate to Cemetery Road Bridge was quantified during the 2013 restoration project design effort. Channel geometry, slope, and local sediment characteristics measured in relatively stable stream reaches upstream of the project area were used to calculate bankfull bedload transport rate methods outlined in the *Manual for Computing Bed Load Transport Using BAGS (Bedload Assessment for Gravel-bed Streams) Software* (Pitlick et al., 2009). The analysis determined that the bankfull bedload transport rate in the upstream functional reach of Teton Creek is about 4.7 lbs/s (pounds per second).

Suspended sediment movement within the system was investigated through application of regional regressions that estimate suspended sediment load at the 1.5-year recurrence interval discharge within various ecoregions. The regressions indicate that a value of 93.4 mg/L (the median value within the ecoregion) is a reasonable estimation of suspended sediment concentration in Teton Creek during the bankfull discharge.

The bankfull bedload and suspended sediment transport rates were used to scale dimensionless sediment transport rating curves to the Teton Creek project area. The sediment transport rating curves quantify sediment movement rates across the range of discharge rates experienced within Teton Creek. Annual bedload and suspended sediment load delivered to the project area were calculated by applying the Teton Creek mean daily flow duration curve to the sediment transport rating curves. The analysis indicated that the upstream functional reach of Teton Creek delivers (or supplies) about 1,900 tons/year of sediment to the Assessment Reach, and that the annual sediment load is comprised of about 1,750 tons of bedload and 150 tons of suspended sediment.

Restoration activities completed in Teton Creek upstream of the Cemetery Road Bridge in 2013 re-established a channel morphology designed to convey the annual sediment supply of about 1,900 tons under the current hydrologic regime. Therefore, available data suggest that the reach of Teton Creek considered during the geomorphic assessment effort receives about 1,900 tons of sediment per year from the upstream reach.

GEOMORPHIC ASSESSMENT

The Teton Creek geomorphic assessment incorporated available fluvial system data supplemented with field investigations completed between the fall of 2016 and the spring of 2017. Field investigations included the observation of channel, stream bank, and floodplain conditions throughout the Assessment Reach during periods of dry and wetted channel conditions. The Bank Erosion Hazard Index (BEHI) model was used to qualify bank stability based upon seven variables including bank height, root depth, root density, bank angle, surface protection, bank material, and stratification of bank material. The model was used to rank bank stability throughout the Assessment Reach using 6 categories ranging from ‘very low’ to ‘extreme’. The BEHI survey methodology was applied in fall of 2016 throughout the Assessment Reach, but was also conducted previously in 2007 (by FTR staff).

Available LiDAR (Light Detection and Ranging) data depicting site topography of the Assessment Reach were obtained. The active stream channel area described by the 3-dimensional topographic surface was subsequently updated (by Pierson Land Works LLC) with high resolution topographic data obtained in the early winter of 2016 using an aerial drone and photogrammetry technology. The topographic surface was subsequently determined to inaccurately describe channel morphology in the downstream portion of the Assessment Reach. Instream flows present within the channel during the periods of both LiDAR and photogrammetry data collection efforts precluded the collection of accurate topographic data within the active stream channel. Professional grade GPS survey equipment was subsequently used to measure channel morphology in the downstream portion of the Assessment Reach, and the field-surveyed topographic data were incorporated into the existing 3-dimensional surface to generate an accurate model of channel and floodplain topography that encompassed the Assessment Reach.

The current alignment of Teton Creek was digitized in the Geographic Information System (GIS) platform, and the alignment was used to generate a longitudinal profile of Teton Creek throughout the Assessment Reach. The profile depicted bed features (riffle-pool sequences) and channel slope throughout the reach. The channel profile was used to identify more than 50 representative riffle bed features located evenly throughout the Assessment Reach. The refined 3-dimensional topographic surface was then used to generate cross sections that depict floodplain and channel topography at the identified riffle locations. The cross sections were the used to compile a hydraulic model (HEC-RAS, or the Hydrologic Engineering Center's River Analysis System) of the Teton Creek Assessment Reach. The HEC-RAS model was used to quantify numerous hydraulic parameters at the bankfull discharge, including water surface elevation, hydraulic radius, top width, flow area, velocity, and slope. Model output was used to quantify fluvial function and processes within the Assessment Reach.

ASSESSMENT RESULTS

The reach of Teton Creek located between the Cemetery Road Bridge and the vicinity of the Highway 33 Bridge has experienced direct and indirect impact from upstream disturbances and local land uses. The historic dredging that occurred upstream of the Assessment Reach resulted in the formation and upstream migration of a head-cut that propagated channel enlargement. The massive volume of sediment that was entrained and mobilized during channel enlargement was delivered to the Assessment Reach, and resulted in widespread channel filling. Severe bank erosion and lateral channel migration occurred as the fluvial system responded to the influx of sediment. Efforts to protect proximate development and infrastructure resulted in bank armoring treatments that altered the natural channel recovery process by establishing hardened boundary conditions at distinct locations along the reach. Current conditions observed within the Assessment Reach are diverse and include the following:

a. Sub-reaches that are aggrading (raising in elevation due to sedimentation), migrating laterally, and promoting erosive meander cutoff channels or avulsions;

b. Sub-reaches that are excessively wide but are forming inset floodplain benches with available sediment in a natural recovery process;

c. Sub-reaches that continue to respond to bank armoring that prohibits natural channel recovery and establishment of functional channel form; and

d. Sub-reaches where mature vegetation on the channel margin has persisted and enabled maintenance of relatively functional channel geometry.

Site Conditions

Current morphologic conditions observed within the Assessment Reach are presented on the following pages. Presented photographs are georeferenced on the attached Sheets 2-6, which depict mapped conditions and site attributes from the upstream end of the reach (Station 0+00 ft ft) downstream to the lower terminus of the reach (Station 146+00 ft ft).

Localized deposition and channel aggradation are evident at the Cemetery Road Bridge (which is located at Station 0+00 ft ft in the Assessment Reach). Rock rip rap installed to prevent scour at the bridge location is evident under 2-3 feet of gravel deposition that has occurred at the location (Figure 3). Downstream of Cemetery Road Bridge, braided channels are separated by vegetated islands and complex large wood structure. Individual channels have relatively functional channel geometry with mature vegetation on the channel margins, and intact low flow (inner berm) channels and suitable geometry (Figure 4).

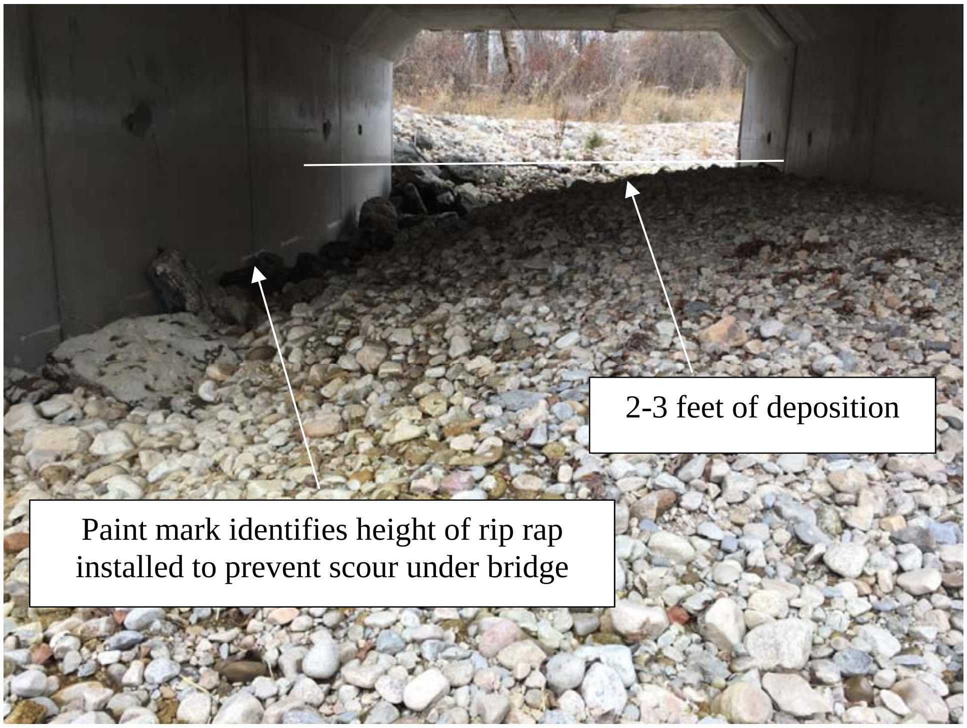

Figure 3. Photograph 1, deposition and channel aggradation at the Cemetery Road Bridge, Assessment Reach Station 0+00 ft.

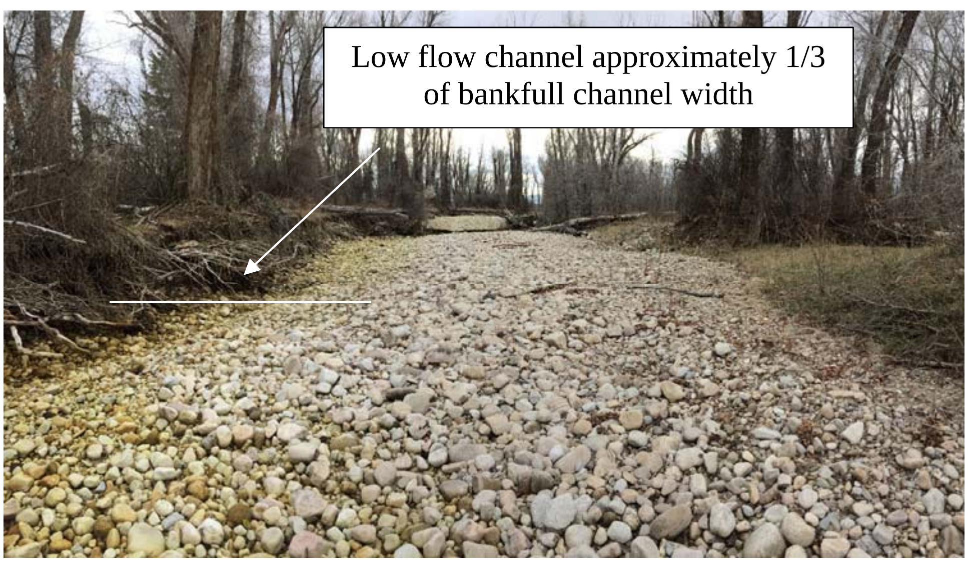

Figure 4. Photograph 2, relatively functional channel geometry with vegetated banks and low flow channel downstream of Cemetery Road Bridge at Station 2+00 ft.

Widespread sedimentation and the formation erosive meander cutoff channels is evident from about station 7+00 ft downstream to station 18+00 ft (Figures 5 and 6).

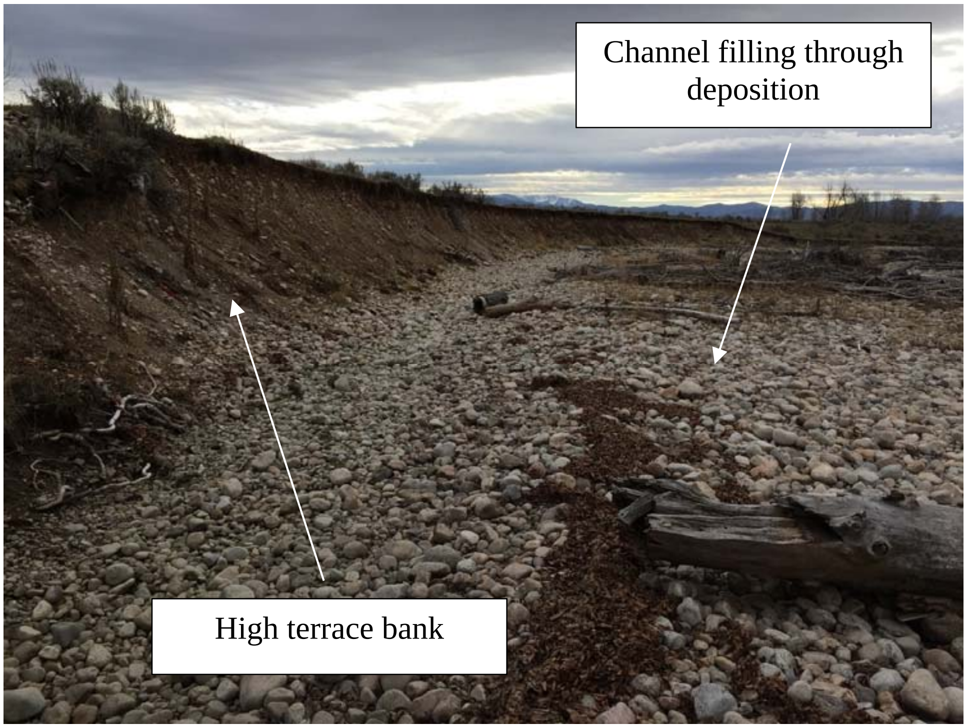

Figure 5. Photograph 3, exposed vertical terrace bank and sedimentation, Station 10+00 ft.

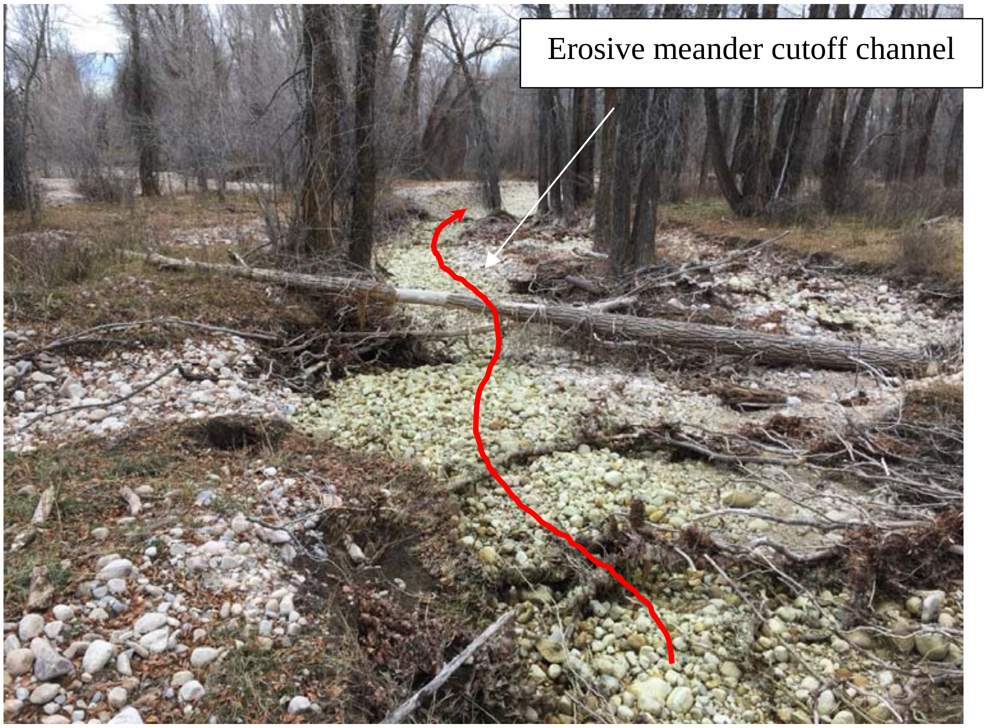

Figure 6. Photograph 4, newly formed erosive meander cutoff channel, Station 10+00 ft.

Isolated areas with intact functional channel form are evident within braided and single-thread sub-reaches located from Station 19+00 ft downstream to Station 28+00 ft (Figure 7). Widespread sedimentation in the form of point bar enlargement and inset floodplain bench creation are evident from Station 24+00 ft downstream to Station 67+00 ft (Figure 8).

Figure 7. Photograph 5, relatively functional sub-reach with mature vegetation on the channel margins and defined low flow channel, Station 20+00 ft.

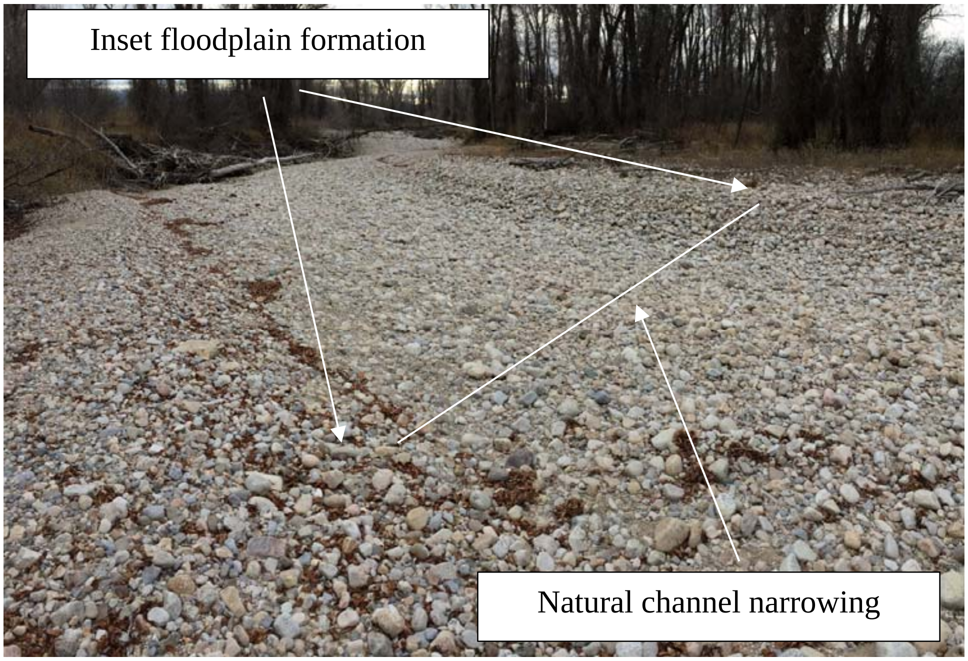

Figure 8. Photograph 6, area of natural channel narrowing through formation of inset floodplain benches, Station 34+00 ft.

Levees and dikes constructed of sidecast and placed alluvium are evident along both river right and river left stream banks from about Station 38+00 ft to Station 64+00 ft (Figures 9 and 10). Floodplain dikes are generally constructed of coarse alluvium and have been colonized by woody vegetation.

Figure 9. Photograph 7, floodplain levee and diking on the river left bank, Station 38+00 ft.

Figure 10. Photograph 8, floodplain levee and diking on the river right bank, Station 40+00 ft.

Sub-reaches with high width/depth ratio persist in areas where natural channel recovery is not occurring (Figure 11). Extensive bank armoring is in place from Station 62+00 ft downstream to Station 88+00 ft (Figure 12). At numerous locations where bank armoring has been installed, changes in channel form have resulted in localized deposition that has buried rip rap or changes flow dynamics proximate to the armoring.

Figure 11. Photograph 9, high width/depth ratio homogeneous channel, Station 47+00 ft.

Figure 12. Photograph 10, bank armoring on the channel margin, with localized deposition that has filled the inlet to a side channel, Station 52+00 ft.

Widespread sedimentation in the form of point bar enlargement and inset floodplain bench creation are evident from Station 24+00 ft downstream to Station 67+00 ft (Figure 13). Bank armoring is prevalent from about Station 62+00 ft downstream to Station 88+00 ft. At some locations rip rap has been installed on opposing stream banks, such that river confinement promotes increased flow velocities and the transfer of erosive potential to downstream sub-reaches (Figure 14).

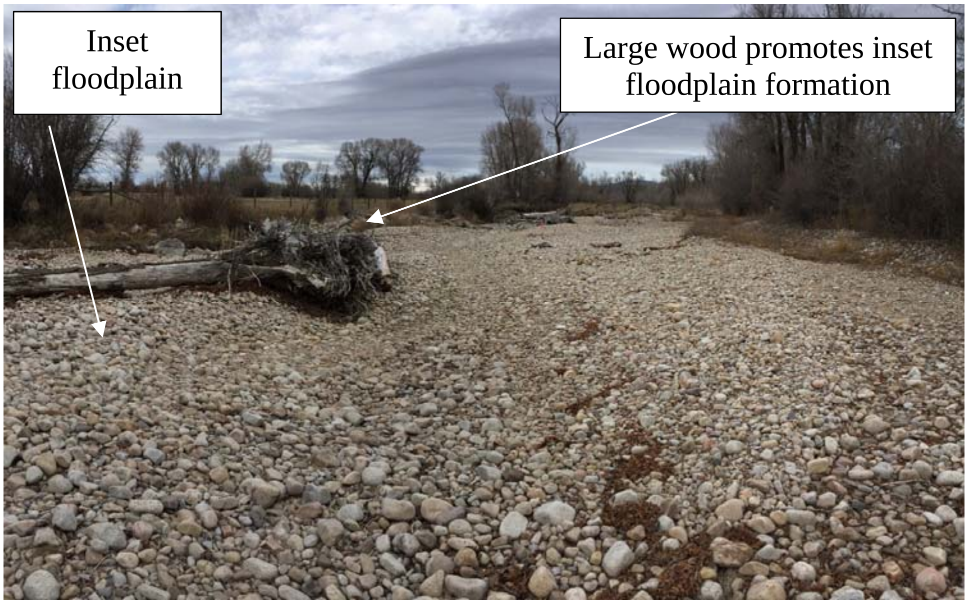

Figure 13. Photograph 11, wood debris promotes natural channel recovery through floodplain bench formation and channel narrowing, Station 57+00 ft.

Figure 14. Photograph 12, bank armoring through rip rap installation on opposing stream banks, Station 59+00 ft.

Bank armoring is prevalent from about Station 62+00 ft downstream to Station 88+00 ft (Figure 15). The channel is relatively straight, homogeneous (lacking a low flow channel, or inner berm), and has high width/depth ratio from about Station 65+00 ft to 76+00 ft (Figure 16).

Figure 15. Photograph 13, bank armoring through rip rap installation on opposing stream banks, Station 64+00 ft.

Figure 16. Photograph 14, high width/depth ratio homogeneous channel, Station 73+00 ft.

Widespread deposition and channel aggradation are evident from about Station 77+00 ft downstream to 114+00 ft. In some areas deposition has covered rock structures installed for grade control (Figure 17). In other areas, point bar enlargement and formation is achieving sediment storage and promoting lateral channel migration and increased sinuosity (Figure 18).

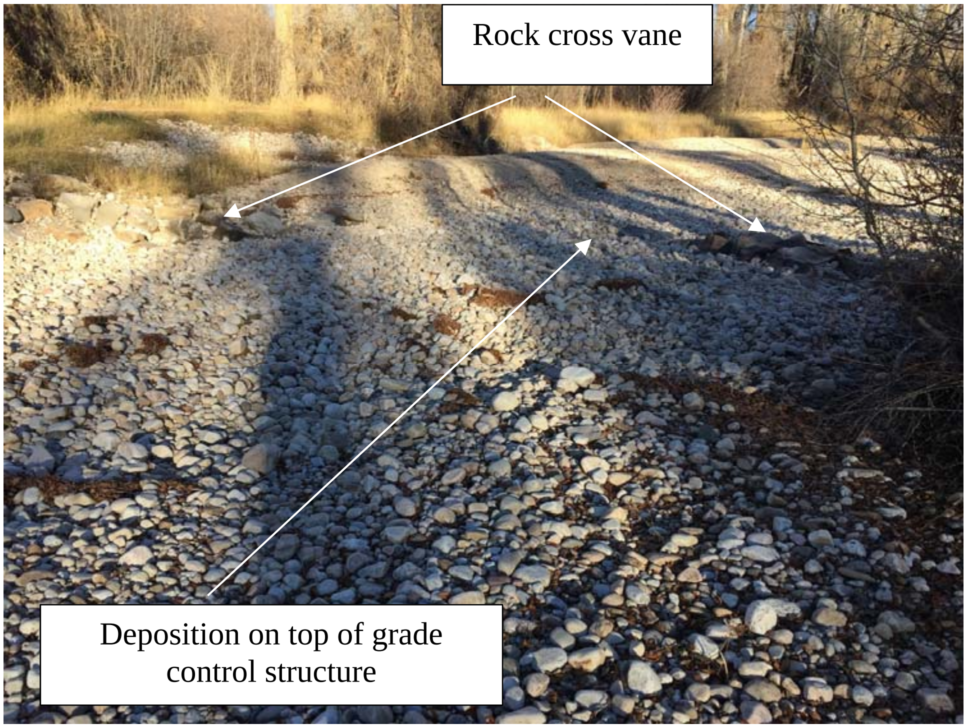

Figure 17. Photograph 15, aggradation on top of installed rock cross vane grade control structure, Station 78+00 ft.

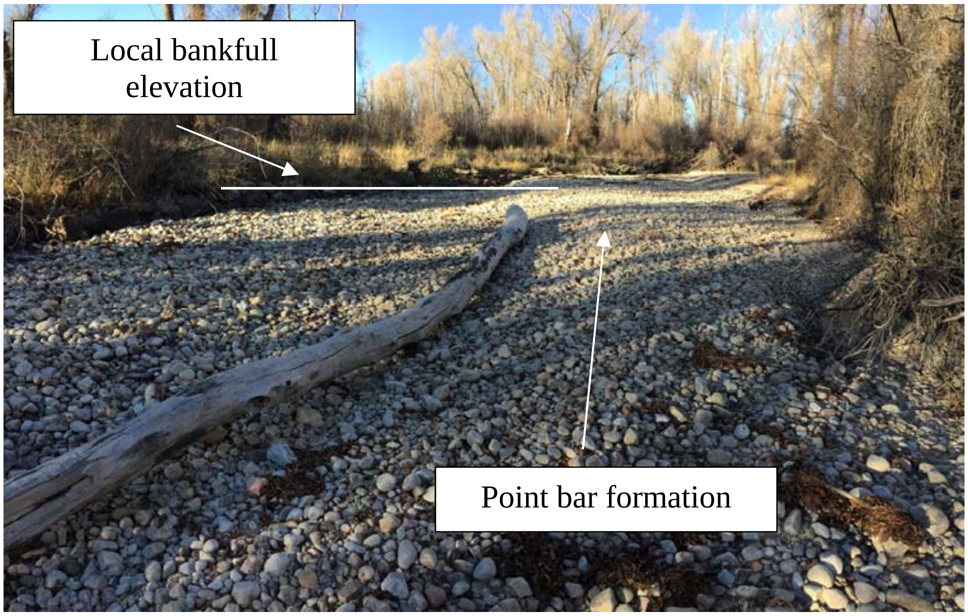

Figure 18. Photograph 16, sediment deposition and bar formation to the local bankfull/floodplain elevation, Station 79+00 ft.

Widespread deposition and channel aggradation are evident from about Station 77+00 ft downstream to 114+00 ft. Point bar enlargement and filling of side channels are prominent (Figure 19). Channel aggradation and pool filling are severe proximate to the Creekside Meadows Bridge (Figure 20).

Figure 19. Photograph 17, high width/depth ratio channel and widespread sedimentation, Station 85+00 ft.

Figure 20. Photograph 18, high width/depth ratio channel and sedimentation/aggradation at Creekside Meadows Bridge, Station 87+00 ft.

Severe aggradation, coupled with point bar enlargement and pool filling, has resulted in deposition that now covers rock rip rap previously installed to protect stream banks from erosion (Figures 21 and 22).

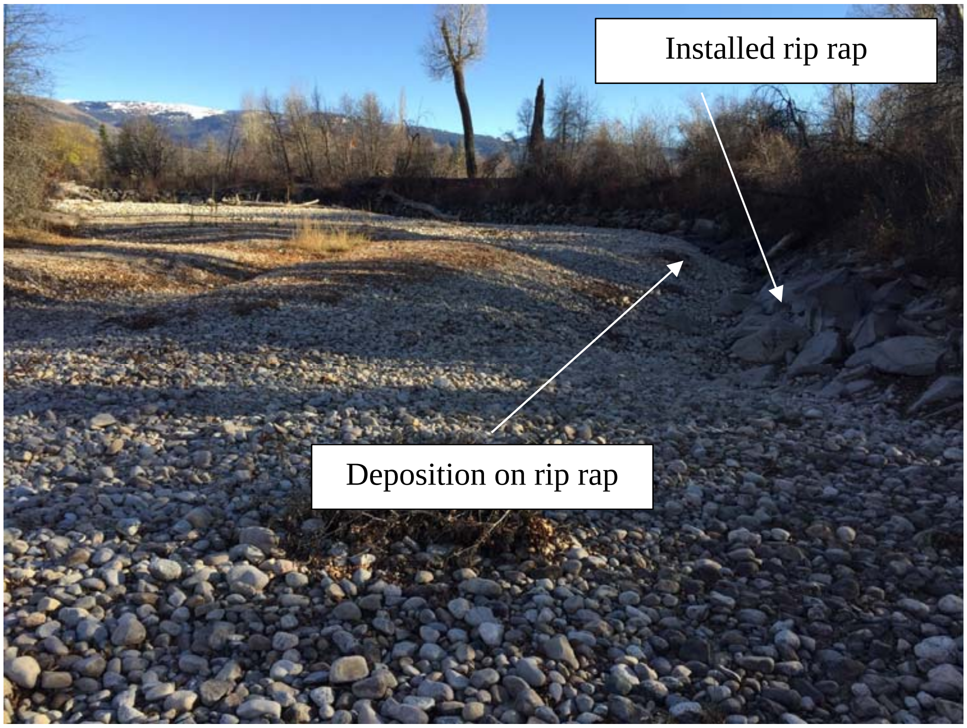

Figure 21. Photograph 19, sedimentation, pool filling, and channel aggradation covering installed rock rip rap, Station 89+00 ft.

Figure 22. Photograph 20, sedimentation, pool filling, and channel aggradation covering installed rock rip rap, Station 93+00 ft.

Point bar enlargement and sedimentation are typical of the sub-reach located in Creekside Meadows upstream of the Highway 33 Bridge (Figure 23). Point bar enlargement and widespread sedimentation promote increased sinuosity and bank erosion on the outside of meanders. (Figure 24).

Figure 23. Photograph 21, rapid bar formation, sediment storage, herbaceous vegetation colonization, and lateral channel migration, Station 101+00 ft.

Figure 24. Photograph 22, sedimentation and point bar enlargement promote bank erosion at the outside of meanders, Station 109+00 ft.

Near the downstream end of prominent aggradation in Creekside Meadows, individual transverse bars demonstrate high local gradient (Figure 25). Channel aggradation and sediment deposition are evident in the sub-reach of Teton Creek located upstream of the Highway 33 Bridge (Figure 26).

Figure 25. Photograph 23, transverse bar with 20 inches of local gradient, Station 111+00 ft.

Figure 26. Photograph 24, deposition in river left bay of Highway 33 Bridge, Station 115+00 ft.

Below the Highway 33 Bridge there is a short sediment starved reach that has robust riparian vegetation and stable banks. About 500 ft downstream of the Bridge, the channel regains a sinuous meandering channel form characterized with low bank height and moderate bank stability (Figure 27). From Station 124+00 ft downstream to Station 129+00 ft, severe aggradation is evident. A large debris jam precludes conveyance of instream flows within the historic channel alignment, bank heights are nominal, and instream flows escape the channel and are conveyed across the floodplain even during base flow levels (Figure 28).

Figure 27. Photograph 25, functional meandering single thread channel form downstream of Highway 33 Bridge, Station 121+00 ft.

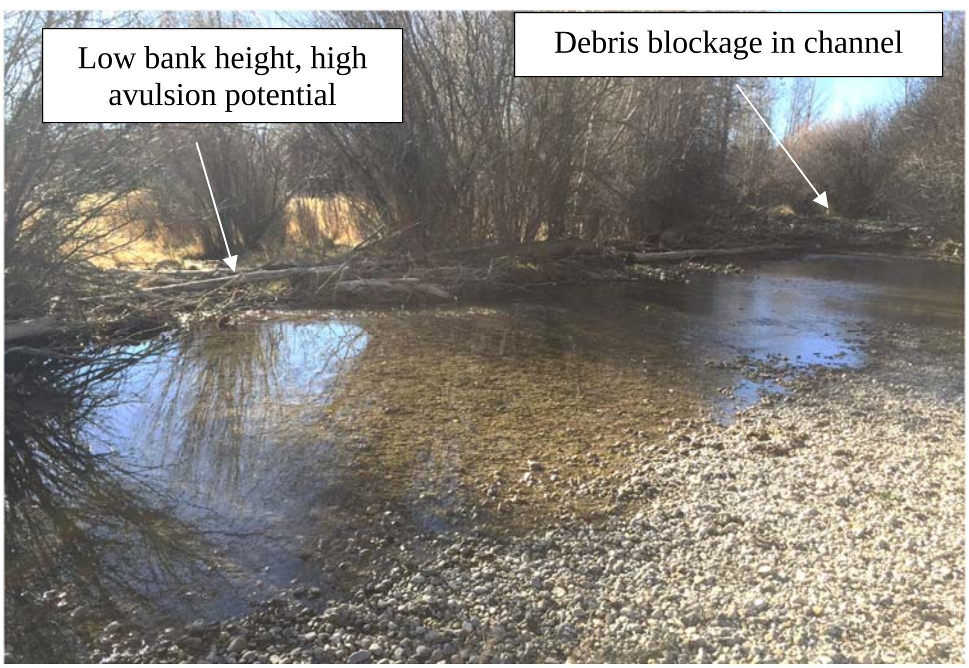

Figure 28. Photograph 26, channel blockage debris jam, widespread aggradation, and high avulsion potential, Station 128+00 ft.

Floodplain conveyance paths generally converge at about Station 139+00 ft to form a southern channel of Teton Creek that has a sinuous single channel form with low bank height and point bar formations (Figure 29). The northern channel of Teton Creek, which maintains a separate alignment from the southern historic channel, also has a sinuous single channel form and demonstrates point bar formation and bank erosion at the outside of meanders (Figure 30).

Figure 29. Photograph 27, typical highly sinuous meandering channel form with point bar formation and low bank height near downstream end of Assessment Reach, Station 143+00 ft.

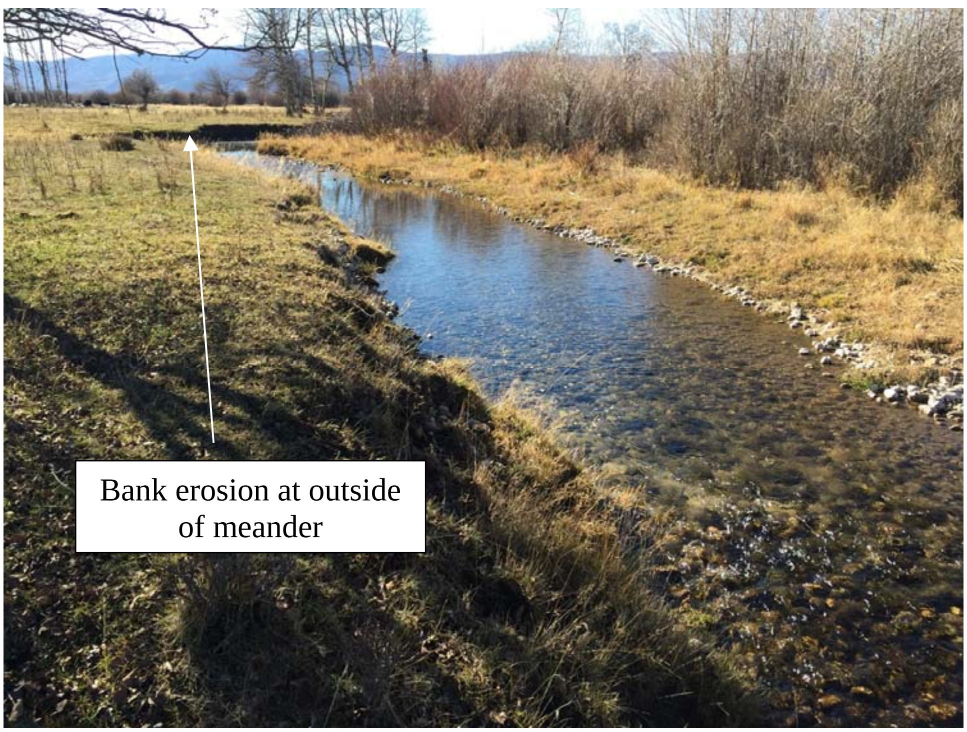

Figure 30. Photograph 28, typical highly sinuous meandering channel form with low bank height and ongoing lateral channel migration, Station 143+00 ft.

BEHI Results

The Bank Erosion Hazard Index (BEHI) survey results from the 2007 effort identified 20 segments of stream bank that had 'high' erosion hazard index with combined bank length of 4,360 ft (Sheet 7). The 2016 survey effort identified 11 segments of stream bank that have 'high' erosion hazard with combined bank length of 1,840 ft, and 32 segments of stream bank that have 'moderate' hazard with combined bank length of 5,675 ft (attached Sheet 8). Results of the two BEHI surveys were compared to identify areas of concern common to both assessments, and notably those areas of concern identified during the recent 2016 survey effort. Identified areas of concern related to bank instability (attached Sheet 9) include 23 segments of stream bank with combined bank length of 6,440 ft within the Assessment Reach. Bank instability areas of concern are generally concentrated in the upstream portion of the Assessment Reach where widespread point bar enlargement is promoting lateral channel migration, and in the sub-reach of Teton Creek located between Creekside Meadows and the Highway 33 Bridge where widespread aggradation is resulting in nearly contiguous bank erosion.

Bankfull Channel Slope

Bankfull channel slope was calculated for more than 50 sub-reach of Teton Creek associated with analyzed riffle bed feature locations. Bankfull slope in the Assessment Reach ranges from 0.13% to 1.01%, and the reach as a whole has an average slope of 0.66% with standard deviation of 0.21% (Figure 31). The reach of Teton Creek located upstream of the Cemetery Road Bridge has average bankfull slope of 1.1%, and the decreased channel slope within the Assessment Reach is attributed to a transition from the alluvial fan to the broad wide valley floor of the Teton River.

The channel slope within the Assessment Reach generally ranges from 0.6% to 1.0%. There is a sub-reaches with notably low channel slope located downstream of the Cemetery Road Bridge (from Station 0+00 ft to Station 10+00 ft). There is also a notable decrease in channel slope upstream of the Highway 33 Bridge (from Station 90+00 ft to 115+00 ft). These declines in channel slope are attributed to widespread channel aggradation occurring in the sub-reaches. Downstream of the Highway 33 Bridge, channel slope again decreases in the vicinity of the existing debris jam blockage in the primary channel (Station 125+00 ft).

The identified sub-reaches that demonstrate decreasing channel slope are areas of concern due to reduced sediment transport capacity and increased lateral channel migration. Isolated sub-reaches with elevated channel slope are of concern because increased channel slope results in increased energy and erosive potential. Sheet 10 (attached) depicts the slope of channel sub-reaches with a chloropleth map that identifies prioritized areas of concern due to discrepancies in channel slope; sub-reaches depicted in pink and beige have minimal channel slope, and sub-reaches depicted in red have elevated channel slope.

Bankfull Velocity

Bankfull flow velocity was calculated for more than 50 sub-reach of Teton Creek associated with analyzed riffle bed feature locations. Bankfull velocity in the Assessment Reach ranges from 1.34 ft/s to 6.52 ft/s, and the reach average velocity is 3.50 ft/s and standard deviation is 1.21 ft/s (Figure 32). The bankfull flow velocity is generally consistent throughout the Assessment Reach, with notable exceptions within a sub-reach located downstream of Cemetery Road Bridge and in sub-reaches located proximate to the Highway 33 Bridge.

Downstream of the Cemetery Road Bridge, decreased flow velocity in the primary channel is observed in an area where the channel is braided and meander cutoff channels are forming. In the middle of the Assessment Reach (from Station 50+00 ft to 80+00 ft) elevated flow velocities are observed in a reach that has relatively low sinuosity and moderate lateral confinement. Downstream of the bridge influence (Station 125+00 ft to 135+00 ft) decreased flow velocities are observed proximate to the debris blockage of the primary channel. Sheet 11 (attached) depicts the bankfull flow velocity of sub-reaches with a chloropleth map that identifies prioritized areas of concern due to discrepancies in velocity; sub-reaches depicted in pink and beige h ave minimal channel slope, and sub-reaches depicted in red have elevated channel slope.

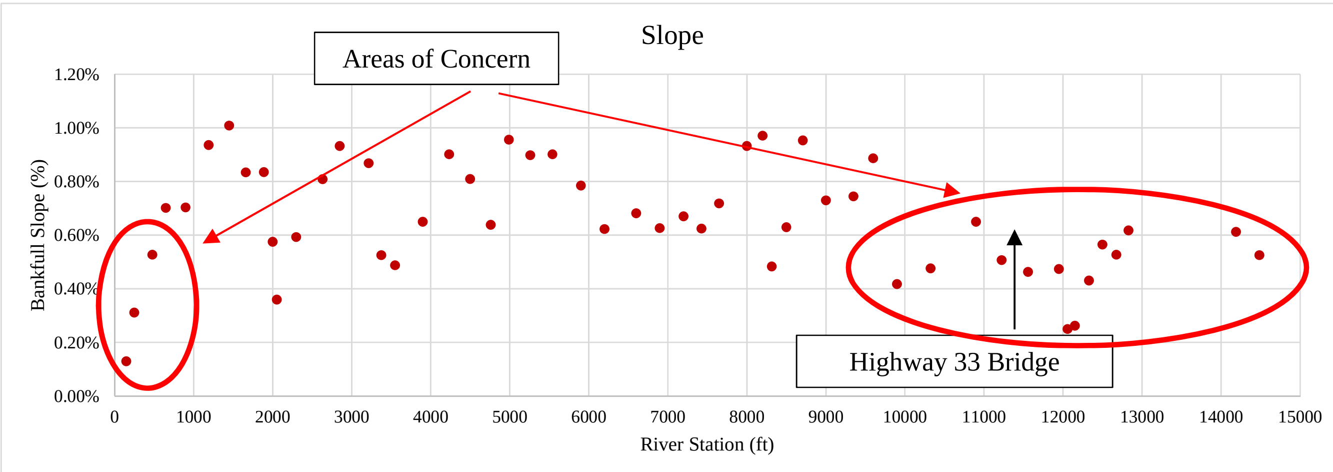

Figure 31. Chart of bankfull channel slope values within the Assessment Reach.

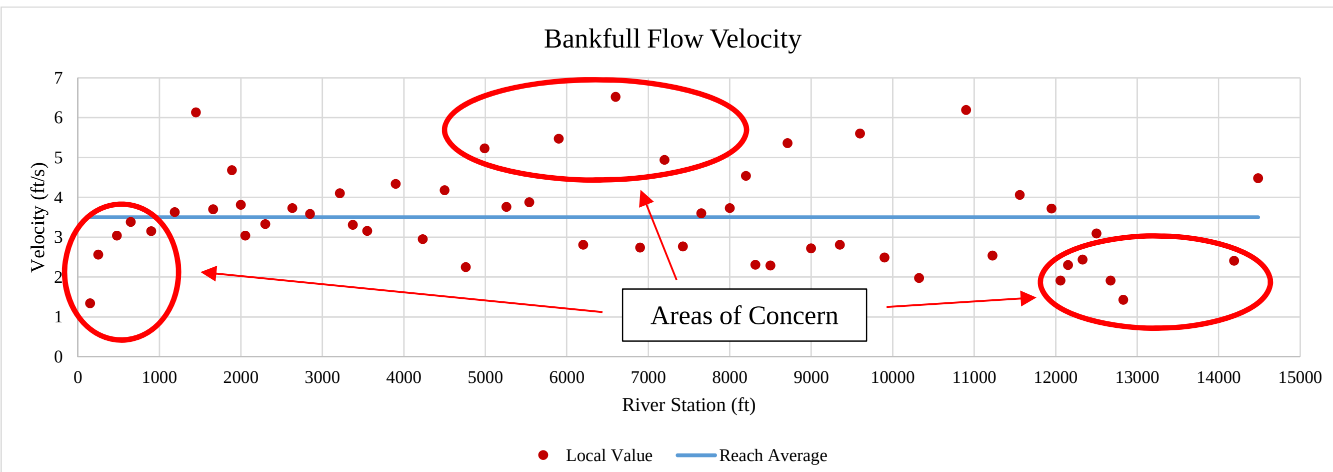

Figure 32. Chart of bankfull flow velocity values within the Assessment Reach.

Shear Stress

Bankfull shear stress is the force imposed on the channel margins (bed and banks) during the conveyance of instream flows. Shear stress was calculated for more than 50 sub-reach of Teton Creek associated with analyzed riffle bed feature locations. Bankfull shear stress in the Assessment Reach ranges from 0.10 lbs/sq ft to 0.93 lbs/sq ft, and the reach average shear stress is 0.50 lbs/sq ft and standard deviation is 0.19 lbs/sq ft (Figure 33). The shear stress analysis indicates areas of concern within the Assessment Reach where shear stress is either excessively high or significantly low.

Sub-reaches with elevated shear stress are generally located in the middle of the Assessment Reach (Station 25+00 ft to 80+00 ft) where the river is relatively straight and confined by bank armoring (rip rap). Elevated shear stress is also observed proximate to the Highway 33 Bridge where the bridge configuration eliminates floodplain conveyance and results in confinement of peak flows within the channel. These areas are of concern because elevated shear stress results in increased force imposed on the channel bed and banks, which results in increased erosive potential.

Areas of concern due to reduced shear stress are located downstream of Cemetery Road Bridge and in Creekside Meadows where widespread aggradation is observed. An extended sub-reach with reduced shear stress is located proximate to the debris blockage downstream of the Highway 33 Bridge (Station 130+00 ft). Sheet 12 (attached) depicts the bankfull shear stress of sub-reaches with a chloropleth map that identifies prioritized areas of concern due to discrepancies in shear stress; sub-reaches depicted in pink have minimal shear stress, and sub-reaches depicted in red have elevated shear stress.

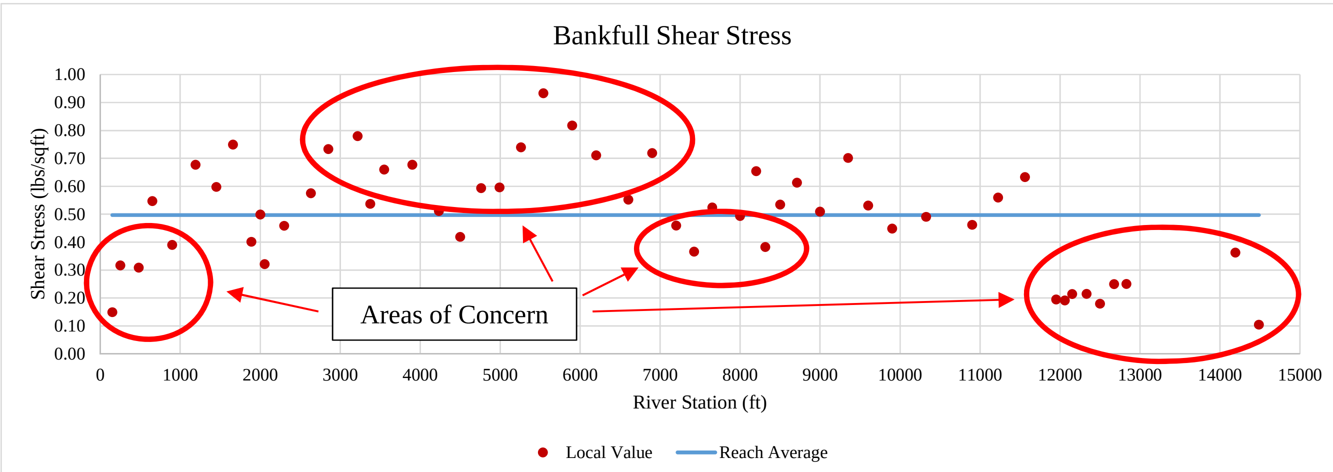

Figure 33. Chart of bankfull shear stress values within the Assessment Reach.

Stream Power

Stream power is the rate of energy dissipation against the channel margins (bed and banks) during the conveyance of instream flows, and relates to the ability of the stream to do work (alter) the channel bed and banks. Unit stream power was calculated for more than 50 sub-reach of Teton Creek associated with analyzed riffle bed feature locations. Bankfull unit stream power in the Assessment Reach ranges from 0.20 to 4.47, and the reach average stream power is 2.50 and standard deviation is 1.03 (Figure 34). The unit stream power analysis indicates areas of concern within the Assessment Reach where stream power is either excessively high or significantly low.

Sub-reaches with elevated stream power are generally located in the middle of the Assessment Reach (Station 50+00 ft to 75+00 ft ft) where the river is relatively straight and confined by bank armoring (rip rap). Elevated stream power is also observed proximate to the Highway 33 Bridge where the bridge configuration eliminates floodplain conveyance and results in confinement of peak flows within the channel. These areas are of concern because elevated stream power results in increased ability of the system to alter the channel bed and banks through erosive processes.

A sub-reach with reduced stream power was identified downstream of Cemetery Road Bridge in an area of channel braiding and deposition. Additional areas of concern due to reduced stream power are located in Creekside Meadows where widespread aggradation is observed (Station 80+00 ft to 100+00 ft), and proximate to the debris blockage downstream of the Highway 33 Bridge (Station 125+00 ft to 140+00 ft). Sheet 13 (attached) depicts the unit stream power stress of sub-reaches with a chloropleth map that identifies prioritized areas of concern due to discrepancies in stream power; sub-reaches depicted in pink and beige have minimal stream power, and sub-reaches depicted in red have elevated stream power.

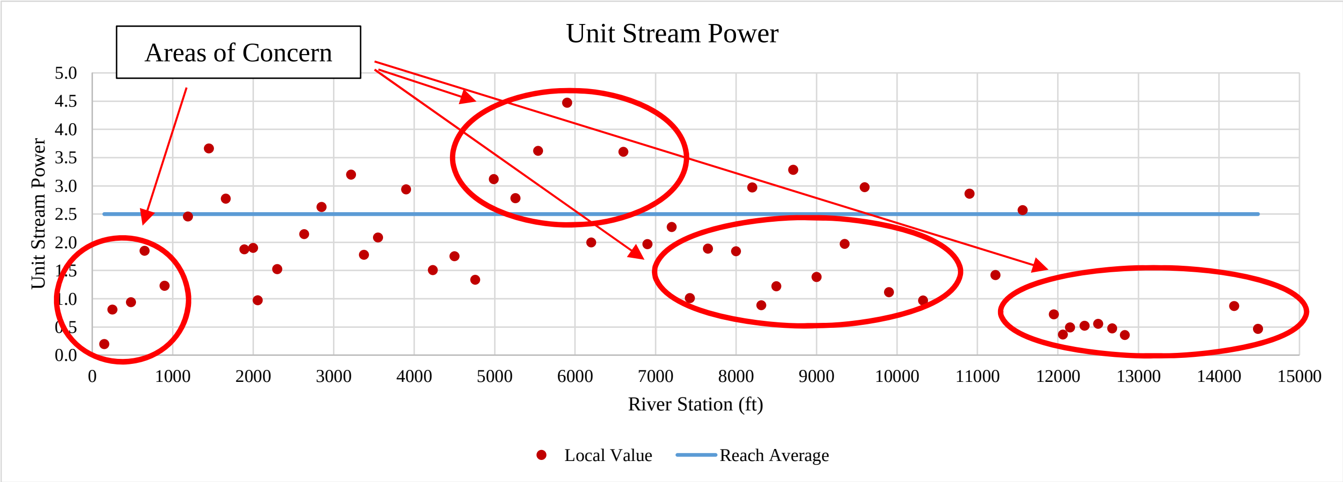

Figure 34. Chart of bankfull unit stream power values within the Assessment Reach.

Sediment Transport Competence

Sediment transport competence, or the ability of a river to entrain substrate based upon particle size, was quantified for more than 50 sub-reach of Teton Creek associated with analyzed riffle bed feature locations. Calculated dimensional shear stress values were used to identify the size particle entrained at bankfull discharge based upon a modified Shields curve depicting the incipient motion of sediment particles based on shear stress. Sub-reaches of the Assessment Reach are competent to mobilize surface grains with maximum sizes ranging from 1.1 to 5.7 inches, and the average reach condition is competent to mobilize particles up to 3.5 inches in diameter (Figure 35).

Friends of the Teton River (FTR) collected extensive sediment data from the Teton Creek Assessment Reach during previous field investigations. Sediment samples were collected in accordance with the Wolman pebble count protocol, and represent the measured B-axis of each particle. These data were obtained and stratified based upon sample site bed feature classification (riffle, pool, glide), and the samples collected from riffle bed features encompasses the active bed sediment sample. The sample has median particle size (D_{50}) of 1.4 inches, D_{84} of 2.8 inches, and D_{95} of 3.9 inches, and D_{100} of 7.1 inches. The size distribution of the surface grain sample is depicted in Figure 36.

Transport competence results were compared to the surface grain size class distribution to assess potential for the channel to mobilize stream bed material. Sediment transport analysis indicates areas of concern within the Assessment Reach where competence is high and there is potential for channel degradation (lowering), and where competence is low and there is potential for aggradation (sedimentation).

Sub-reaches with elevated sediment transport competence are generally located in the middle of the Assessment Reach (Station 25+00 ft to 80+00 ft) where the river is relatively straight and confined by bank armoring (rip rap). Elevated sediment transport competence is also observed proximate to the Highway 33 Bridge where the bridge configuration eliminates floodplain conveyance and results in confinement of peak flows within the channel. These areas are of concern because increased sediment transport competence could result in mobilization of substrate and degrading (lowering) of the stream channel.

A sub-reach with reduced sediment transport competence was identified downstream of the Cemetery Road Bridge (Station 10+00 ft) in a sub-reach with excessive channel width where deposition is resulting in channel filling. Additional areas of concern due to reduced sediment transport competence are located in Creekside Meadows where widespread aggradation is observed (Stations 75+00 ft, 85+00 ft, and 10+00 ft), and proximate to the debris blockage downstream of the Highway 33 Bridge (Station 125+00 ft to 140+00 ft). Sheet 14 (attached) depicts the sediment transport competence of sub-reaches with a chloropleth map that identifies prioritized areas of concern due to discrepancies in competence; sub-reaches depicted in pink have minimal sediment transport competence, and sub-reaches depicted in red have elevated sediment transport competence.

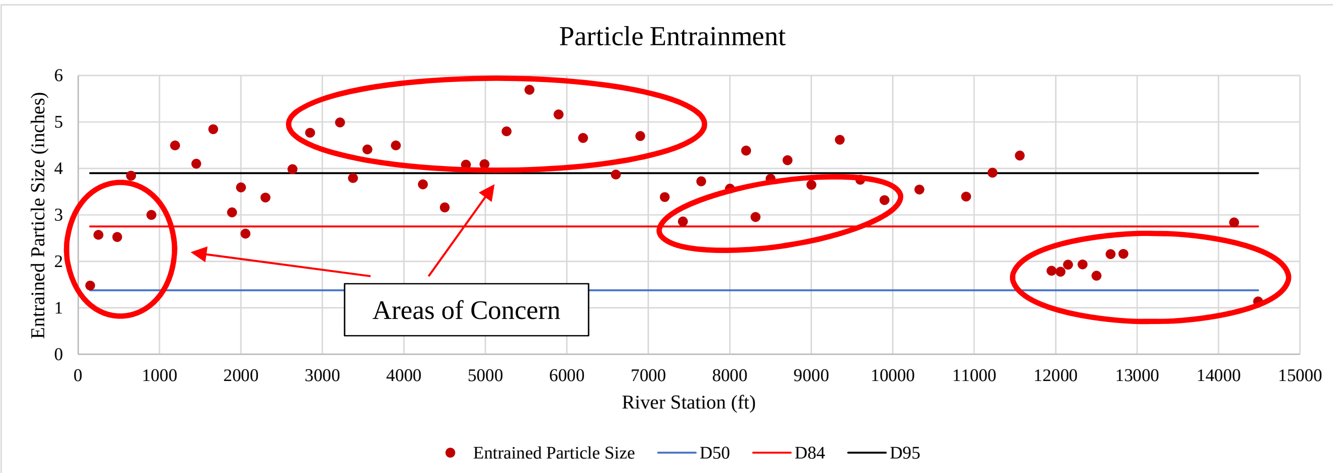

Figure 35. Chart of sediment transport competence (grain size) values within the Assessment Reach.

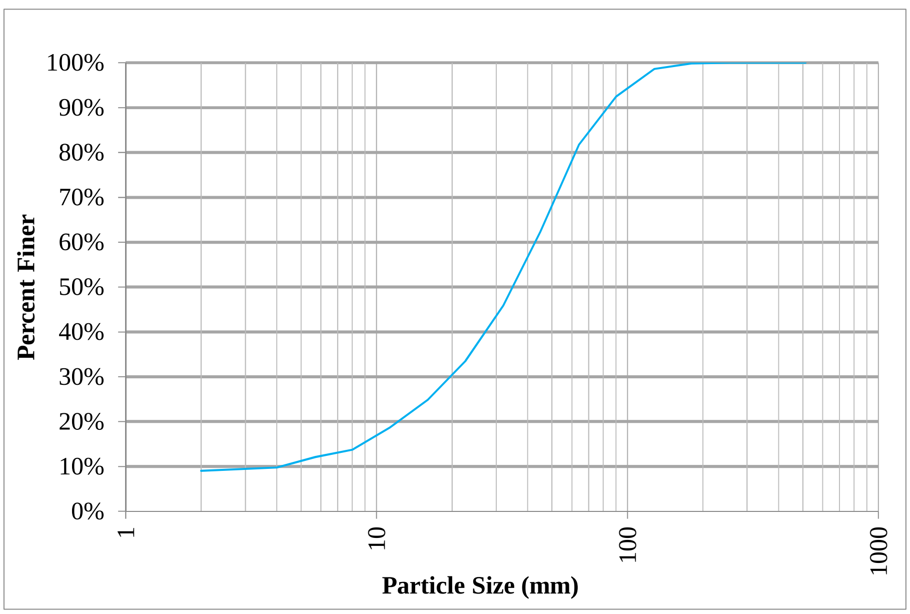

Figure 36. Chart of surface grain size distribution (grain size) within the Assessment Reach.

Sediment Transport Capacity

Sediment transport capacity is the total annual sediment load conveyed by a river segment. Annual bedload, suspended, and total sediment transport capacities were calculated for more than 50 sub-reach of Teton Creek associated with analyzed riffle bed feature locations. The sediment transport characteristics and channel conditions of the reach of Teton Creek upstream of the Assessment Reach (as presented on pages 4-5) were utilized to complete analysis of sediment transport with the FLOWSED/POWERSED model. The model calculates stream power in the supply and analysis reaches based on hydraulic geometry, develops sediment transport rating curves as a function of stream power, and applies the local flow duration curve to quantify stream power and derive total annual sediment transport capacity of the analysis reach.

Sediment transport capacity in the Assessment Reach ranges from 93 tons/yr to 1,499 tons/yr, and the reach average capacity is 370 tons/yr. Total annual sediment transport capacity of analyzed sub-reaches of Teton Creek are depicted in Figure 37, in which bedload capacity is depicted in red, suspended load capacity is depicted in blue, and the total sediment capacity is depicted by the total (summed) height of the bars in the chart.

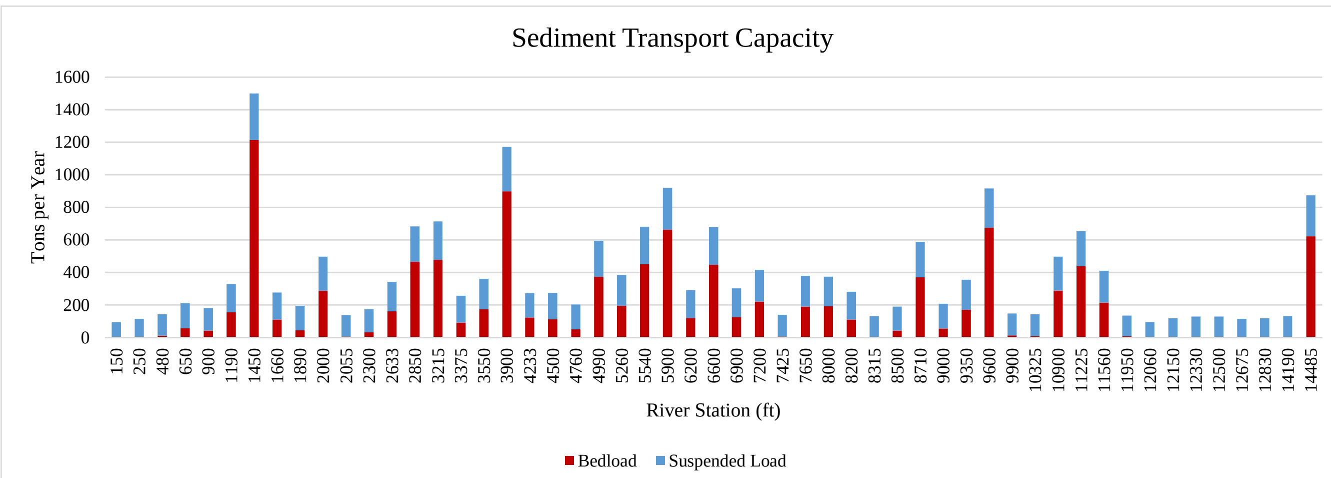

Figure 37. Chart of sediment transport capacity within the Assessment Reach.

Available analysis and data indicate that the reach of Teton Creek located upstream of the Cemetery Road Bridge supplies approximately 1,900 tons/yr of sediment to the Assessment Reach. In general, the Assessment Reach has insufficient sediment transport capacity to convey the sediment load supplied from upstream of Cemetery Road Bridge. The percentage of the total supplied load that could be conveyed by each analyzed sub-reach in the Assessment Reach is presented in Figure 38. The majority of the Assessment Reach has capacity to transport less than 50% of the supplied sediment load, and more than half of the Assessment Reach has capacity to transport less than a quarter of the supplied sediment load.

Continuity in sediment transport, or the equal balance between sediment supplied and sediment transported through a sub-reach, is not a realistic condition within the Assessment Reach. This is attributed to the fact that the Assessment Reach is located at the downstream terminus of the Teton Creek alluvial fan, at a location where valley (and stream) gradient are decreasing and sediment storage is anticipated to be a naturally occurring process in the reach. However, longer sub-reaches that consistently lack capacity to transport even a quarter of the sediment load are identified as areas of concern because sedimentation is anticipated to cause continued aggradation, lateral migration, and damage to proximate lands and infrastructure. These areas of concern are generally located downstream of the Cemetery Road Bridge

(Station 0+00 to 10+00), in Creekside Meadows (Station 7+50 to 110+00), and in the downstream reach proximate to the debris jam blockage of the primary channel (Station 125+00 to 130+00). Sheet 15 (attached) depicts the sediment transport capacity of sub-reaches as a percentage of the supplied sediment load with a chloropleth map that identifies prioritized areas of concern. Sub-reaches depicted in pink and red lack capacity to transport the supplied sediment load. Because the Assessment Reach generally lacks ability to transport the supplied sediment load, the whole reach is depicted in pink and red in the chloropleth map.

To further inform the analysis of sediment transport capacity, analysis was completed to quantify sediment transport capacity of sub-reaches as a percentage of the average condition in the Assessment Reach (Figure 39). The analysis identifies three areas where sub-reach sediment transport capacity is less than 50% of the Assessment Reach average condition. These impaired sub-reaches are located downstream of the Cemetery Road Bridge (Station 0+00 to 10+00), in Creekside Meadows (Station 7+50 to 110+00), and downstream of the Highway 33 Bridge (Station 120+00 ft to 140+00 ft).

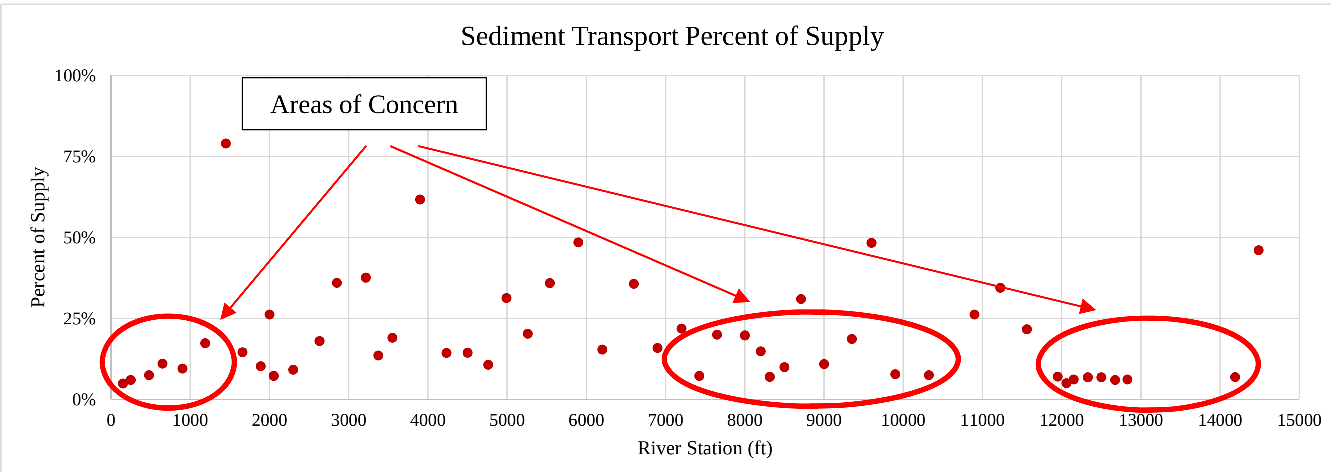

Figure 38. Chart of sediment transport capacity as a percentage of the sediment load supplied to the Assessment Reach from the upper reaches of Teton Creek.

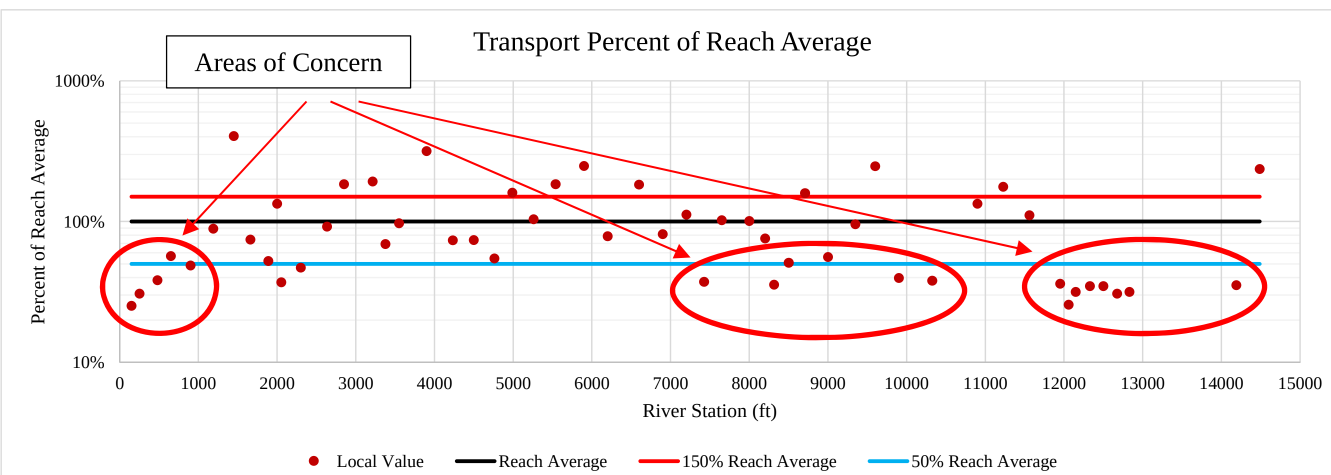

Figure 39. Chart of sediment transport capacity as a percentage of the Assessment Reach average condition.

The assessment of sediment transport capacity identifies the challenges of sediment storage within the Assessment Reach. The existing residential development and infrastructure proximate to Teton Creek present challenges to achieving appropriate sediment storage in the Assessment Reach because sediment storage is often associated with channel aggradation and lateral channel migration that pose direct threats to adjacent infrastructure. However, design components could be pursued in the Assessment Reach in order to make sediment transport capacity more consistent throughout the reach. Due to the discrepancy between average sediment transport capacity in the Assessment Reach and the upstream supply reach, it is unlikely that improving sediment storage and transport capacity in the Assessment Reach would have dramatic influence on the availability of finer grained sediment (e.g. gravels) that are critical for biological components of the system such as cutthroat trout spawning habitat. Improved sediment transport conditions would not be expected to store all the sediment moving through the reach, but could alleviate concerns over severe localized problem areas.

HISTORIC FLUVIAL CONDITIONS

Analysis of historic aerial imagery reveals changes in channel alignment and length that have occurred within the Assessment Reach. Historic aerial imagery from 1943 was obtained and the alignment of Teton Creek within the Assessment Reach was mapped (attached Sheet 17). Historic imagery from 1973 was also obtained and the channel alignment mapped (attached Sheet 18). The length of the Teton Creek channel within the Assessment Reach in 1943 was 13,110 ft. By 1973 the channel length had increased by 550 ft to a total of 13,600 ft. By 2015 the length of the Teton Creek channel within the Assessment Reach was 14,490 ft, indicating that the channel length had increased by 1,380 ft since 1943, or by over 10%.

Fluvial system impairment within the Creekside Meadows reach of Teton Creek was identified during field assessment of channel conditions and Bank Erosion Hazard Index in addition to hydraulic analysis of bankfull channel slope, shear stress, stream power, sediment transport competence, and sediment transport capacity. Analysis of historic aerial imagery within the Creekside Meadows reach indicates that the length of the Teton Creek channel increased from 3,001 ft in 1943 to 3,877 ft in 2015 (attached Sheet 19). The increase in channel length of 876 ft within Creekside Meadows accounts for more than half of the total increased channel length observed across the nearly 3 mile long Assessment Reach. Furthermore, the changes in channel alignment observed within Creekside Meadows equates to a localized increase in channel length of 30%. The dramatic localized increase in channel length could be attributed to the influx of excessive sediment mobilized during channel enlargement and head-cut migration in the upstream destabilized reaches of Teton Creek. Excessive sediment delivery would have resulted in deposition that filled the channel and promoted increased lateral channel migration and increased sinuosity. Restoration efforts within Creekside Meadows should consider treatments that reduce channel length in order to increase local slope and sediment transport capacity in order to reduce ongoing severe aggradation.

ASSESSMENT REACH AREAS OF CONCERN

Specific areas of concern within the Assessment Reach were identified during the geomorphic assessment (attached Sheet 20), and are presented below from upstream to downstream.

DOWNSTREAM OF CEMETERY ROAD BRIDGE (STATION 5+00 TO 20+00 FT)

The reach of Teton Creek located downstream from Cemetery Road Bridge (approximate Stationing 5+00 to 20+00 ft) demonstrates below average flow velocity, shear stress, and stream power in the primary channel. The reach has impaired sediment transport competence and capacity, and numerous meander cutoff channels are forming and enlarging. The reach is an area of concern because impairment in the primary channel is promoting meander cutoff channel formation, which results in loss of riparian areas and the entrainment and delivery of supplemental sediment to downstream stream reaches. Restoration efforts in this reach should explore opportunities to establish functional channel dimension, pattern, and profile to increase sediment transport capacity while simultaneously providing opportunities for sediment storage in a manner that does not result in primary channel aggradation.

MID- REACH (STATION 60+00 TO 75+00 FT)

The segment of Teton Creek located near the middle of the Assessment Reach (approximate Stationing 60+00 to 75+00 ft) demonstrates elevated shear stress and stream power in addition to the highest sediment transport competence observed within the reach. This segment of Teton Creek has extensive bank armoring, and numerous locations where rock rip rap has been installed on point bars and on opposing river banks. Restoration efforts in this reach should explore opportunities remove excessive bank armoring and increase floodplain conveyance in order to reduce in-channel energy, reduce potential for channel degradation (lowering), and reduce potential for the entrainment and delivery of excessive sediment to impaired downstream reaches.

CREEKSIDE MEADOWS (STATION 80+00 TO 114+00 FT)

The reach of Teton Creek located within Creekside Meadows (approximate Stationing 80+00 to 114+00 ft) demonstrates significantly diminished bankfull channel slope, shear stress, and stream power. The reach has impaired sediment transport competence and capacity, and is experiencing severe and widespread channel aggradation and lateral erosion. This reach is an area of concern because continued impairment of fluvial function has potential to adversely impact proximate infrastructure and public health, safety, and welfare. The Creekside Meadows Bridge does not appear to be a primary cause of fluvial system impairment within the reach, although floodplain conveyance under the Creekside Meadows Avenue roadway could be improved through addition of culverts at the bankfull elevation north of the bridge proper. Restoration efforts in the Creekside Meadows reach should explore opportunities to establish functional channel dimension, pattern, and profile to increase sediment transport competence and capacity. Treatments that reduce stream length in order to increase slope and sediment transport regime should be considered.

HIGHWAY 33 BRIDGE

The reach of Teton Creek located adjacent to the Highway 33 Bridge (approximate Station 115+00 ft) demonstrates elevated bankfull flow velocity, shear stress, stream power, and sediment transport competence. The elimination of floodplain conveyance by the bridge structure results in the convergence and confinement of peak flows within the primary channel. This segment of Teton Creek is an area of concern because backwater conditions maintained by the bridge during peak flow events adversely impact the upstream impaired reach of creek through Creekside Meadows by promoting aggradation and lateral migration while increasing avulsion potential. Restoration efforts in this reach should explore opportunities to increase floodplain conveyance through installation of culverts at the bankfull elevation adjacent to the highway and pathway bridges, or through installation of longer bridges that span an inset floodplain of sufficient width to reduce backwater effects during peak flow events.

DEBRIS BLOCKAGE AREA (STATION 125+00 TO 135+00 FT)

The reach of Teton Creek proximate to the debris blockage downstream of the Highway 33 Bridge (approximate Stationing 125+00 to135+00 ft) demonstrates reduced channel slope, the lowest flow velocities observed within the Assessment Reach, and reduced shear stress and stream power. The reach has impaired sediment transport competence and capacity, and is experiencing severe channel aggradation that has resulted in nominal bank height and channel capacity in addition to the establishment and enlargement of cutoff channels that are activated even during low flow conditions. The debris blockage (log jam) located within the reach does not appear to be the cause of local fluvial system impairment, but is a symptom of insufficient sediment transport capacity and aggradation. This reach is an area of concern because heightened avulsion potential within the reach could result in dramatic shifts in the alignment of Teton Creek and the loss of extensive riparian areas. Restoration efforts in this reach should explore opportunities to establish functional channel dimension, pattern, and profile to increase sediment transport competence and capacity. Treatments that establish braided (anastomosing) channel configurations that facilitate sediment storage without promoting aggradation or avulsions should be considered.

BANK EROSION HAZARD INDEX PRIORITIZED LOCATIONS

The BEHI methodology was used to characterize stream banks throughout the Assessment Reach, and to identify areas of concern related bank erosion. These areas of concern are generally concentrated in the upstream portion of the Assessment Reach where widespread point bar enlargement is promoting lateral channel migration, and in the sub-reach of Teton Creek located between Creekside Meadows and the Highway 33 Bridge where widespread aggradation is resulting in nearly contiguous bank erosion. These areas are of concern because increased bank erosion results in the entrainment of additional sediment to the stream reach, most of which is already impaired as a result of excessive sediment load. Restoration efforts to increase bank stability at identified locations should be pursued. Bank stabilization treatments should not simply be implemented to stabilize stream banks at the existing location. Instead, bank stabilization efforts should be implemented in order to establish and maintain functional channel dimension and pattern in order to accomplish previously identified sub-reach objectives of improving sediment transport regime.

UPSTREAM AREAS OF CONCERN

Additional areas of concern within Teton Creek were identified upstream of the Assessment Reach (attached Sheet 21). These areas of concern are identified as priorities for additional investigation because existing or potential fluvial conditions at these locations could result in severe impacts to the Teton Creek corridor, including the Assessment Reach.

CHANNEL DIVERGENCE, WYOMING

The existing channel split, or divergence, located in Teton Creek approximately ½ mile upstream of the State Line should be assessed in order to identify potential need for active maintenance of the location. Future changes in the configuration of the channel divergence could result in uneven distribution of the instream flows between the northern and southern channel alignments, which would directly impact the bridges located at the State Line and more than a mile of Teton Creek corridor through which the watercourse currently has a split flow configuration. The enlargement of either of these distinct channels resulting from changes at the channel divergence would result in additional sediment entrainment and delivery to downstream reaches of Teton Creek that are currently impaired as a result of excessive sediment load. Assessment of the channel divergence should consider whether or not additional stabilization of management of the channel split is warranted.

STATE LINE ROAD BRIDGES

The bridges that cross the two distinct channels of Teton Creek at State Line should be assessed in order to determine whether or not efforts to increase bridge span or conveyance capacity are warranted. Severe localized bank erosion has occurred along the right bank of the southern bridge, and was stabilized through installation of stream bank bioengineering treatments in 2013. If future changes at the upstream channel convergence occur, the existing bridges may be inadequate to convey delivered flows and sediment, which could result in significant damage to public transportation infrastructure and threat to public welfare.

DISPERSED HEAD-CUT REACH

Geomorphic investigations completed in 2013 identified the location of a dispersed head-cut feature located proximate to the Redtail Subdivision and the Targhee Hill Estate Subdivision. The head-cut formed as a result of illegal dredging activities that occurred in Teton Creek in the 1980's, and has since dispersed and migrated upstream. Resultant channel enlargement has resulted in the entrainment and delivery of excess sediment load to downstream reach of Teton Creek. Continued migration of the head-cut could result in further channel enlargement, and additional delivery of excess sediment to downstream reaches. Assessment should be completed to investigate economical ways though which the head-cut feature could be stabilized in order to prevent further impact to the Teton Creek corridor. Head-cut stabilization could be accomplished through installation of grade control structures and reconstruction of stable channel geometry designed to achieve continuity in sediment transport competence and capacity under the expected hydrologic conditions.

GREEN RANCH PROPERTY BANK EROSION

Areas of localized severe bank erosion on the historic Green Ranch property located about 1 mile upstream of Cenetery Road Bridge are contributing excessive sediment to Teton Creek. Restoration efforts at these locations should be considered, and treatments that increase bank stability while increasing local sediment transport competence and capacity explored.

BUFFALO SPRINGS DIVERSION

The Buffalo Springs side channel divergence located approximately 500 ft upstream of the Cemetery Road Bridge should be modified to reduce near bank velocity and shear stress, to improve continuity in sediment transport, and to improve the consistent delivery of water to the diversion. Localized deposition or shifts in channel configuration at the location could impair the delivery of appropriated water to downstream users, who could subsequently pursue efforts to modify local channel conditions to restore water delivery without regard for reach-wide fluvial processes or fluvial management objectives. Restoration treatments should be implemented that maintain reliable delivery of appropriated water while accomplishing reach-wide objectives of fluvial function.

CONCEPTUAL DESIGNS

Restoration efforts within the Teton Creek corridor should establish a self-maintaining channel form that conveys the supplied peak flows with improved sediment transport capacity and storage. The establishment of suitable channel width, depth, and profile is critical to achieving these objectives. This aspect of river restoration is depicted visually in Figure 40 in which an impaired channel form (overly widened, deepened, and straightened) lacks the ability to convey hydrologic and sediment inputs without severe localized erosion and flooding. The reference condition for the reach (also depicted in Figure 40) has more narrow and shallow geometry, but provides the ability to convey hydrologic and sediment inputs without severe localized erosion or flooding.

The functional (restored) channel geometry can be established in impaired reaches through channel narrowing and the establishment of an inset floodplain bench. This treatment type is depicted in Figure 41, in which the placement of alluvium is used to narrow the existing channel and the fill is placed in order to establish a bench at the local floodplain elevation. The bench is then vegetated with native riparian vegetation through installation of vegetative transplants, direct seeding, or passive recruitment.

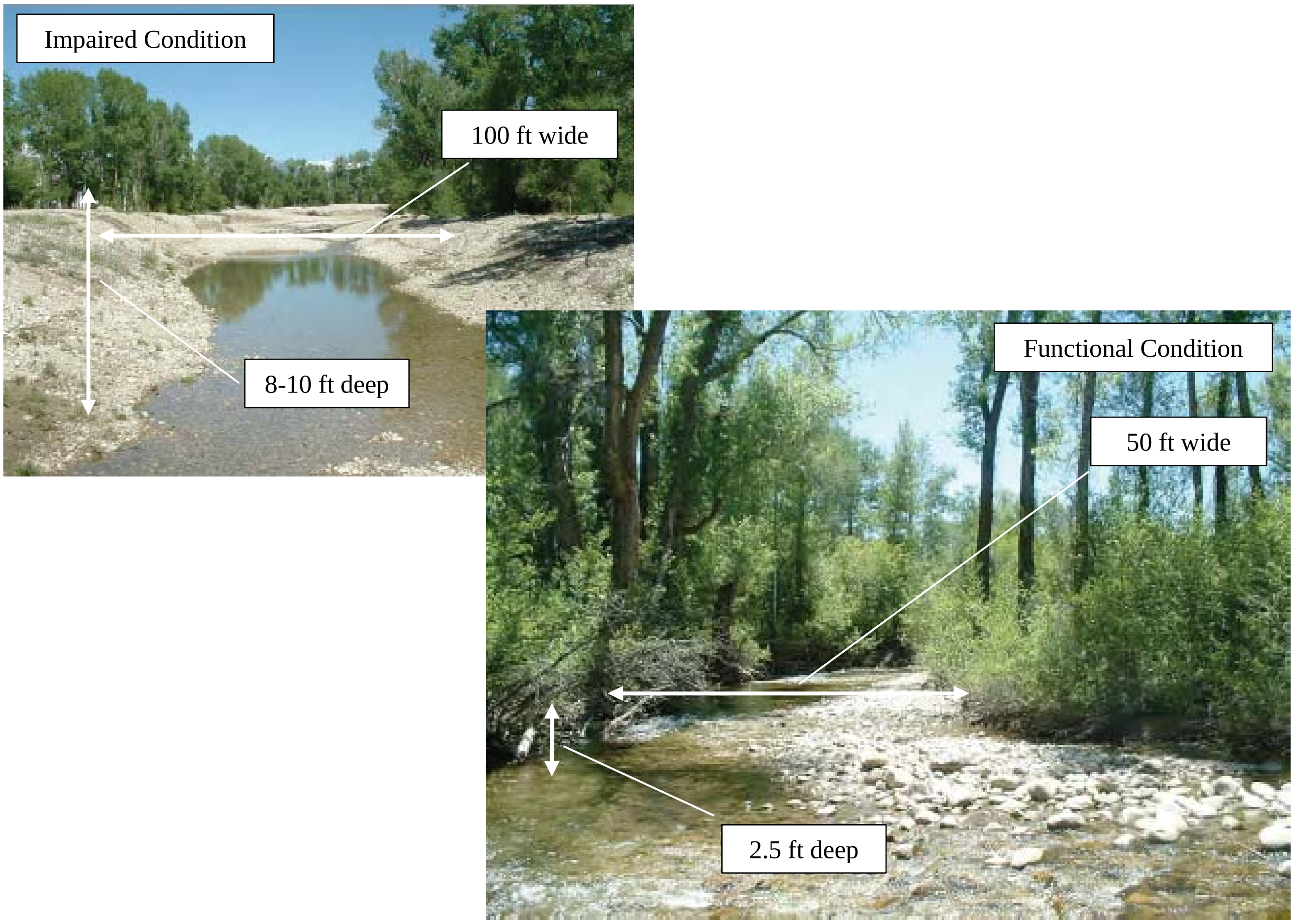

Figure 40. Photographic depicting of impaired channel form compared to functional channel form in Teton Creek.

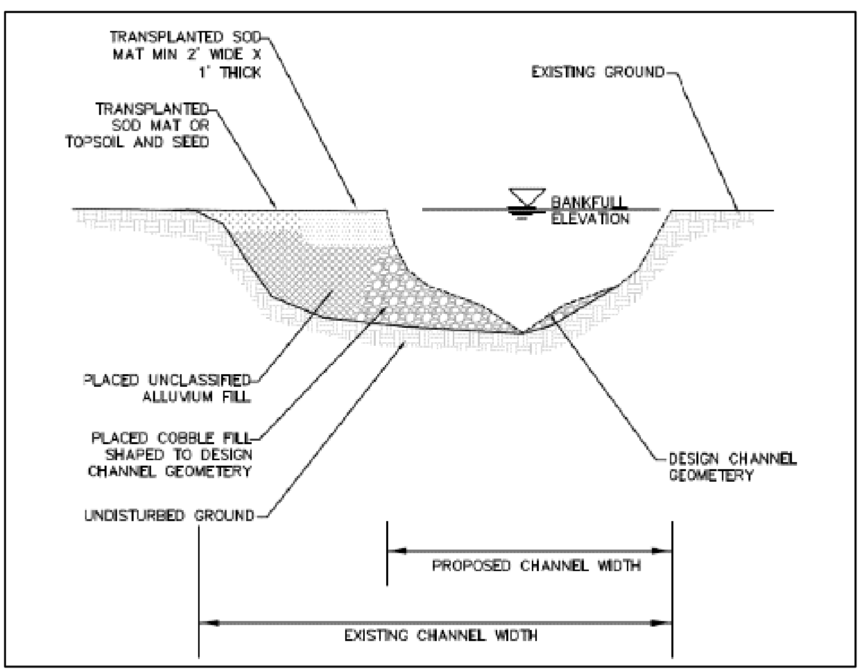

Figure 41. Typical design of channel narrowing and floodplain bench creation.

Channel realignment is another restoration tool that can be applied to establish a functional channel pattern (alignment) that conveys flood waters while allowing for energy dissipation and channel stability. The typical application of this restoration approach is depicted visually in Figure 42 from a project that involved construction of a functional channel alignment where the existing channel meander pattern impaired sediment movement, compromised bank stability, and reduced fish habitat values.

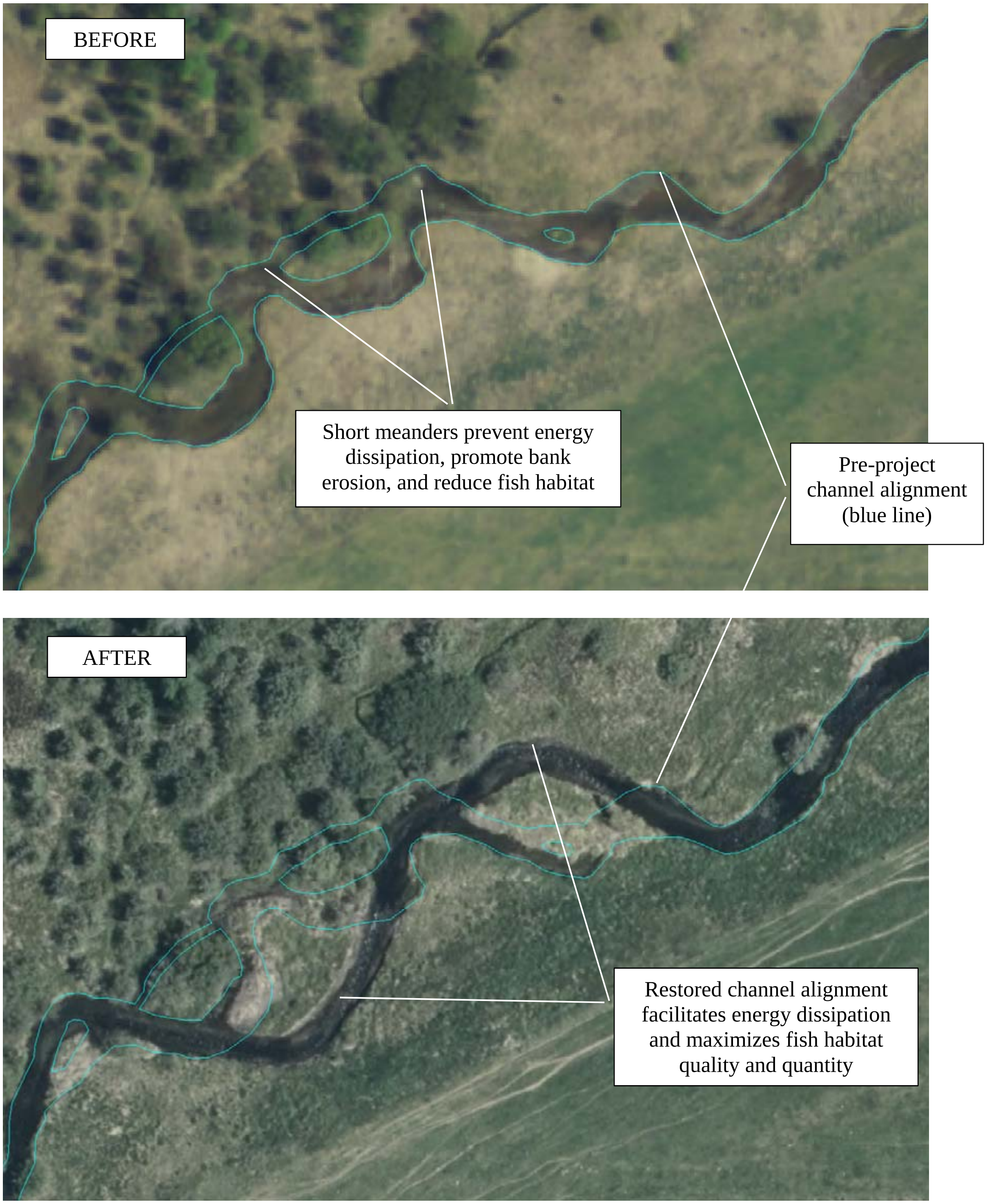

Figure 42. Photographic example of channel realignment applied to establish functional channel pattern to convey flood flows while enable energy dissipation and channel stability.

WOOD REVETMENT BANK STABILIZATION

The wood revetment bank stabilization treatment can be used to establish the functional channel geometry and alignment. The treatment utilizes large woody members (root wads, conifer or cottonwood logs, woody shrubs, broken-ended logs) to stabilize the bank toe, transplanted woody clump vegetation to increase near-bank hydraulic roughness, and transplanted sod mats (or similar herbaceous vegetative treatment) to achieve a vegetated bench at the local bankfull elevation. The incorporation of woody members to accomplish bank stabilization is preferable to a traditional rock riprap treatment because the protrusion of wood into the bankfull channel increases hydraulic roughness at the channel margin and reduces near-bank flow velocities and shear stress. These effects, in combination with hardening of the bank toe material, constitute a multi-faceted approach to bank stabilization that reduces near bank erosion potential while simultaneously increasing the erosion resistance of the bank.

The treatment design does not incorporate unnatural materials such as cable, rebar, or concrete. All live plant materials associated with the bank stabilization treatment are installed in precise configurations using techniques described in Hoag's 2002 *Streambank Soil Bioengineering Field Guide*. Figures 43 and 44 depict the bank stabilization treatment in profile and plan view.

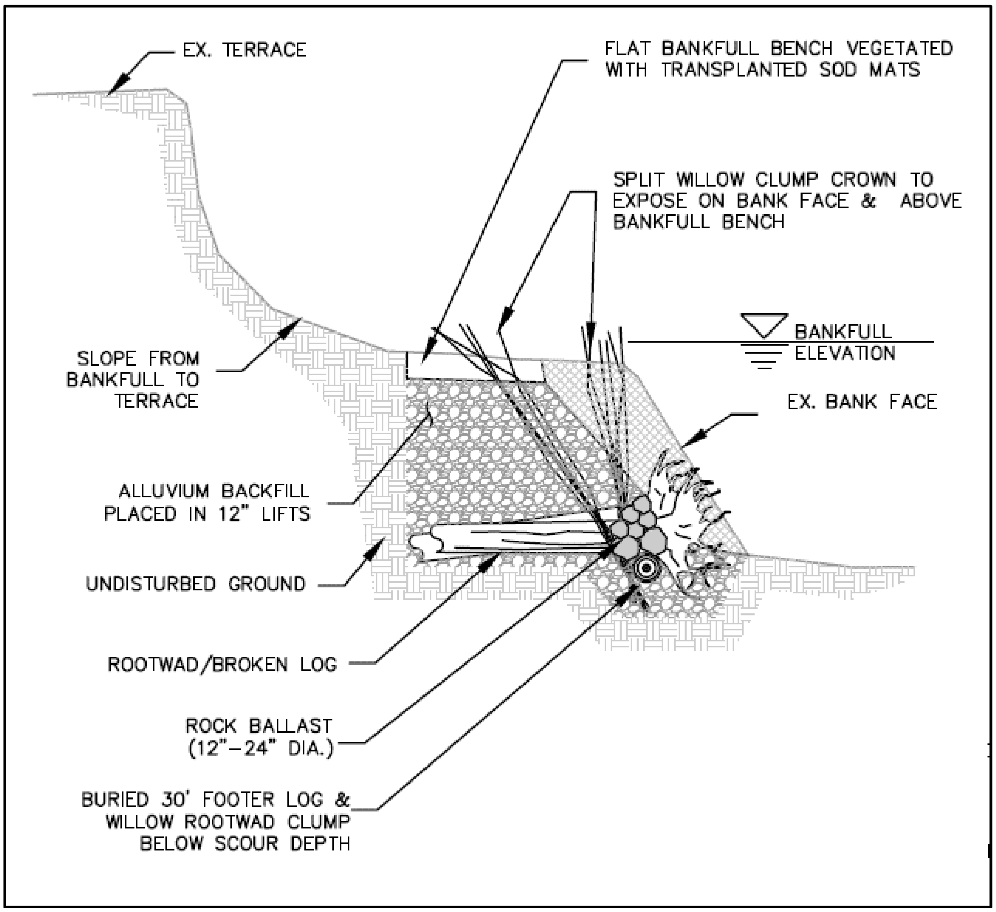

Figure 43. Profile view of typical wood revetment bank stabilization treatment.

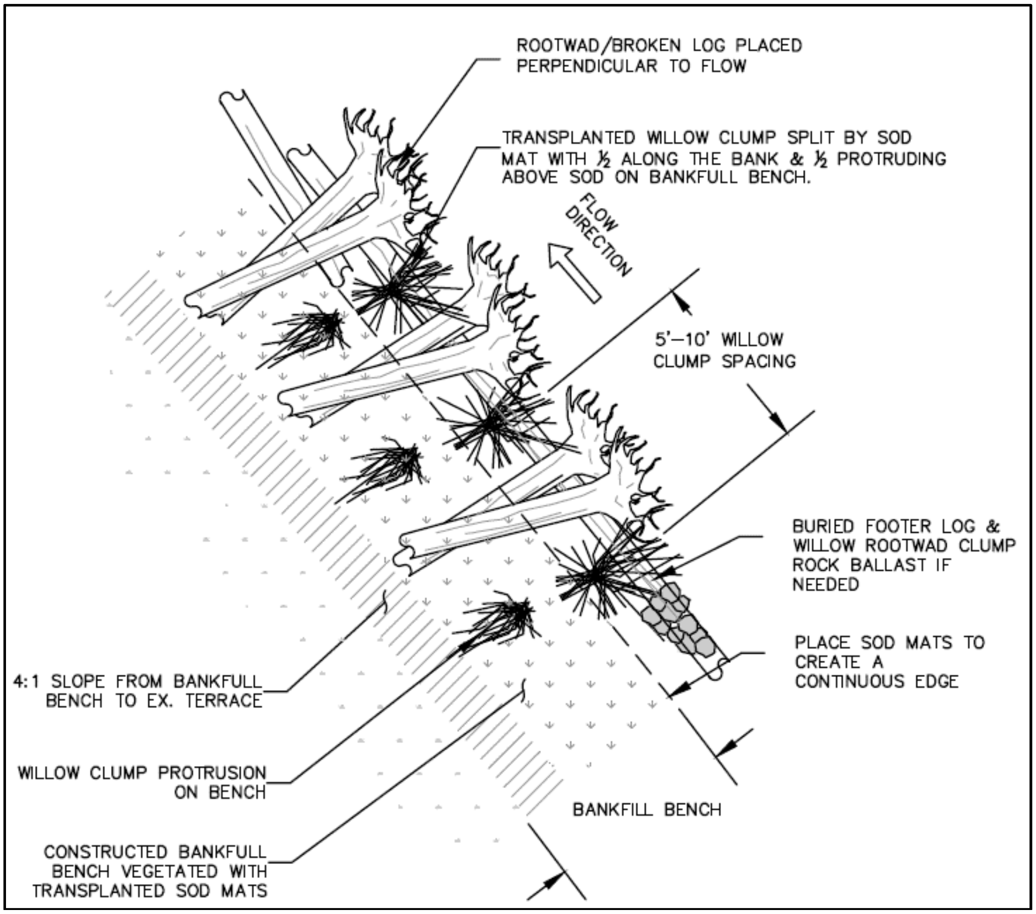

Figure 44. Plan view of typical wood revetment bank stabilization treatment.

The wood revetment bank treatment is depicted visually in Figures 45 and 46 from projects recently completed in the region. Installed large wood (root wads and logs) harden the lower half of the river bank. Ballast and herbaceous vegetation were installed to establish a floodplain bench at the bankfull elevation. The installed large wood protrudes into the channel several feet (below the water surface), which reduces flow velocities, increases bank stability, and provides complex cover for fisheries benefit.

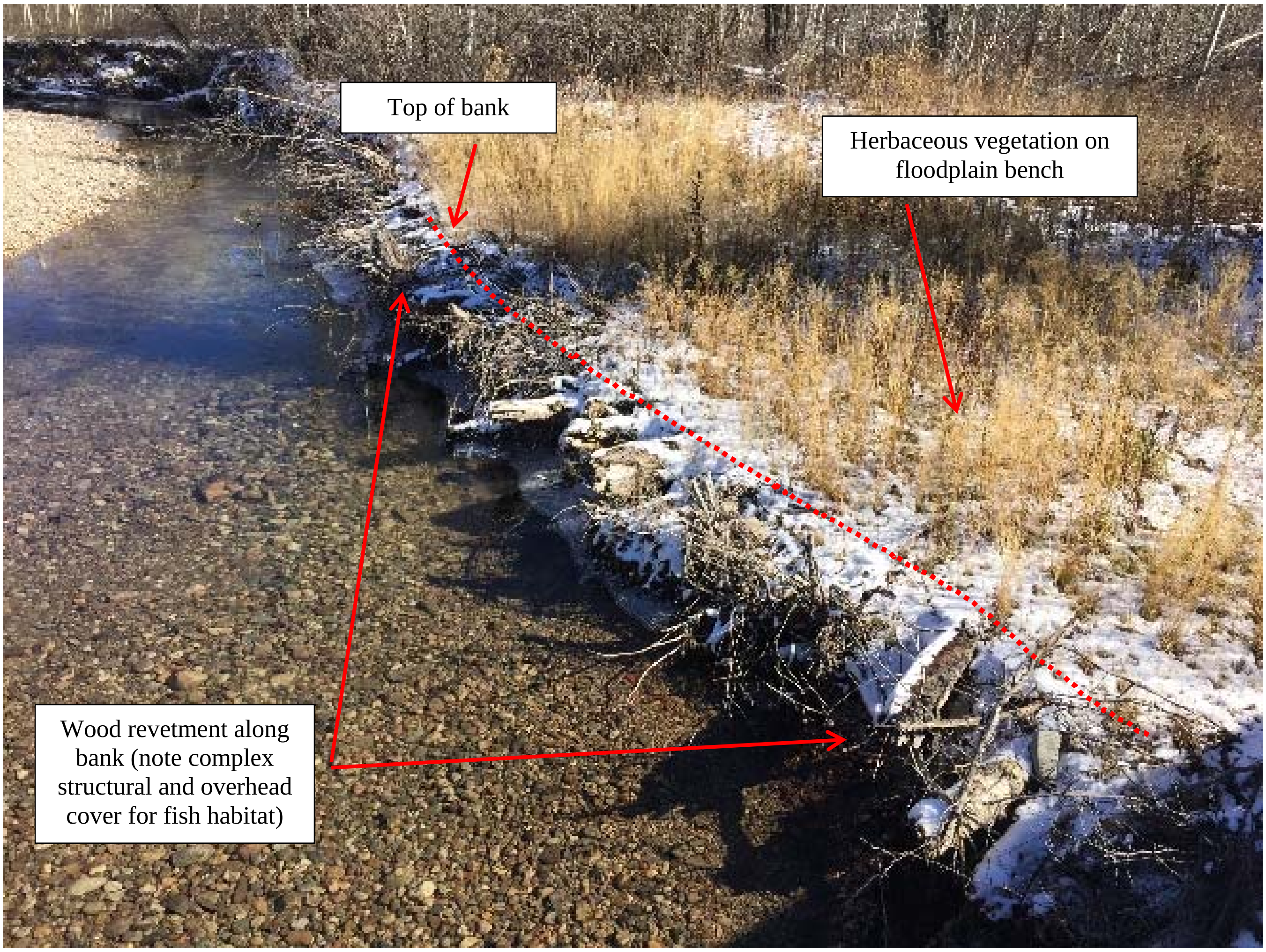

Figure 45. Wood revetment installed along river bank to prevent bank erosion, establish suitable channel width, and enable floodplain inundation.

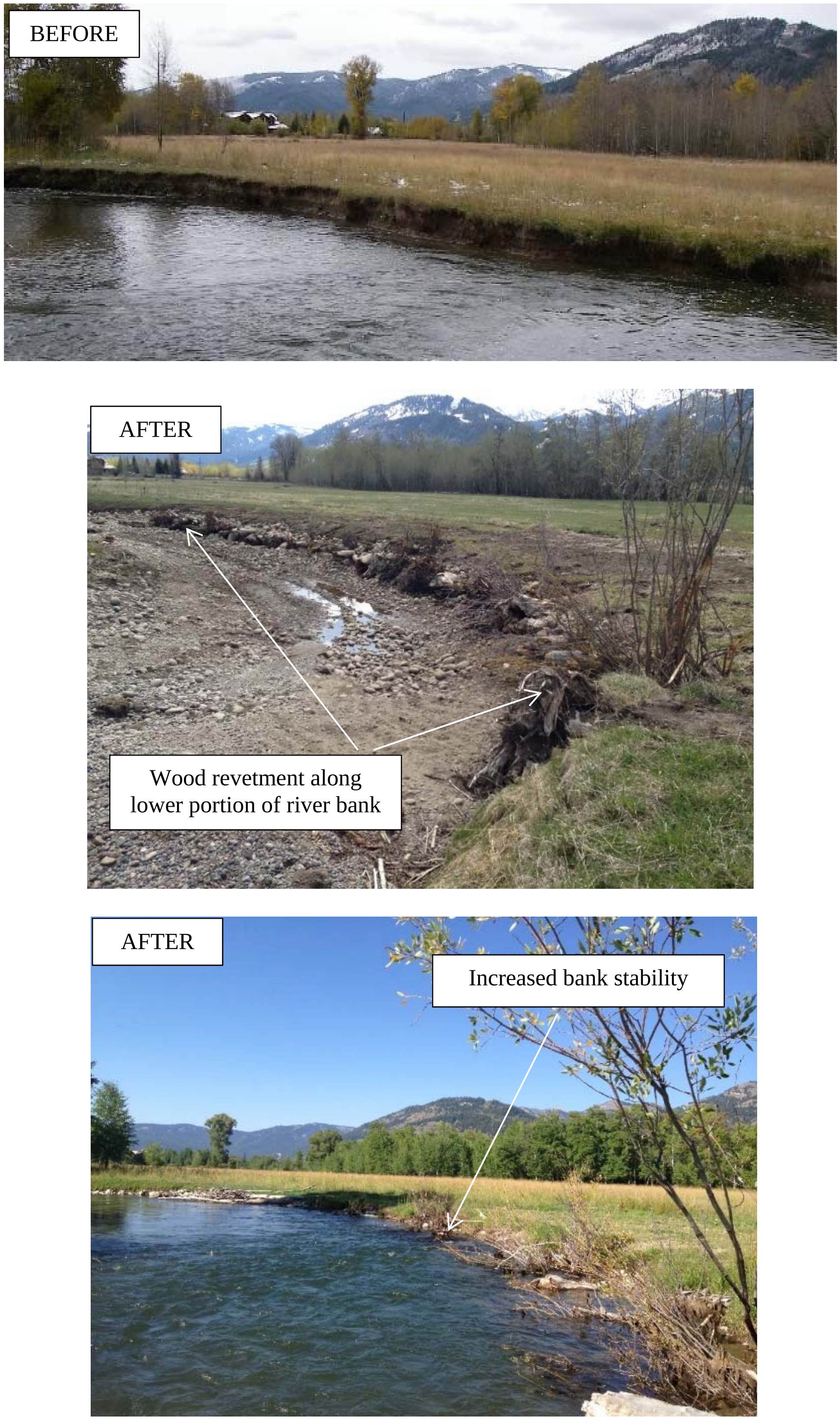

Figure 46. A severely eroding river bank (top) stabilized with the wood revetment treatment (middle). The treatment effectively reduces bank erosion hazard by reducing near-bank flow velocities and shear stress.

ROCK REVETMENT BANK STABILIZATION

Rock revetment bank stabilization is a less preferable treatment than the wood revetment treatment because the rock treatment typically does not incorporate features that increase hydraulic roughness or reduce flow velocities in the near bank zone. However, rock revetments can be better suited to bank stabilization at locations where existing infrastructure or landforms inhibit the installation of woody members that are sufficiently keyed into the bank.

The rock revetment treatment involves placement of rock from a key trench located adjacent to the bank toe up to the local bankfull elevation. Installed rock should not protrude above the local bankfull elevation and should not encumber flood water access to the floodplain; the dispersal of peak flows across the floodplain enables energy dissipation and helps prevent excessive shear stress (and related erosion) in the near bank zone. During installation of the rock revetment, bundles of dormant woody vegetation cuttings are installed in the river bank at sufficient depth to access the lowest seasonal groundwater elevation. Bundles are installed vertically and at 45 degree angles from horizontal. The rock revetment treatment is designed to accomplish bank stabilization with minimal excavation into the river bank itself. The incorporated vegetative bundles provide long-term benefit associated with increased deep root mass, increased near bank hydraulic roughness, canopy cover at the channel margins, and increased riparian vegetative complexity. Figure 47 depicts the typical rock bank stabilization treatment in profile view.

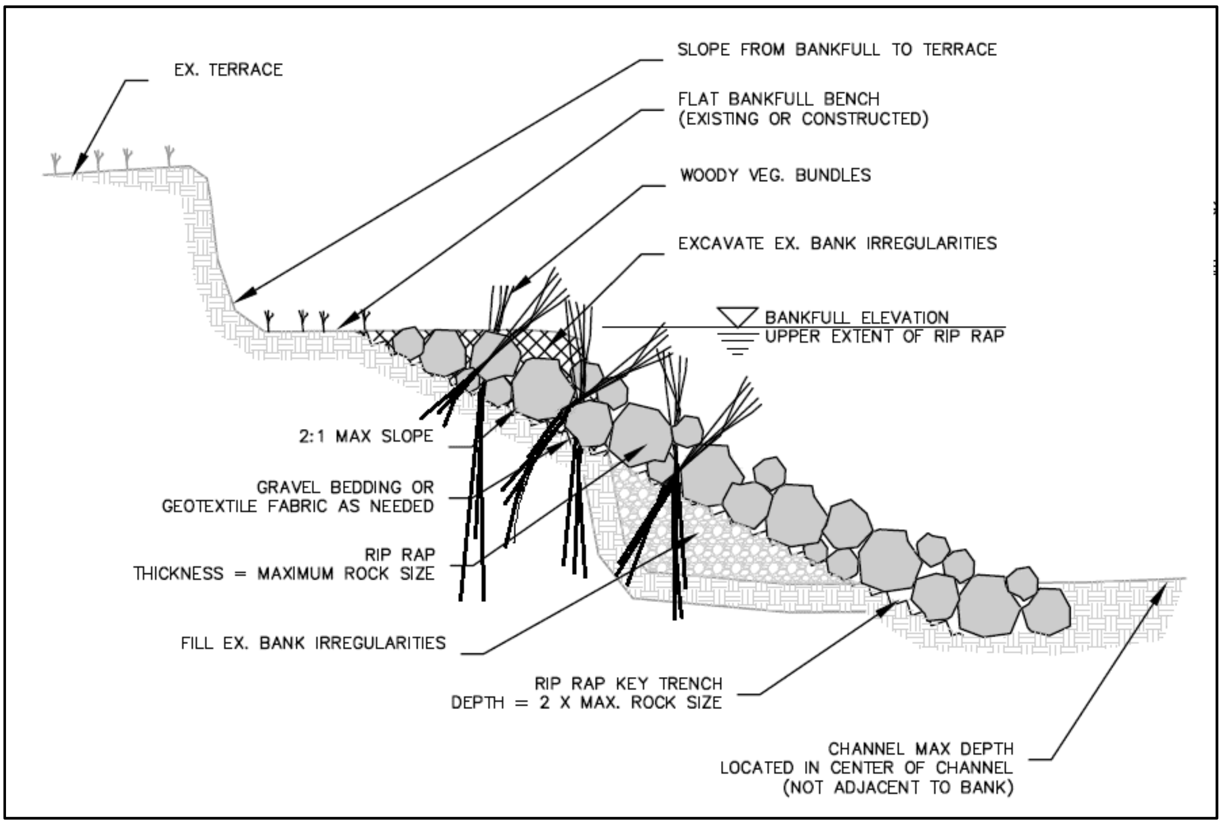

Figure 47. Profile view of typical bank rock protection treatment.

The incorporation of woody vegetation within the rock revetment increases the functional and ecological benefits of the treatment through improved riparian vigor and structure, increased channel shading (and cooling), and increased roughness and overhead cover for fish habitat. The rock revetment treatment is depicted visually in Figure 48 from a project recently completed in the region.

Figure 48. The rock revetment with bioengineering treatment incorporates vegetative material installed throughout the placed rock (top left). Installed vegetation establishes in the first year after construction (top right) and continues to expand in the second year after construction (bottom). The vegetation eventually establishes a complex root system to reinforce bank stability, and develops a robust canopy to provide over-head cover and fish habitat in addition to shade and riparian structure.

FLOODPLAIN CONSTRUCTION

Floodplain construction includes the placement of fill to create an inset floodplain in excessively wide channel conditions or the excavation of high terrace banks to create a floodplain bench at the local bankfull elevation. Establishment of a hydraulically connected floodplain with suitable width is paramount to the restoration and stability of Teton Creek. Floodplain width determines channel entrenchment ratio, which dictates channel form and processes associated with sediment transport, stable peak flow hydraulic conditions, and aquatic habitat. Reestablishment of suitable floodplain width also provides for seasonal inundation of riparian lands, which facilitates sediment deposition, flood water attenuation, and recruitment of woody vegetation adjacent to the river channel.

Floodplain creation is designed to provide distinct bank zones (Figure 49) to establish suitable conditions for the recruitment and growth of specific riparian vegetation. The overbank zone is comprised of active floodplain located at the bankfull elevation. This zone is inundated by the approximate 1.5-year return interval flow. Micro-topographic variability in the overbank zone provides for frequent scouring, fine sediment deposition, and recruitment of robust willow and riparian shrub communities.

The transitional bank zone is located beyond the overbank zone and transitions between the bankfull and floodprone elevations. The transitional bank zone is inundated by large peak flow events and provides suitable conditions for the recruitment and establishment of overstory vegetation inclusive of robust cottonwood galleries. Establishment of these bank zones could be pursued to enable Teton Creek to convey flood waters during peak flow events in a designated area while accommodating existing residential development and infrastructure located proximate to the channel corridor.

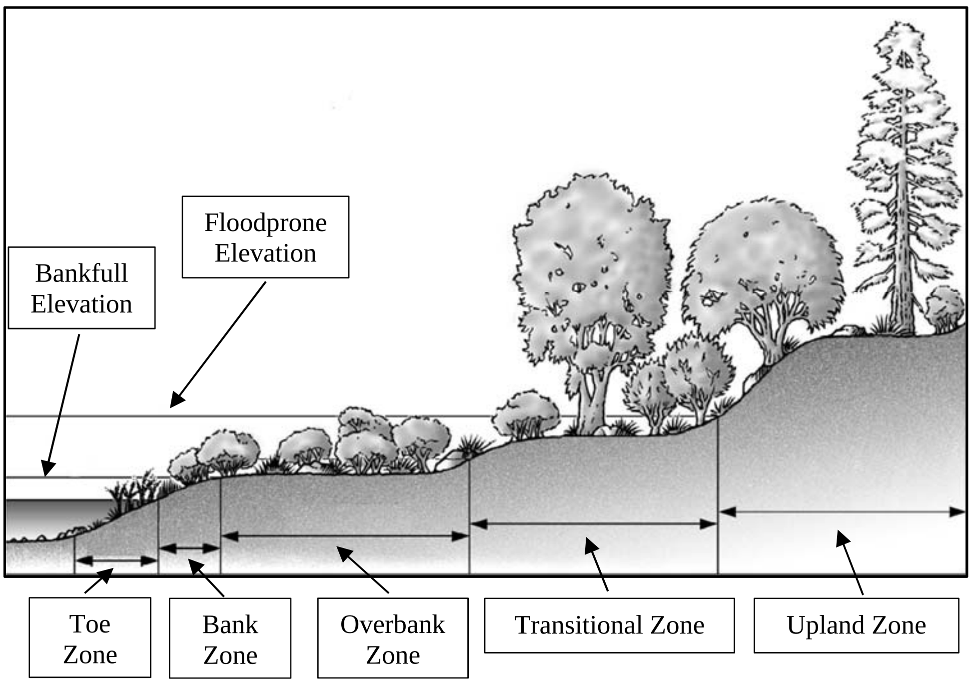

Figure 49. Profile view of typical bank zones.

Floodplain creation through fill involves the placement of consecutive lifts of native alluvium below the ordinary high water mark, compaction of lifts with excavator bucket or similar force, and installation of transplanted woody and herbaceous vegetation mats atop placed fill to achieve the design elevation. The most coarse available materials (or imported rock of specified gradation) are placed on the river side of the fill to achieve increased critical shear of the constructed feature; fine sediments and unclassified fill materials are generally placed on the landward side of the fill area. All implemented channel narrowing treatments are oriented and situated to achieve the functional bankfull channel width.

The channel constriction design utilizes the following treatment configurations to construct the edge of the floodplain fill, or the new stream bank, dependent upon local bank erosion potential:

A. At locations where bank erosion potential is high due to near bank shear stress, local slope, or channel alignment, new stream bank construction incorporates a log or rock revetment bank stabilization treatment;

B. At locations where bank erosion potential is low (e.g. inside of meanders, stream banks with low near bank shear stress), the density of woody members is reduced and the quantity of transplanted woody clump vegetation remains consistent; and

C. At locations where flood flows have potential to bypass channel meanders, the treatment should incorporate large rock (2-4 ft diameter) placed as ballast on woody members to reduce potential for post-construction meander cutoff during elevated flow events.

Floodplain creation through excavation involves removal of materials from high terrace features in order to construct a vegetated floodplain bench at the bankfull elevation. Floodplain excavation is completed using equipment and techniques (e.g. tracked excavator operating from the terrace elevation) that enable sorting of materials during excavation so that salvaged topsoil and vegetation can be placed on floodplain surfaces to achieve finish grade. Typical treatment installation includes collection and stockpiling of existing vegetation and top soil with an excavator bucket (e.g. scooping motions instead of dragging or pushing motions), mass excavation of unclassified fill material from the treatment area, and replacement of topsoil and salvaged vegetation on the sub-graded floodplain feature. The landward side of the treatment area is gently sloped (e.g. 5H:1V) up to the existing terrace grade, and intermediate benches should be constructed on the slope face to increase revegetation success and slope stability, as site conditions allow.

At all locations where floodplain creation (through fill or excavation) is implemented, the post-construction floodplain benches (river right and left) and the river channel should have a combined width to convey large magnitude flood events (50- and 100-year floods) with floodwater depths and velocities on the floodplain that preclude severe erosion or destruction of riparian vegetation. A typical section depicting existing and design floodplain geometry is depicted in Figure 50, in which the floodplain created through excavation is depicted in green fill and the floodplain created through discharge is depicted in blue fill.

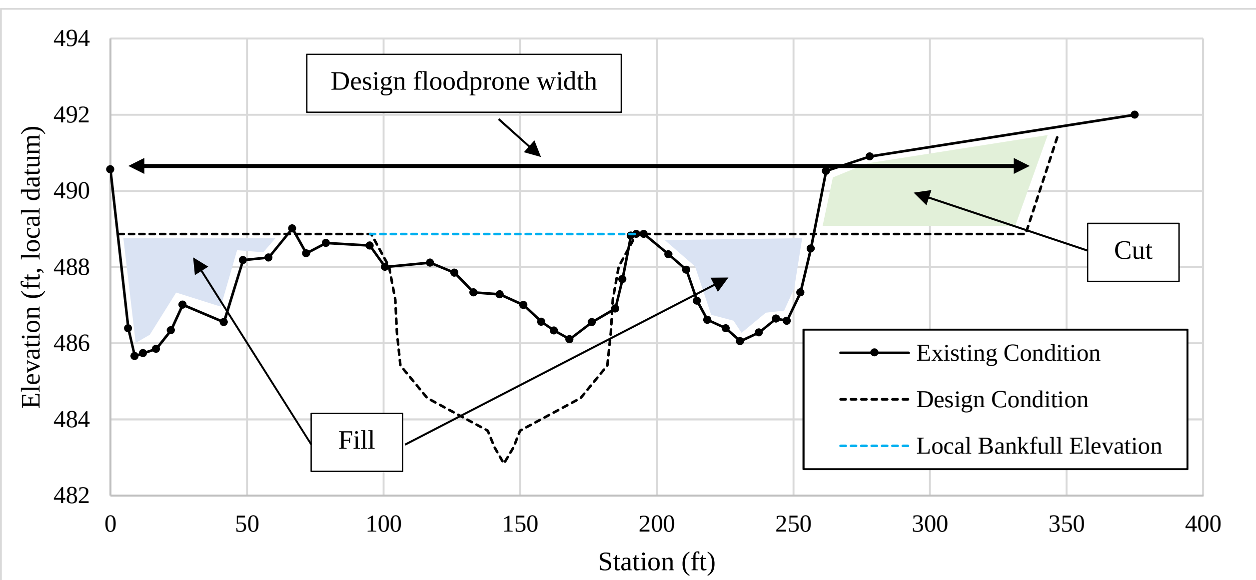

Figure 50. Typical existing and design floodplain geometry.

Floodplain reconnection and re-establishment is an important component of river system restoration because it enables flood waters to escape the active channel in order to disperse, which reduces erosive energy. Floodplain inundation alleviates erosive potential of the active channel, and could be facilitated within an inset floodplain adjacent to the Teton Creek channel in a manner that accommodates existing proximate residential development and infrastructure. Floodplain restoration is depicted visually in Figures 51 and 52 from projects recently completed in the region.

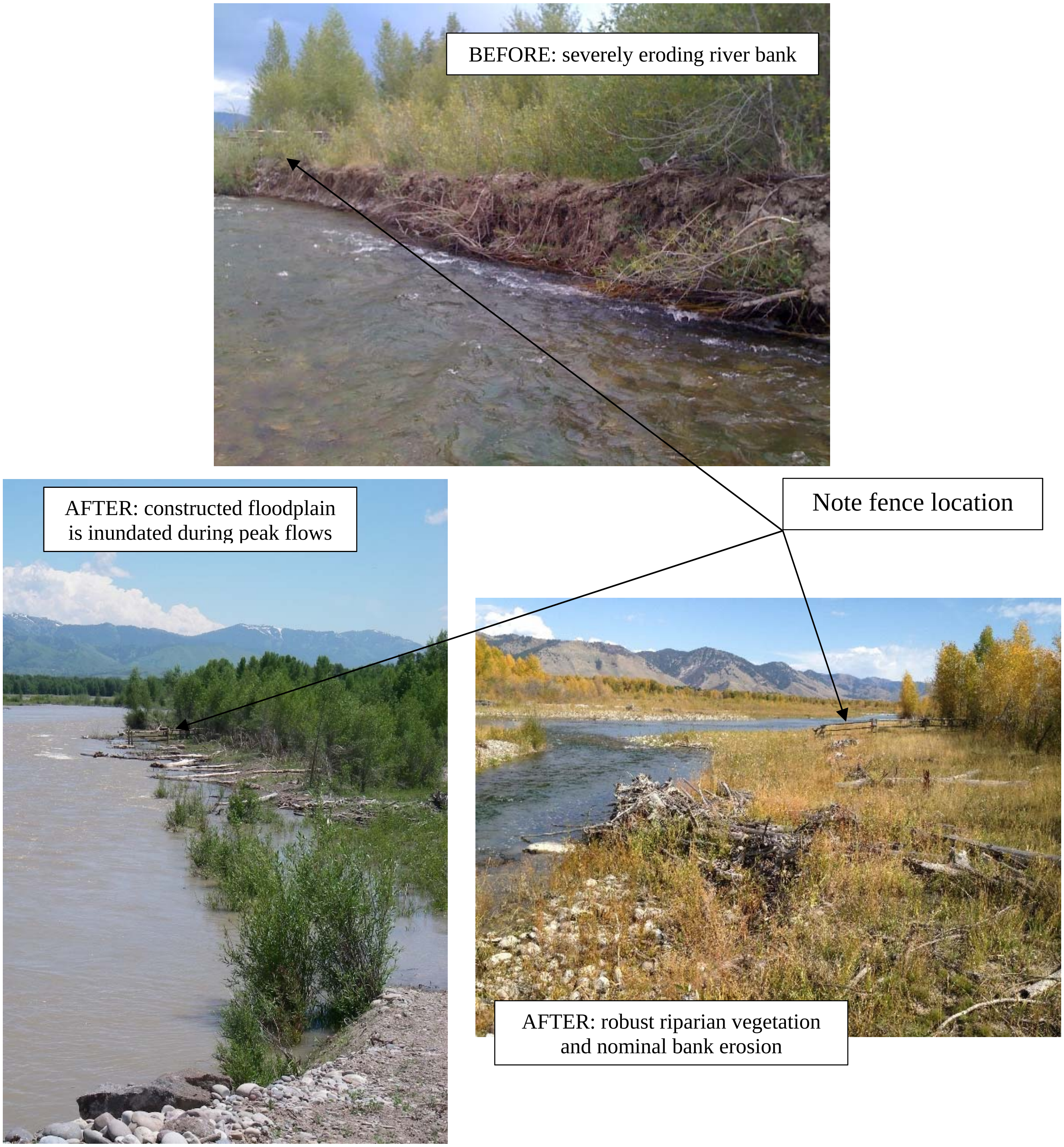

Figure 51. A floodplain bench was created within an over-widened reach of river to eliminate severe bank erosion (top), promote over-land flooding (bottom left), and aquatic conditions and riparian vegetation (bottom right).

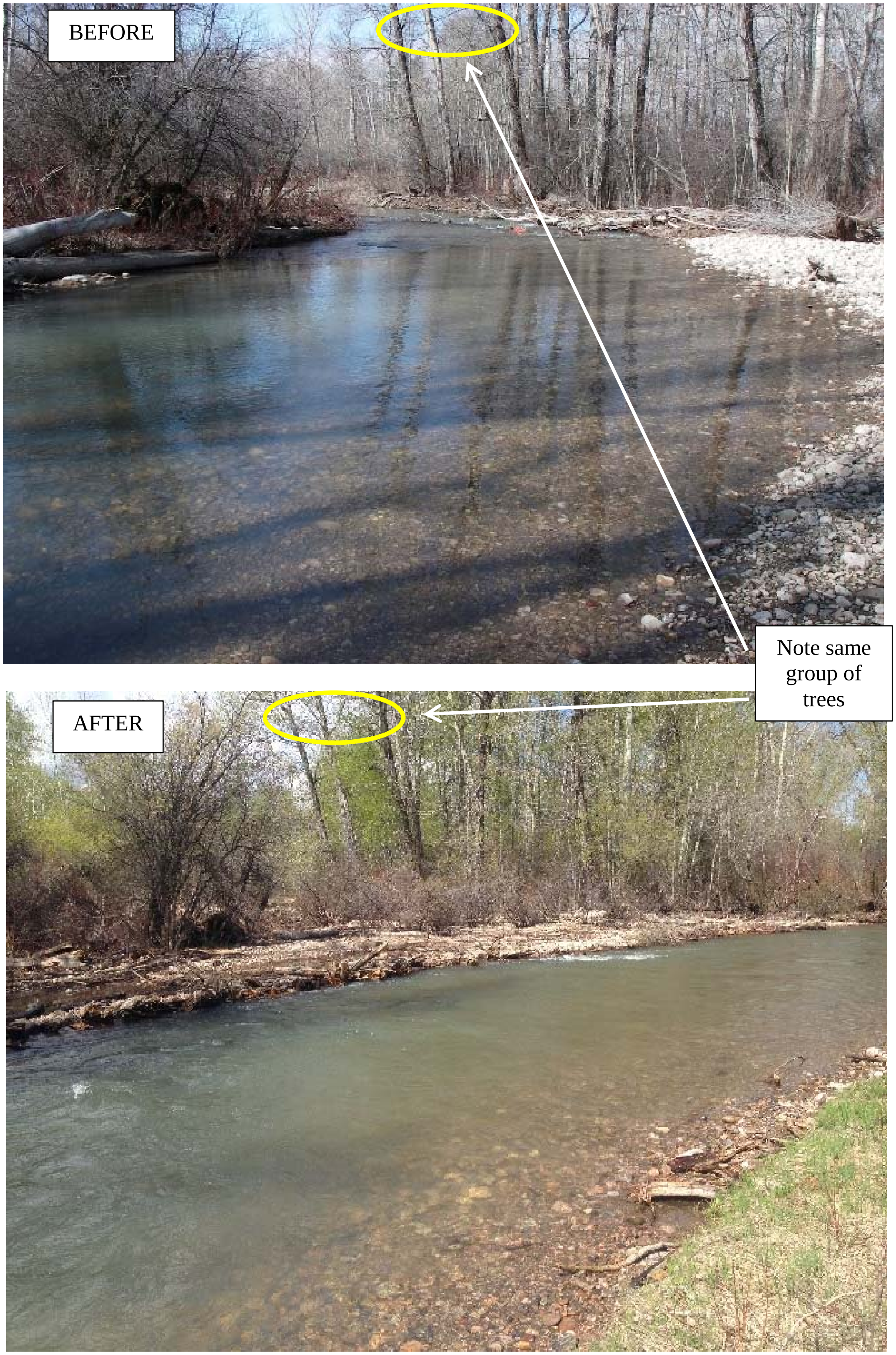

Figure 52. Floodplain creation was used to fill a braided channel network and restore functional channel width within a re-activated historic channel alignment. The treatment achieved flood water dissipation across the floodplain, increased riparian vegetation complexity and abundance, and improved fish habitat associated with increased depth, turbulence, and structural cover.

GRADE CONTROL

Grade control is necessary when the gradation of native alluvium is deficient of particles large enough to resist channel degradation. Reference channel conditions typically result in shear stress competent to mobilize up to only the D65 to D75 of the surface grain size class distribution at the bankfull discharge. Existing impaired reaches, or future project designs, in Teton Creek that result in hydraulic conditions capable of mobilizing particles larger than the D65 to D75 of the available surface grain size class distribution may warrant application of suitable grade control treatments. Hardened riffles, or distinct riffle bed features constructed of particles that are immobile under design hydraulic conditions, are an appropriate treatment to achieve vertical channel stability. Hardened riffles are preferable to typical rock vane structures, or hybrid rock-log vane structures, because hardened riffles distribute available gradient, are less prone to failure than vane structures, maintain fish passage at lower installed densities than vane structures, are more economical to install than structures comprised of large rock, and are less aesthetically obtrusive than large rock structures that span the bankfull channel.

Typical installation of hardened riffle structures includes excavation of unsuitable foundation material from the treatment footprint, followed by placement of rock (with specified gradation) in a layer that is twice as thick as the maximum particle size (Figure 53). Bank keys are constructed at the corners of the treatment area to prevent erosion around the grade control feature (Figure 54). Bank keys are vegetated with dormant woody vegetation cuttings installed around the perimeter of placed rocks with buried ends extending to the low water groundwater elevation. Bank key footprints are capped with topsoil and revegetated with transplanted herbaceous and woody vegetation, and broadcast seeding is completed across remaining areas of open soil. Placement of the rock mix layer achieves the design finish channel geometry with maximum depth, mean depth, bank slopes, and inner berm attributes (Figure 55). Treatments maintain constructed gradient distribution and are aesthetically unobtrusive within the riverine environment.

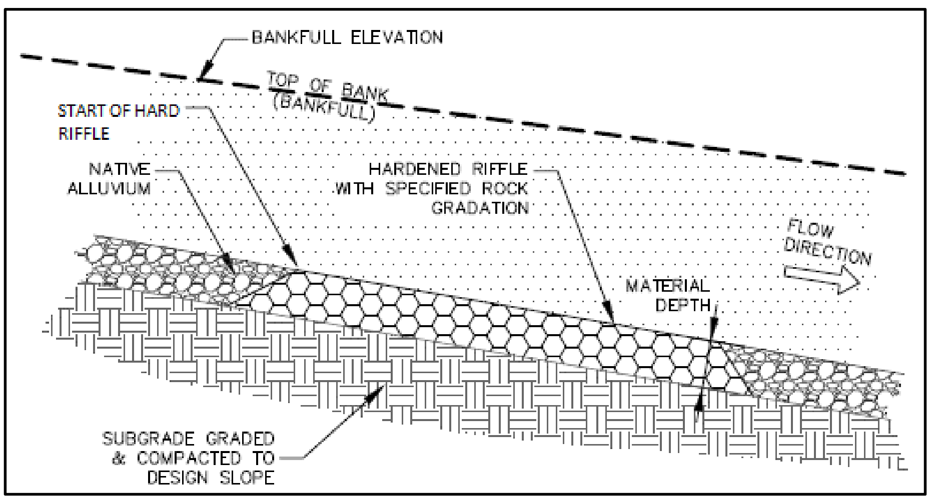

Figure 53. Profile view of typical hardened riffle treatment design.

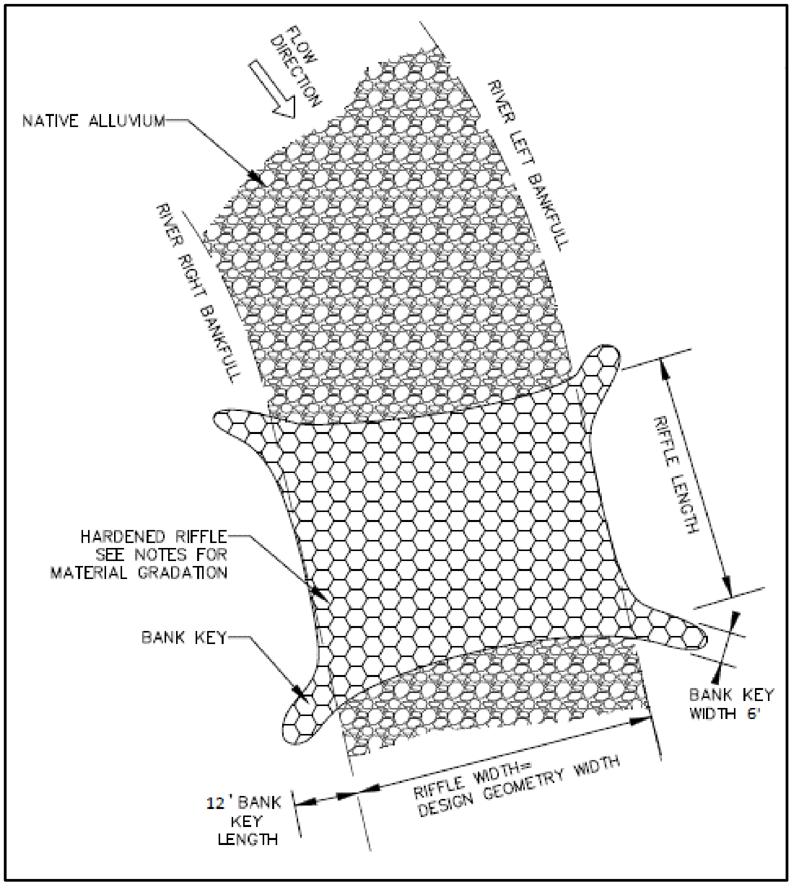

Figure 54. Plan view of typical hardened riffle treatment design.

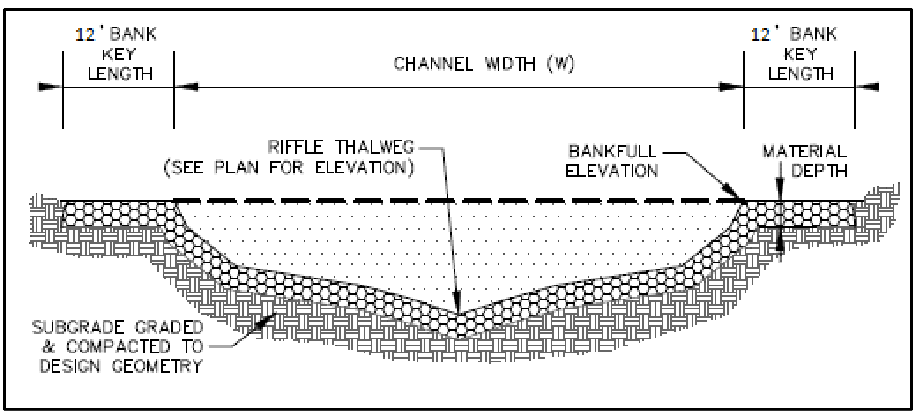

Figure 55. Section view of typical hardened riffle treatment design.

The hardened riffle treatment does not incorporate large boulders, but utilizes moderately sized rock to achieve vertical channel stability. The treatment maintains long riffle bed features, downstream scour pools for energy dissipation, and depth and turbulence cover for fish habitat. The hardened riffle treatment is depicted visually in Figure 56 from work previously completed within Teton Creek, and in Figures 57 and 58 from projects recently completed in the region.

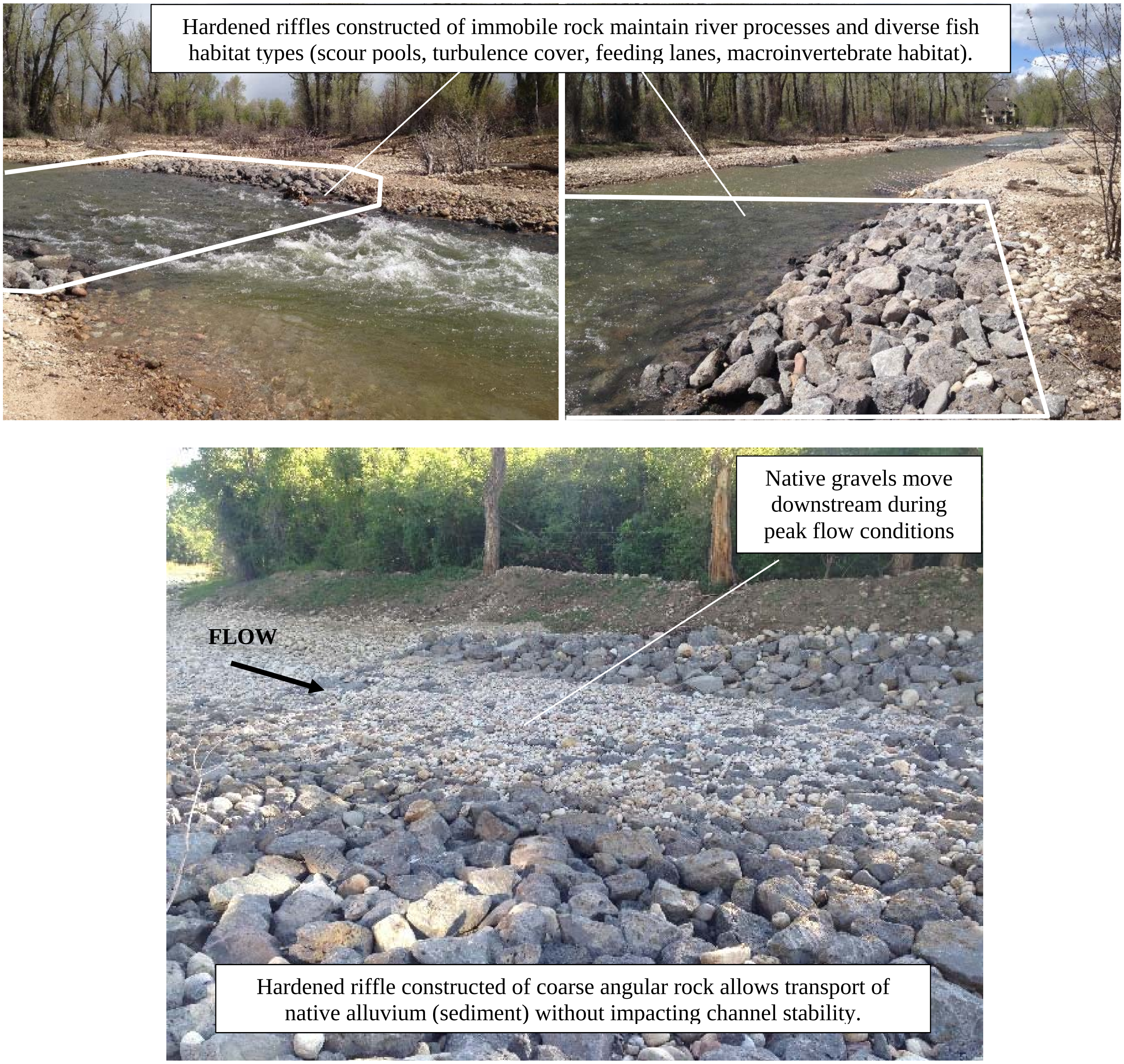

Figure 56. Hardened riffles maintain vertical channel stability and establish design channel width while maintaining downstream scour pools (top left and right). The hardened riffle treatment enables conveyance of native alluvium (sediment transport) while maintaining channel stability using moderately sized rock (bottom).

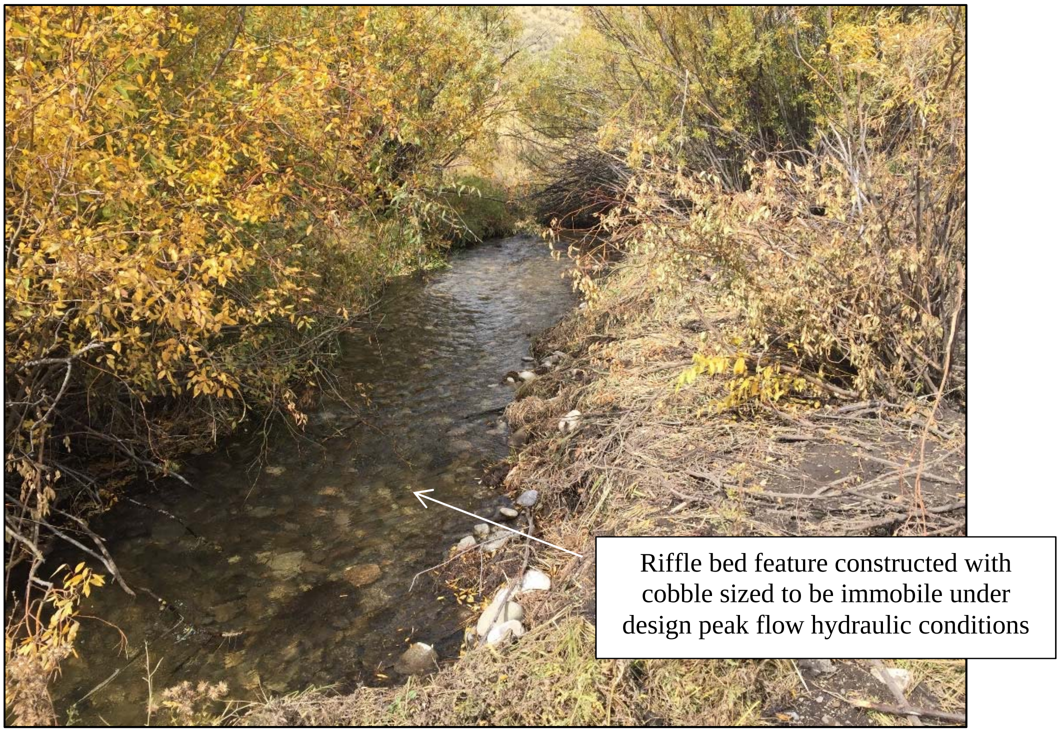

Figure 57. Photograph of installed hardened riffle grade control treatment.

Figure 58. Photograph of installed hardened riffle grade control treatment.

The rock cross vane treatment can also be used to accomplish grade control, but this treatment alternative is less desirable than the hardened riffle because cross vanes are susceptible to failure (if individual boulders are undermined or mobilized) and vanes promote artificially short drops with plunge pools instead of more natural lengthy riffles with scour pools. However, rock cross vanes are preferable to traditional rock sills that extend straight across the river channel because vanes consolidate flows in the center of the channel in order to maximize sediment transport and downstream scour. The treatment is depicted visually in Figure 59 from a project recently completed in the region.

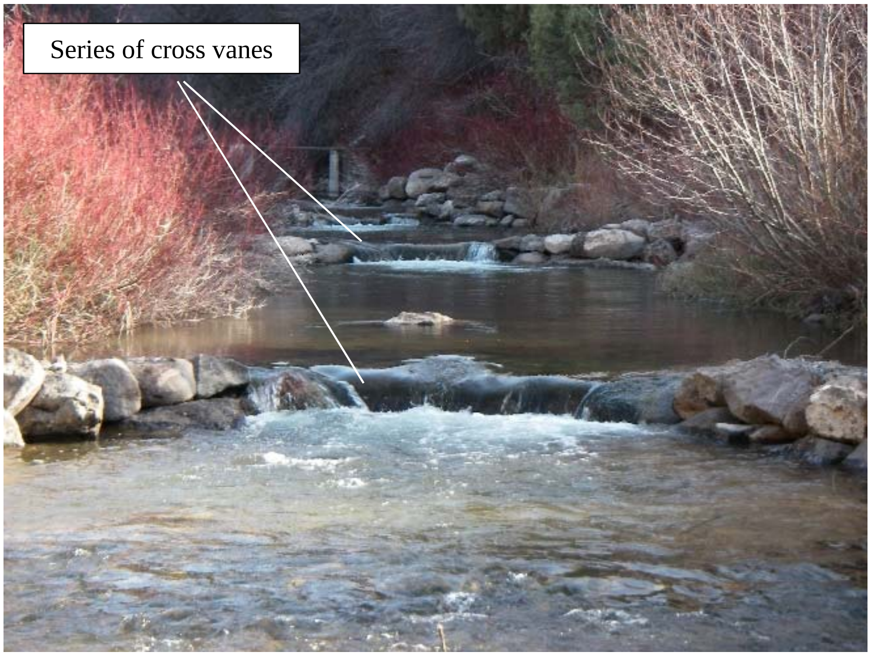

Figure 59. A series of rock cross vanes (top) distributes excessive local gradient while enabling sediment transport and maintaining downstream pools and mid-channel turbulence cover for fish habitat. A single large rock cross vane (bottom) maintains grade control and channel width while consolidating low flows in the center of the channel for hydraulic and fisheries benefits.

SEDIMENT STORAGE

Sediment storage facilities could be incorporated into active restoration efforts along Teton Creek in order to provide storage for the available sediment load in areas that do not compromise integrity of adjacent residential development or infrastructure. It may be unrealistic to provide storage for the entire sediment load supplied to the Assessment Reach from the upstream basin, but localized storage could be pursued in order to alleviate severe local channel instabilities in problem areas such as below Cemetery Road Bridge, in Creekside Meadows, and downstream of the Highway 33 Bridge.

Sediment storage facilities in the Assessment Reach of Teton Creek could consist of lateral storage areas that are appropriate within relatively straight sections of channel. A lateral storage area (exemplified in Figure 60) consists of a defined gap in the stream bank that is hydraulically connected to the bankfull channel and enables for the deposition of bedload during peak flow events. Lateral storage areas can be located in areas where adequate equipment access provides for the economical removal of sediment from storage facilities as needed, in order to provide long-term sediment storage functionality.

Sediment storage could also be provided through establishment of undersized point bar features during active restoration activities. The naturally occurring slope of the face of point bars is predominantly determined by meander radius and channel slope. During active restoration activities, undersized point bar features could be constructed on the inside of meander bends (Figure 61). These features can be expected to promote localized deposition as the point bar enlarges to the naturally maintained size and slope. Sediment deposited and stored within point bars is often difficult to access with heavy equipment for long-term maintenance due to the depositional natural the inside of meanders and the riparian vegetation that can be anticipated to establish in such areas. However, the construction of undersized point bars can be used to provide storage for an anticipated pulse of sediment or a distinct sediment load that is moving through a stream reach as a result of past channel destabilization.

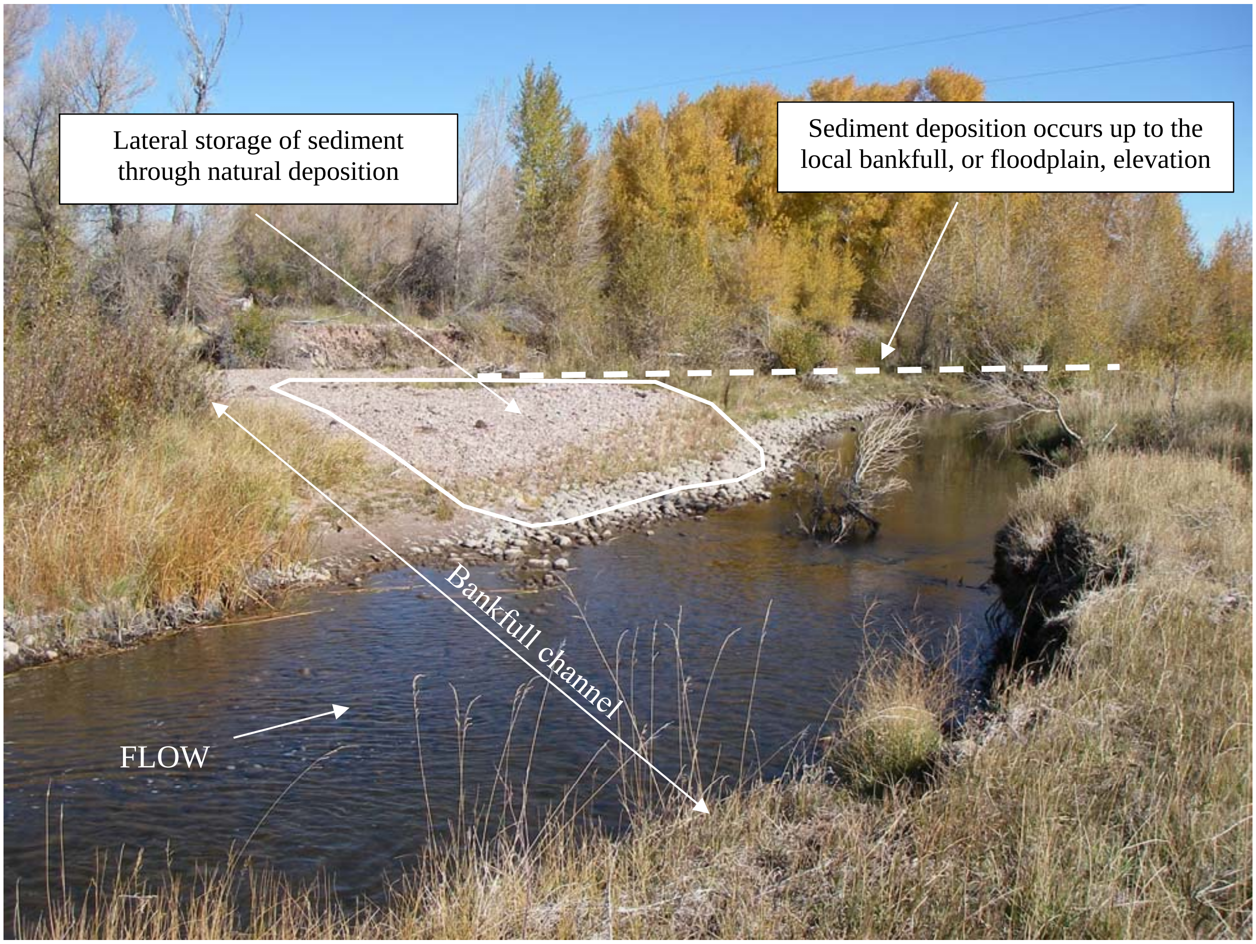

Figure 60. A photograph depicting a lateral storage facility.

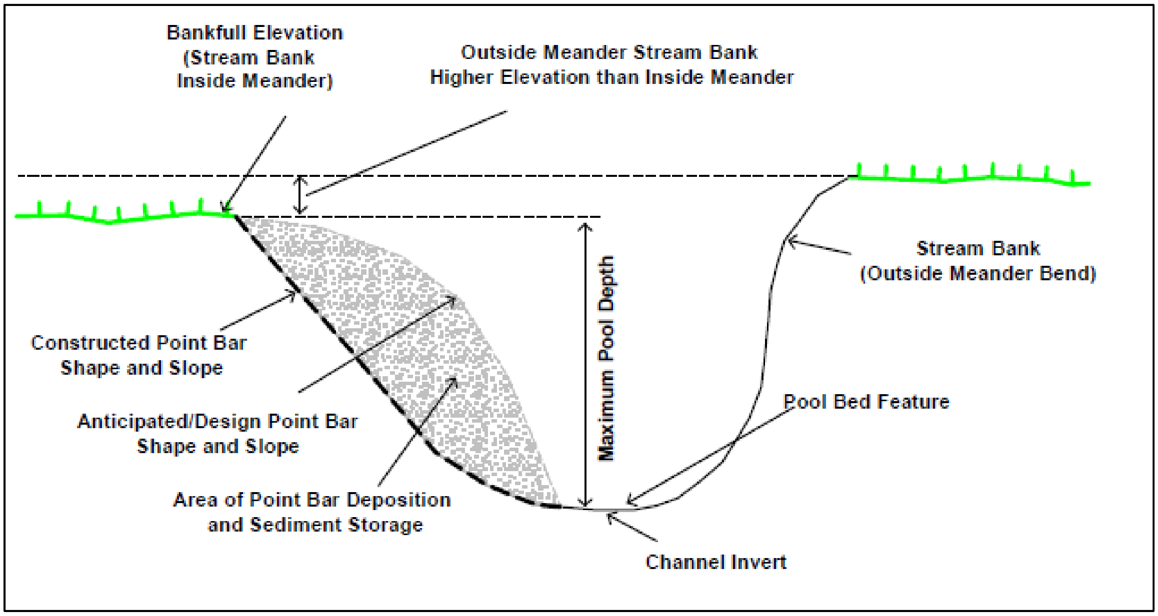

Figure 61. A typical design of undersized point bar sediment storage facility.

CREEKSIDE MEADOWS CONCEPTS

The reach of Teton Creek located within Creekside Meadows (approximate Stationing 80+00 to 114+00 ft) demonstrates significantly diminished bankfull channel slope, shear stress, and stream power. The reach has impaired sediment transport competence and capacity, and is experiencing severe and widespread channel aggradation and lateral erosion. The sediment deposition experienced within the reach is exemplified in Figure 62, which contains a 2008 photograph (left) of a rock weir constructed in the reach and a 2017 photograph (right) of the same location.; the weir was buried by localized deposition in the reach.

Figure 62. Photographic documentation of conditions within Creekside Meadows in 2008 (top) and 2017 (bottom).

Continued impairment of fluvial function has potential to adversely impact proximate infrastructure and public health, safety, and welfare. Restoration efforts in the Creekside Meadows reach could explore opportunities to establish functional channel dimension, pattern, and profile to increase sediment transport competence and capacity. Treatments that reduce stream length in order to increase slope and sediment transport regime should be considered. The length of channel within this sub-reach of Teton Creek increased from 3,001 ft in 1943 to 3,877 ft in 2015, an increase of 876 ft or about 30%.

A conceptual approach to improving stream function within this reach could include establishment of a shorter, less sinuous, channel alignment. A conceptual design (attached Sheet 22) would reduce stream length within the treatment area from 3,600 ft to 2,580 ft, in order to increase local channel slope from 0.6% to 0.9%. The concurrent establishment of channel geometry that is generally 42 feet wide 2.2 feet deep (mean depth) would enable the channel to convey normal peak flows in addition to the sediment load delivered from the upstream reach. The conceptual channel alignment and geometry could utilize the existing Creekside Bridge structure, and would have about 3.75 ft of freeboard under the low chord of the bridge during bankfull discharge. Establishment of an inset floodplain in existing disturbed areas adjacent to the conceptual channel alignment, in addition to improved floodplain conveyance under Creekside Meadows Avenue, would enable conveyance of larger magnitude peak flow events through the reach. Preliminary hydraulic modelling suggests that the conceptual inset floodplain could convey large magnitude flood events, but efforts to advance design concepts could investigate whether or not slight elevation of Woodland Way and Creekside Meadows Avenue along the north side of Teton Creek would be necessary to contain the 100-year flood within the established inset floodplain.

WEST OF HIGHWAY 33 CONCEPTS

The reach of Teton Creek proximate to the debris blockage downstream of the Highway 33 Bridge (approximate Stationing 125+00 to135+00 ft) demonstrates reduced channel slope, low flow velocities, and reduced shear stress and stream power. The reach has impaired sediment transport competence and capacity, and is experiencing severe channel aggradation. The reach has nominal bank height and channel capacity, and established meander cutoff channels are activated even during low flow conditions.

Restoration efforts in this reach should explore opportunities to increase sediment transport competence and capacity. The existing channel form promotes sediment storage within the primary channel. Resultant channel filling then reduces conveyance capacity, which causes instream flows to escape the channel and flow across the floodplain until reaching cutoff channels that convey water back to a downstream primary channel. This configuration precludes the conveyance of coarse sediment downstream through the reach.

A conceptual design approach would establish braided (anastomosing) channel configurations that improve sediment transport while providing dispersed sediment storage without promoting aggradation. Divergence log jam structures could be installed to establish and maintain defined channel splits with secondary and tertiary channels that have specified dimension and profile. A conceptual log divergence structure (Figure 63) creates split flow conditions, protects downstream vegetated islands, creates and maintains proximate scour pools, facilitates sediment sorting, and accumulates natural debris through time. These structures would be located at the head of defined channel divergences to promote scour and enable sediment to enter downstream braided channel reaches. Divergence structures would incorporate key logs secured into the bank, boulders for ballast, racking logs for structure and roughness, and pining logs for stability.

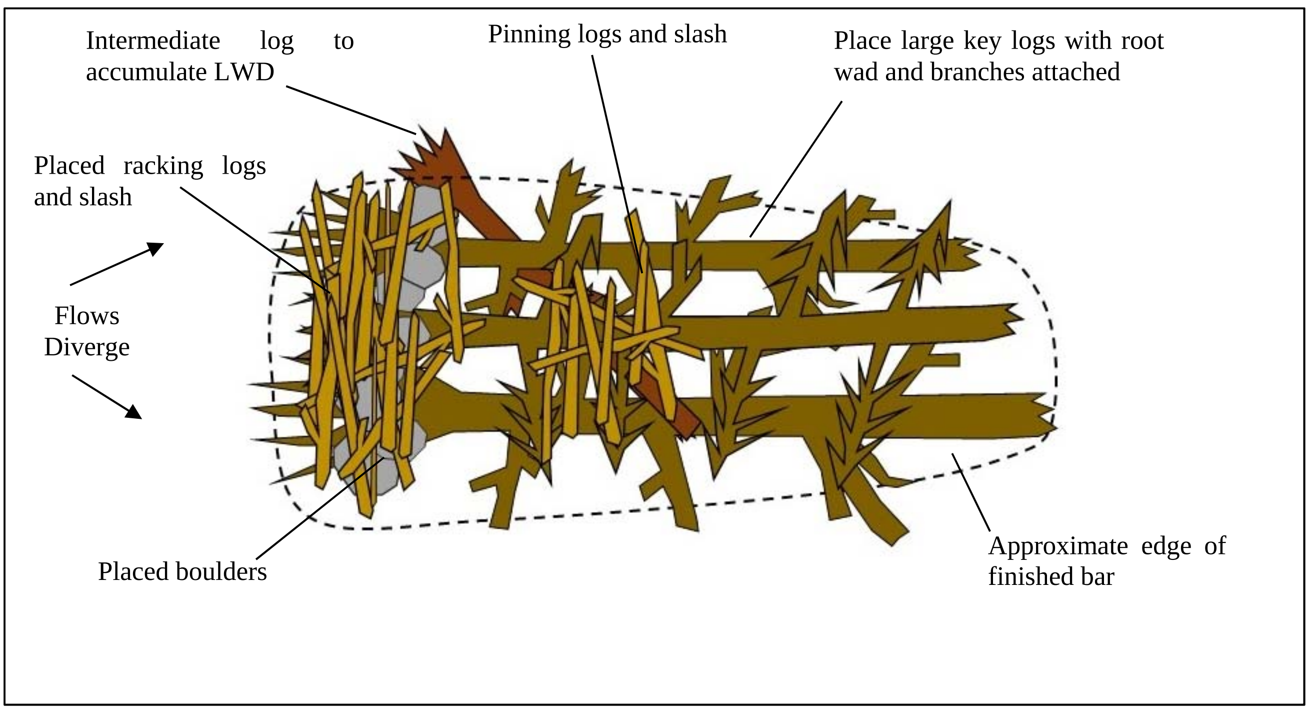

Figure 63. Concept plan view of a log divergence structure.

The utilization of divergence log structures and defined channel splits would enable instream flows *and* coarse sediment to enter diverging channels within which hydraulic conditions would be sufficient to transport bedload downstream. This configuration would preclude floodplain inundation at low to moderate flows in order to maintain the transport of coarse sediment within active stream channels. The established and maintained split flow channels would simultaneously provide dispersed sediment storage through typical point bar formation and outside meander bank erosion processes.

SUMMARY

The Teton Creek Geomorphic Assessment focused on the characterization of geomorphic conditions within the fluvial system from Cemetery Road Bridge downstream to the vicinity of the Highway 33 Bridge. A secondary focus of the effort was to identify areas of concern, or hot spots, between the Idaho state line and the vicinity of the Highway 33 Bridge.

Field observations were made along the entire length of the Assessment Reach and upstream and downstream proximate sub-reaches of Teton Creek in order to assess and document current stream form and function. High resolution topographic data compiled from multiple sources were then used in conjunction with available hydrologic data to complete hydraulic modeling throughout the Assessment Reach. Sub-reaches of the project area were ranked based upon quantitative hydraulic model outputs associated with stream bank stability, channel slope, flow velocity, shear stress, stream power, sediment transport competence, sediment transport capacity, and analysis of historic channel conditions. Analysis results were used to identify prioritized areas of concern within the Assessment Reach, and to describe the fluvial processes responsible for documented system impairment. Additional areas of concern located upstream of the Assessment Reach were simultaneously identified during site observations and review of available information. Conceptual design plans and approaches suitable for application within impaired reaches of Teton Creek were identified and described, and recommendations presented for the review and consideration of the flood control district, the municipality of Driggs, local resource managers, and land owners.