**REPORT
FINAL DESIGN
BALL CREEK REALIGNMENT, RESTORATION
AND RECONNECTION WITH THE KOOTENAI
RIVER
BOUNDARY COUNTY, IDAHO**

JULY 8, 2009

**FOR
KOOTENAI TRIBE OF IDAHO**

**Report
Final Design
Ball Creek Realignment, Restoration and
Reconnection with the Kootenai River
Boundary County, Idaho
File No. 9229-002-04**

July 8, 2009

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EXECUTIVE SUMMARY

This report presents the results of our design services for the proposed realignment, restoration and reconnection of Ball Creek with the Kootenai River in Boundary County, Idaho. The landscape of the Kootenai River Valley was formed by glaciers and has been shaped and maintained by Kootenai River floods. Prior to European settlement, most of the valley consisted of forests and wetlands maintained through annual, seasonal flooding and recession in a system that historically supported a thriving ecosystem. After European settlement, the area was converted to agricultural use, and significant changes to the floodplain related to dam construction and stream re-channelization have occurred since the late 1800s, causing significant alteration to the historically productive ecosystem throughout the valley. Although restoring or rehabilitating the entire system to its pre-European settlement historical condition is not feasible in the foreseeable future, the current project is intended to re-create, to the extent practicable, a floodplain ecosystem that incorporates river/floodplain connectivity, a natural tributary, an expansion of low-velocity habitats, and expanded wetlands associated with tributary hydrology and Kootenai River backwater flooding. In addition to benefits to the ecosystem in restoring wetlands and plant and animal habitats, the project will benefit the human community both aesthetically and economically through construction operations and, later, increased long-term recreational opportunities.

This report presents the final design for the three planned phases of the project:

1. Construction Phase, which includes: the construction of the proposed Ball Creek channel, floodplain and wetlands; connection between the Kootenai River and the proposed Ball Creek channel; construction of the temporary Ball Creek inlet structure; and seeding and planting.
2. Establishment Phase, during which the new channels, wetlands and vegetation become established over two growing seasons.
3. Final Connection Phase, during which Ball Creek is permanently diverted from its current alignment into the new alignment.

The design has been developed to a construction bid level of detail, and Appendix C of this report presents construction bid documents, including graphics showing details of the project. The design is based on extensive research into the historical and current conditions in the area. To facilitate the stream design, the proposed alignment was divided into nine distinct segments, or “reaches,” based on geomorphic conditions, existing landscape and the proposed landscape. Each of the reaches involves specific proposed conditions and design considerations detailed in the body of the report. The design also presents a recommended sequence for construction and the application of Best Management Practices (BMPs) promulgated by the Idaho Department of Environmental Quality (IDEQ), as well as estimates of construction costs.

The establishment of healthy, self-sustaining native vegetative community throughout the project site is vital to the success of a stream restoration project. To this end, the design presents plans for planting, based on dividing the area into four “planting zones,” designating specific plant communities based on the anticipated hydrology available for each zone.

The proposed improvements will result in enhancing, expanding and diversifying the function and values of the aquatic and riparian habitat along the stream corridor itself while enhancing the continuity to the larger mosaic of upland habitats. Construction will occur in a sensitive manner that minimizes the disruption of the existing habitat as much as possible. In addition, a detailed monitoring and maintenance plan has been developed to address the full range of anticipated adjustments that the stream and riparian areas will undergo as they settle into their revised surroundings.

**FINAL DESIGN
BALL CREEK REALIGNMENT,
RESTORATION AND RECONNECTION WITH THE KOOTENAI RIVER
BOUNDARY COUNTY, IDAHO**

1.0 INTRODUCTION

This report presents the results of our design services for the proposed realignment, restoration and reconnection of Ball Creek with the Kootenai River in Boundary County, Idaho.

1.1 PROJECT OVERVIEW

Our understanding of the historical condition of the Kootenai River, Ball Creek and floodplain interactions is largely based on historical aerial photos, historical accounts of the landscape and natural resources, literature reviews and recent digital elevation model (DEM) products created from Laser Imaging Detection and Ranging (LiDAR) data. It is clear that the Kootenai River, its floodplain and its tributaries were heavily impacted by land use practices and hydroelectric development.

The Kootenai River Valley, which is also known as the Purcell Trench, is relatively wide (up to 5 miles) and relatively flat and is located between Bonners Ferry, Idaho, and Kootenay Lake, British Columbia. The landscape was formed by glaciers during the most recent ice age and has since been shaped and maintained by Kootenai River floods. Prior to European settlement, most of the valley was forested, and up to 50 percent of the floodplain area consisted of wetlands. These wetlands were inundated with water during flood events, and the water gradually receded throughout the growing season. As the water and wetlands receded, nutrients and associated trophic levels were carried back to the streams and the river as part of the nutrient spiral within the annual flood pulse. Additionally, the large wetland area maintained a relatively high groundwater table, which eventually contributed cool, shallow groundwater to sinuous tributary streams that existed in the floodplain during summer months. Overall, the system historically supported a thriving ecosystem.

After European settlement, it was discovered that fertile floodplain soils would provide large crop yields, thereby providing the base to the local economy. To claim these soils for agricultural production, most of the forested portion of the 50,000-acre floodplain was logged and cleared, leaving little evidence of the historical condition. About 22,000 acres of forested floodplain wetlands were drained and isolated by levees from the river, and by 1960, less than 3,000 acres of wetlands remained. Of those remaining wetlands, most were converted from forested wetlands to emergent wetlands, thus altering pre-settlement wetland function.

Levees and the channelization of the lower Kootenai River began in the late 1800s in an effort to utilize fertile soils for agricultural purposes and protect adjacent communities and infrastructure from flooding. By the 1920s, drainage districts were forming in most of the lower Kootenai Valley, and by the 1950s, all of the lower Kootenai River was affected by channelization and levees to limit floodplain inundation (Richards, 1997). To control flooding in the lower Kootenai Valley, Libby Dam was constructed in Montana, upstream of the current project site, and began operations in 1972. Since then, the natural Kootenai River hydrograph has been significantly altered by the dam's effect of attenuating spring flood flows, effectively eliminating valley flooding. Since Libby Dam operations began, river stage at the proposed project site has not achieved a level that would overtop the natural levee of the river or the constructed levee, as shown in Appendix C, Sheet 3.2, "Digital Elevation Model (Existing Condition, 2005)." In addition to the attenuation of spring flows, winter flows have increased to generate hydroelectric power and make space in Libby Reservoir for subsequent spring flows.

River and tributary flood control over the last 100 years has caused significant alteration to the historically productive ecosystem throughout the valley. Restoring or rehabilitating the entire system to its pre-European settlement historical condition is not feasible in the foreseeable future because actions causing significant disruption to the geomorphic processes continue to be maintained (GeoEngineers, 2006). It is our assertion that Libby Dam starves downstream reaches of sediment, and the construction of a continuous series of levees confined the river and cut off the floodplain, thereby channelizing flow between the banks/levees. Both of these alterations restricted the channel's natural ability to migrate and dissipate energy through bank erosion and flooding. As a result, in-stream velocities increased, causing the channel to degrade. The small delta forming in Kootenai Lake at the mouth of the Kootenai River downstream in British Columbia is likely a result of the sediment derived from this apparent degradation, because the Kootenai River is otherwise starved of sediment by the Libby Dam. Persistent degradation caused the banks to become steeper and higher. As the steeper and deeper channel continues to erode downward, the floodplain becomes relatively higher, dryer and unable to support historical riparian vegetation and floodplain interactions.

Because large-scale holistic ecological and geomorphic restorations are not feasible along this length of the Kootenai River, restoration efforts must consider limitations to natural functions and provide alternatives that mimic natural function within the limitations imposed by dam operations, current land uses, land ownership, public opinion and applicable laws and regulatory processes. In 2005, GeoEngineers conducted a feasibility and alternatives analysis to determine areas where ecological restoration would be most beneficial (GeoEngineers, 2006). The Ball Creek Ranch property was selected for restoration because of its continuous ownership and cooperative landowner, its contiguous frontage along the Kootenai River, its location in an active floodplain prior to construction of the levees and dam, its presence entirely within a single drainage district, and the fact that its hydrology is suitable for mimicking natural floodplain function.

Ball Creek Ranch has been managed for agricultural production for about a century. The conversion of the property from an active floodplain involved draining wetlands and diverting Ball Creek into a channel at the southern end of the property to reduce the frequency and duration of flood events. Presently, the floodplain lacks natural riparian vegetation, has limited connectivity with the main-stem channel and provides limited beneficial habitat for native fish and other wildlife. The drainage system throughout the property is generally characterized by three main features:

1. Ball Creek has been removed from its original channel, which traversed the property from south to north. The current alignment flows through the southern edge of the property in a southeasterly direction and is roughly one-eighth the length of the original channel. The existing channel is deeply incised and effectively prevents Ball Creek floodwater from accessing the floodplain.
2. Drainage ditch 'A' bisects the property and flows from west to east as shown in Appendix C, Sheet 3.3, "Existing Site Conditions." This ditch is confined by roughly 10-foot-high banks and is fed with a drain tile system, shallow groundwater and localized surface water runoff. The eastern terminus of the ditch is located at the base of the levee separating the ranch property from the Kootenai River. At that point, water in the ditch is pumped through the levee into the Kootenai River by means of a 24-inch-diameter pipe. This pump station effectively eliminates biological connectivity between the river and floodplain.

3. Drainage ditch 'B' is present on the southern end of the property and flows in a northerly direction, as shown in Appendix C, Sheet 3.3, "Existing Site Conditions." The ditch functions in the same manner as drainage ditch A and drains the southern portion of the project area. Ultimately, this ditch flows into drainage ditch A near the pump station. Water from the combined ditches is pumped through the levee as described above.

The floodplain portion of the property was largely managed for agriculture until 2003, when The Nature Conservancy (TNC) purchased a majority interest in the property. Since that time, some of the property has been converted into wetlands; however, a commitment was made to maintain about 50 percent of the ranch as productive cropland and grazing pastures. To date, TNC has restored about 150 acres of wetlands to the portion of the property north of ditch A. The proposed Ball Creek restoration project is located to the south of ditch A. The proposed Ball Creek alignment and associated riparian corridor will pass through pastureland, grain cropland, and hay cropland and will occupy more than 200 acres.

The focus of this project is to re-create, to the extent practical, a floodplain ecosystem that incorporates river/floodplain connectivity, a natural tributary, an expansion of low-velocity habitats, and expanded wetlands associated with tributary hydrology and Kootenai River backwater flooding. Based on the results of the feasibility analysis (GeoEngineers, 2006), it is clear that Ball Creek hydrology will be a major factor driving ecosystem restoration. Historically, Kootenai River hydrology was largely responsible for floodplain productivity; however, Libby Dam operations effectively maintain the stage of the Kootenai River below a level that would allow substantial and reliable floodplain inundation and subsequent biological connectivity. Therefore, the goal of this project is to re-create periods of local flood pulse inundation with water from Ball Creek rather than the Kootenai River. Implementation of this proposed project will be completed in three general phases:

4. Construction Phase, which includes: the construction of the proposed Ball Creek channel, floodplain and wetlands; connection between the Kootenai River and the proposed Ball Creek channel; construction of the temporary Ball Creek inlet structure; and seeding and planting.
5. Establishment Phase, during which the new channels, wetlands and vegetation become established over two growing seasons.
6. Final Connection Phase, during which Ball Creek is permanently diverted from its current alignment into the new alignment.

This report represents the final design for the three phases of the project listed above. After restoration construction is complete and natural processes are reestablished, it is expected that native species such as white sturgeon (*Acipenser transmontanus*), bull trout (*Salvelinus confluentus*), kokanee (*Oncorhynchus nerka*), rainbow trout (*O. mykiss*), burbot (*Lota lota*) and numerous avian and local terrestrial species populations will positively respond.

1.2 PURPOSE OF REPORT

This stream design report and its appendices (referred to collectively as the Report) are intended to serve a number of different purposes and are organized accordingly. This Report is intended to:

1. Support the environmental review and the acquisition of the environmental permits necessary to complete this project. Specifically, these permits involve the Joint Application for Permits, which includes:
2. United States Army Corps of Engineers (USACE) 404 Permit

3. Idaho Department of Water Resources Stream Alteration Permit
4. Idaho Department of Environmental Quality (IDEQ) 401 Certification
5. National Environmental Policy Act (NEPA) process
6. Graphically depict the proposed enhancement measures.
7. Document and support the technical assumptions, methods, calculations and results of the proposed stream restoration design. Many of these analyses are based on a hydraulic model for the stream.
8. Facilitate the construction bidding process for the stream enhancement measures.
9. Identify monitoring and maintenance procedures aimed at making sure that the enhanced stream functions as intended. A detailed Monitoring and Maintenance Plan will be provided under separate cover.

1.3 ORGANIZATION OF REPORT

This Report is organized to first provide a general understanding of the historical, existing and proposed conditions of the site as they pertain to the proposed enhancement design. Because of the nature of stream designs, a majority of the discussions pertain to the site's geomorphic (geologic/stream interaction), hydrologic (stream discharges), hydraulics (stream flow) and habitat characteristics. The proposed stream enhancement project is then described in greater detail, specifically describing the proposed enhancement designs themselves as well as the underlining intent of the design and the anticipated results and benefits. Construction quantities and construction cost estimates are included in this Report to provide a baseline for comparison among various contractors during the bidding process. The end of this Report focuses on vegetation and the proposed plantings associated with the stream enhancement as well as a monitoring and maintenance plan to provide the appropriate outline to measure the successes of the proposed enhancements.

The Stream Restoration Construction Bid Documents located in Appendix C graphically depict the historical, existing and proposed site conditions and shall be used to facilitate the stream enhancement construction effort and related construction bidding process. Reference is made to these Stream Restoration Construction Bid Documents "Sheets" throughout this report. Sheet 1, the Cover Sheet, provides a site location map and a table of contents for the subsequent sheets.

1.4 AUTHORIZATION

These services have been authorized and performed, within the limitations of schedule, scope and budget, in accordance with the agreement established between GeoEngineers, Inc. and the Kootenai Tribe of Idaho (KTOI), as authorized on September 4, 2008, by Jennifer Porter, Executive Director of KTOI.

1.5 SCOPE OF SERVICES

The purpose of GeoEngineers' services was to prepare a final design package appropriate for construction bidding purposes for the Ball Creek restoration and Kootenai River floodplain reconnection. This report represents the finalization of GeoEngineers' preliminary design report for this project, dated June 23, 2008 (GeoEngineers, 2008). Our specific scope of services included the tasks listed below in Sections 1.5.1 through 1.5.5.

1.5.1 Describe Existing Conditions

1. Describe project location and watershed setting.

2. Describe site topography.
3. Describe the regulatory floodplain.
4. Describe the existing morphology of Ball Creek downstream from the West Side Road. This task also involved comparing the existing alignment with the historical alignment as determined from aerial photography and DEM data.
5. Describe the existing habitat conditions in Ball Creek downstream of the West Side Road.

1.5.2 Analysis and Design of Proposed Conditions and Construction Bid Documents

1. Assemble all of the readily available data collected to date, as appropriate, for preparing stream channel designs, reconnection designs, diversion designs and lentic habitat design.
2. Develop an appropriate connection design that will allow fish passage into created floodplain habitats stable enough to endure 100-year flood discharges and volumes from both Ball Creek and the Kootenai River.
3. Develop a geomorphically appropriate design for Ball Creek, balancing channel length, sinuosity, slope, cross-sectional dimensions, habitat characteristics and riparian community with physical conditions such as soil characteristics and political constraints such as land ownership.
4. Identify and refine the design of water control structures that can regulate the flood inundation extent and duration of floodplain habitats. This design component was completed in coordination with agriculture managers to simultaneously maximize ecological and agricultural benefits.
5. Examine hydrogeologic data and existing models to maximize potential hyporheic interactions with the construction of the Ball Creek channel.
6. Develop design plans with commensurate specifications and associated supporting calculations.
7. Explain hydrologic conditions supporting the proposed design.
8. Design in-stream habitat structures to encourage hydraulic forces to create habitat complexity while maintaining channel dimensions within a natural realignment pattern.
9. Model backwater effects of the Kootenai River, assuming the design is constructed including control structures.
10. Model Ball Creek discharges in the constructed channel and associated wetlands including interactions from Kootenai River backwater effects at selected stage elevations.
11. Describe and illustrate anticipated floodplain wetlands and expectations for how they will contribute to ecological restoration.

1.5.3 Describe Design/Construction Plans and Costs

1. Give a brief overview of construction sequencing.
2. Quantify the excavated materials and quantities of materials needed for construction.
3. Give a brief overview of the estimated construction costs.
4. Describe applicable Best Management Practices (BMPs).

1.5.4 Describe Planting Plan

1. Describe and illustrate the anticipated riparian community, when mature, and expectations for how it will contribute to ecological restoration.

1.6 STREAM ENHANCEMENT OVERVIEW

1.6.1 Stream Enhancement Goals and Objectives

This restoration project is one part of an incremental process being implemented by KTOI in an effort to improve the larger Kootenai River ecosystem. The specific purpose of this project is to reestablish a portion of the floodplain ecosystem by mimicking the historical condition, to the extent feasible and practical.

The ultimate goal of the project is to re-create, to the extent practical, a natural and self-sustaining floodplain ecosystem on the Ball Creek Ranch. Objectives of this project target multiple species in an ecological context. It is proposed to use Ball Creek flood-flows to mimic historical Kootenai River flood pulses, albeit at a smaller scale. Ball Creek is suitable for this treatment for two primary reasons: (1) surplus discharge is available during runoff events, and (2) the Ball Creek hydrograph is temporally similar to the historical Kootenai River hydrograph, as was shown in Figure A-1 of the project feasibility report by GeoEngineers (GeoEngineers, 2006).

1.6.2 Proposed Enhancements

The enhancements proposed to achieve the aforementioned restoration results include the following and are addressed in greater detail throughout this report:

1. Realign the Ball Creek channel in a path similar to the natural alignment (based on 1934 aerial photo interpretation shown in Appendix C, Sheet 3.1, "Historic Conditions 1934 Aerial Photo"). The proposed channel alignment should be about 18,000 linear feet compared to the existing channel, which is about 3,100 feet.
2. Reconnect the newly constructed Ball Creek channel to the Kootenai River in a manner that will facilitate passage for salmonids during most flow conditions and create low-velocity refugia within the proposed Ball Creek channel.
3. Divert Ball Creek from its current alignment into the proposed alignment. This will involve dissipating energy from the stream as it emerges from the high-gradient Selkirk Mountains onto the low-gradient Kootenai River floodplain.
4. Use water from Ball Creek to establish riparian and forested wetlands (when mature) that are adjacent to the constructed Ball Creek channel.
5. Use water control structures, throughout the floodplain, to control the extent of floodplain inundation during high flow events on the Kootenai River and Ball Creek.
6. Create a geocell, low flow ford stream crossing for farm equipment to allow access on both sides of the proposed Ball Creek stream corridor.

1.6.3 Benefits

1.6.3.1 Ecological Benefits

As previously mentioned (see Section 1.1, "Project Overview"), continuous impacts over the past 100 years have resulted in a disruption of the Kootenai Ecosystem's trophic structure. The construction and operation of Libby Dam and the associated Libby Reservoir (also known as Koocanusa Reservoir) act as

a nutrient sink (Snyder and Minshall, 1996), thereby causing reduced nutrient concentration below the dam and cutting off river continuum processes at that point (Vannote et al., 1980). Flood control has eliminated nutrient flow, which naturally occurred via the flood pulse (Junk et al., 1989) downstream of Libby dam. This project is a relatively small-scale effort to reestablish the flood pulse ecology intended to stimulate the trophic cascade from the bottom (nutrients) to the top (tertiary consumers).

To mimic natural floodplain processes, the proposed project includes establishing new wetland areas adjacent to the proposed Ball Creek alignment, which will be inundated during Ball Creek flood flows and influenced by the Kootenai river stage elevation (GeoEngineers, 2006). The intent is to create lentic areas with high primary production that are connected to the active Ball Creek channel. Past reports have shown that lentic floodplain wetlands are significantly more productive than lotic habitats (GeoEngineers, 2005 and 2006; Holderman et al., 2005). Increasing the area and volume of lentic habitats is expected to increase primary production and primary consumer populations, which stimulate the base of the trophic cascade. Connecting lentic habitats with the active Ball Creek channel should transfer some of that productivity into the lotic environment and subsequent trophic levels.

In the context of this project, humans are included as part of the local ecology. Often, human elements are excluded from ecological considerations; however, land use and ownership cooperation and benefits are necessary for long-term project success. Not only will project implementation be a benefit to fish and wildlife, but human benefits should include improved aesthetic value by encouraging and enhancing fish and wildlife populations and increased outdoor recreational activities, such as hunting, fishing and wildlife photography.

1.6.3.2 Community Benefits

Community support is necessary for the success of this project. The project will demonstrate economic and aesthetic benefits in order to engender community support. The proposed 2,500-acre property is known as the Ball Creek Ranch, of which TNC is the primary owner; however, partial ownership is maintained by numerous parties through tribal allotments ceded as part of the Executive Order officially recognizing the Kootenai Tribe. Owners of the allotments include tribal and nontribal interests who realize economic compensation based on revenue generated by agricultural production/leases and relative ownership of each allotment. Economic compensation for each owner has not been specified or scheduled other than recognizing the need. This effort will be coordinated through KTOI, TNC and individual allotment owners.

Economic value from the project will be realized largely through recreational opportunities and construction operations. Because TNC allows public access to the project site, recreational opportunities can be realized by residents of the local community and/or surrounding communities. Outdoor recreational opportunities, created by the project, should attract hunters, fishers, hikers, bird watchers and wildlife photographers to the area. People and groups that engage in these activities generally contribute significantly to the local economy by frequenting local businesses and establishments. Additionally, project construction will be relatively extensive. By virtue of its size, job opportunities will be made available and commensurate community businesses will be supported through the purchase of construction supplies, fuel, lodging and recreation for construction crews. Local governments will also benefit through taxes generated by increased revenue.

Even though economic benefits are expected to be substantial, aesthetic benefits are the focus of the project by which the community will benefit. Throughout the Kootenai River floodplain, between Bonners Ferry, Idaho, and the Canadian border, tributary streams have been realigned and channelized to maximize farm ground. Implementing this project and restoring natural ecological processes will enable the public to see a small-scale example of how the system once functioned. The potentially most visible

effect, in the short-term, will be the reestablishment of kokanee spawning migrations. The restored habitat should attract kokanee spawners, and it is hoped that the population will naturally rebuild. These migrations can be quite impressive and have not been widely present in the lower Kootenai system for decades, primarily as a result of habitat degradation. These migrations will attract other wildlife, such as bald eagles who feed on the spent fish carcasses after spawning. Additionally, the stream corridor, riparian community and adjacent wetlands will be ecologically functional and provide scenic panoramas with the Selkirk Mountains, Cabinet Mountains, Kootenai River and adjacent cropland as background.

1.6.4 Level of Analysis and Design

The proposed stream enhancement design has been developed to a construction bid level of detail to facilitate planning, permitting and construction bid-related efforts for the project. Overall, the proposed enhancement designs can be considered to be about 95 percent complete for construction.

It was necessary to develop very detailed stream and floodplain designs in order to accurately identify the proposed floodplain extents, floodplain elevations, stable stream geometries, habitat types, habitat extents and construction quantities. The proposed Ball Creek Restoration Construction Bid Documents presented in Appendix C are therefore considered complete and not subject to change.

2.0 GENERAL SITE CHARACTERISTICS

2.1 OVERVIEW

This section of the report describes the historical and existing aspects of the project site that pertain to the proposed stream enhancement design. These discussions are generalized, address the whole project site and are supported by more detailed discussions later in the Report. The analysis and design processes used in the enhancement designs are discussed in Section 3.0 of this Report, "Analysis and Design." Reach-specific enhancement designs are described in detail in Section 4.0 of this Report, "Proposed Enhancement Designs."

2.2 PROJECT LOCATION

Ball Creek Ranch occupies about 2,500 acres on the west side of the Kootenai River. The property borders the river from about River Mile (RM) 135.5 to 141. The total ranch area occupies portions of Sections 12, 13, 24 and 25 Township 63 north, Range 1 west, and Sections 7, 18 and 19 Township 63 north, Range 1 east.

2.3 LANDSCAPE OVERVIEW

The Ball Creek Ranch represents about 2,500 acres (about 5 percent) of the total 50,000-acre portion of the Kootenai River floodplain between Bonners Ferry, Idaho, and the Canadian border. Ball Creek enters the project area near the southwestern boundary where it flows out of a steep-walled canyon in the Selkirk Mountains.

Topography in and around the project area is generally flat, with occasional low-profile swales and ridges, remnant meander scrolls from historical channel migration of the Kootenai River. Human modifications to the landscape include several roughly linear drainage ditches and a continuous levee bordering the bank of the Kootenai River through the length of the project area. Additional infrastructure in and around Ball Creek Ranch includes several buildings on the surface of the historical alluvial fan, and a single road (West Side Road) bisects the alluvial fan laterally from north to south, crossing Ball Creek with a single-span bridge. Occasional unimproved ranch roads border the agricultural fields.

Surrounding properties to the north and south of the Ball Creek project area consist primarily of private agricultural fields and a large wetland immediately to the north managed by TNC. To the west are forested public lands managed by the United States Forest Service, and bounding the project area to the east is the Kootenai River.

2.4 WATERSHED

Ball Creek is a tributary watershed of the Kootenai River originating from Myrtle and Ball Lakes in the Selkirk Mountain Range. The creek flows in generally an easterly direction for about 14 miles until its confluence with the Kootenai River. The watershed area is approximately 26.6 square miles. Elevations range from roughly 7,150 feet above Mean Sea Level (MSL) in the headwaters to about 1,742 feet MSL at the confluence with the Kootenai River, yielding a vertical relief of about 5,408 feet and an average gradient just over 8 percent.

2.5 HYDROLOGY

Some of the hydrologic characteristics for Ball Creek were obtained from the United States Geological Survey (USGS) StreamStats program. River valley temperature was obtained from the Natural Resources Conservation Service (NRCS) WETS station #ID1079. The hydrologic characteristics resulting from these queries are listed in Table 1.

Table 1. Hydrologic Characteristics of the Ball Creek Watershed

Hydrologic Characteristic	Ball Creek
Watershed Area	26.8 square miles
Mean Annual Precipitation	42 inches
Mean Annual Temperature	46.6° F

To estimate recurrence intervals on Ball Creek, a peak flow analysis was conducted on data collected at USGS gauging station #12313500, active on Ball Creek from 1928-1934 and from 1972-1979. A Log Pearson Type 3 (LP3) statistical analysis was used to estimate numerous flow recurrence interval events on Ball Creek. The LP3 distribution utilized the methodology discussed in the USGS 17B Bulletin that utilizes a weighted skew value derived from a generalized location skew value in conjunction with the available record skew (USGS, 1982). Results from the LP3 distribution are shown in Table 2.

Table 2. Hydrologic Analysis on Ball Creek

Peak Flow Event	Ball Creek (cfs)
1-year	126
1.25-year (Bankfull)	323
1.5-year	410
2-year	529
5-year	889
10-year	1,178
25-year	1,603
50-year	1,964
100-year	2,364
500-year	3,470

Note:
cfs = cubic feet per second

Nearby adjacent streams with historical peak flow records were researched to determine whether they were hydrologically similar and could be used to artificially extend the historical data for Ball Creek. Trout Creek and Boundary Creek were both recognized as potential supplements to the Ball Creek data. Trout Creek's historical record, however, was shorter than that of Ball Creek so it was not utilized. Boundary Creek was evaluated, and discharges were corrected to represent Ball Creek strictly based on prorating the discharge by an area ratio between the watershed sizes. These return frequency discharges tended to underestimate the Ball Creek discharge, based on comparisons between the LP3 distribution and the discharge estimates from the USGS StreamStats program. Because the estimates from these methods all varied from the original LP3 distribution, the historical record and associated LP3 distribution of peak discharges for Ball Creek was used in this design.

2.6 FLOODPLAINS

The Federal Emergency Management Agency (FEMA) has identified areas of flooding concern for the Kootenai River and Ball Creek, in the vicinity of Ball Creek Ranch. The boundaries of these flood limits are presented on the FEMA Flood Insurance Rate Map (FIRM) Panel 375 of 800, for Boundary County, Idaho, Community Number 160207 0375B, effective August 2, 1982, included as Figure A-3 of the preliminary design report (GeoEngineers, 2008). The regulatory areas of flooding concern at Ball Creek Ranch are based solely on backwater conditions from the Kootenai River and are relatively small because of protection by levees, and flooding primarily occurs in areas known as "unincorporated areas." There is currently no FEMA floodplain for the Ball Creek Channel.

The flood attributes presented on the FEMA FIRMs are generated with computer models that utilize topography and discharge to approximate the stream's hydraulic characteristics and flood limits. It should be emphasized that all models of this nature are only as precise as the information upon which they are based and should be considered approximate.

The USGS (Berenbrock, 2005; Barton et al., 2004) and GeoEngineers (2006) have developed a more accurate representation of the stream's existing floodplain using the USACE Hydrologic Engineering Center-River Analysis System (HEC-RAS) model. This model is based on topographic data from two

sources: (1) detailed bathymetric topography and associated interpretations within the Kootenai River; and (2) land-surface topography based on DEMs constructed using LiDAR in April 2005.

2.7 FISH HABITAT AND PASSAGE

Downstream of West Side Road, the existing Ball Creek channel can be broken into two distinct habitat reaches. Habitat conditions in both reaches are impaired, and only a small percentage of each reach is considered suitable for native salmonids of any age class. Reach 1 extends from West Side Road downstream approximately 1,000 feet. Reach 2 extends approximately 2,100 feet from the downstream end of Reach 1 to the Kootenai River (see Appendix C, Sheet 3.3, “Existing Site Conditions”).

Reach 1 is located on the distal end of the historical alluvial fan. Habitat conditions consist of almost exclusively shallow riffles and sparse pocket-water formed from scour around boulders. Virtually no riparian vegetation or overhead cover exists. The streambed in Reach 1 is generally loose and lacking fines. These conditions provide good habitat for benthic macroinvertebrates; however, the lack of holding water for fish likely prevents significant energy transfer to tertiary consumers (fish). Furthermore, substrate size is too large and slope too great to support significant spawning activities. From a fish habitat perspective, the value of this reach is limited to a migration corridor accessing upstream habitats that might be used by bull trout but are unlikely to be used by kokanee or rainbow trout.

Reach 2 is characterized by channel incision up to 30 feet. Throughout the backwater influence area, the stream substrate ranges from large gravels, at the upstream end, to sand near the Kootenai River confluence. The channel is relatively wide and shallow and exhibits homogeneous channel conditions with limited cover and roughness. There are two primary pools in this reach. Both pools are created and maintained by logs and rootwads. Both pools are heavily populated by salmonids of several age classes (GeoEngineers, 2008). From a native salmonid habitat perspective, this reach is used primarily for holding, rearing and feeding; however, areas suitable for these behaviors are limited. Kokanee spawning was observed throughout this reach in the autumn of 2007 and 2008. Banks are near-vertical and sloughing, and a riparian corridor does not exist.

3.0 ANALYSIS AND DESIGN

3.1 OVERVIEW

This section of the report describes the key analysis and design assumptions and methods used our enhancement designs. These discussions are generalized and address the whole project site. Reach-specific enhancement designs are described in greater detail in Section 4.0 of this Report, “Proposed Enhancement Designs.”

3.2 GENERAL PROJECT LAYOUT

There are nine proposed stream reaches that will undergo restoration measures as part of this floodplain reconnection. These reaches are different from one another in terms of their geomorphic function, existing and proposed landscape conditions, habitat and restoration potential (including feasibility). Accordingly, each reach required independent, site-specific designs. The proposed stream restoration design is presented in Appendix C, Stream Restoration Construction Bid Documents. In Appendix C, Sheet 1 includes a vicinity map as well as a Table of Contents for the subsequent sheets. Sheet 5 shows the relative location of the proposed channel and nine reaches. Sheets 6.1 through 6.12 and 8.1 through 8.6 show the plan, profile and cross section views.

3.3 UNDERLYING STREAM DESIGN PHILOSOPHY

Over time, natural alluvial stream systems attain a degree of balance between seemingly opposing forces. For example, in a natural stream system, the rate at which a stream's left bank erodes will eventually become equal to the rate at which a gravel bar develops along its right bank. Similarly, erosion and sedimentation along a stream valley becomes balanced such that changes in the stream gradient are gentle over long distances, transitioning from relatively steeper grades upstream to more gentle grades downstream. Such balanced systems are said to be in "dynamic equilibrium" (Rosgen, 1996). Without human intervention such as continued channelization, dam installation or riprap placement, a disturbed stream system will naturally trend toward dynamic equilibrium. Depending upon the stream system, this can take from decades to centuries. The design approach is targeted at fast-forwarding these natural geomorphic processes and promoting a self sustaining and naturally functioning system.

Once established at this geomorphic level, the stream corridor within the Ball Creek Ranch will be the foundation upon which healthy aquatic and riparian habitat will thrive. These habitats will, in turn, enable the stream to maintain and sustain itself. For example, once the wetted stream corridor is constructed and planted, the vegetation will provide bank stability and habitat for terrestrial invertebrates, birds, amphibians and mammals. As the vegetation matures and the channel migrates, some of this vegetation will enter the channel, creating more diverse in-water habitat for fish and the associated aquatic community.

3.4 STREAM DESIGN

3.4.1 Stream Design Approach

The approach used in the design of these streams essentially mimics a stream's natural geomorphic processes, which involves balancing numerous physical attributes of streams simultaneously. Attributes balanced in this process include: water velocity; depth; shear stress; the size and composition of the streambed and stream bank materials; the resistive forces of the riparian vegetation; and ultimately the size, shape and gradient of the stream and floodplain itself. Aspects factored into this approach involve:

1. Conveying the full range of anticipated stream discharges;
2. Conveying the sediment through the stream system to prevent either excessive erosion or sedimentation
3. Establishing sustainable riparian vegetation that will perpetuate a dynamically stable stream corridor indefinitely

Design concerns pertaining to safety, flooding, habitat, irrigation, infrastructure, water rights, water usage and fish passage are considered throughout this design process as well. In addition to balancing these elements along each individual stream reach, the interactions and interdependencies between reaches must be accounted for in the design.

A proprietary computer program was used to achieve this balance in our proposed stream designs. This process ultimately results in the size, gradient and meander geometry of the bankfull channels and floodplains of each stream reach. The size and gradient of the resulting stream channel is consistent throughout each individual reach. Floodplain gradients are consistent throughout each individual reach as well. As in natural stream systems, however, meander geometries are variable along each individual reach, and an appropriate range of meander geometries are developed so individual reaches connect and function as a single system.

The proposed stream dimensions and gradients were derived using a combination of commonly applied hydraulic equations (Chow, 1959) and sediment mobility relationships (Laursen, 1980; Neill, 1973; and Shields, 1936). The proposed meander geometries were derived from empirical relationships from Rosgen (Rosgen, 1998), which were originally based on Williams (Williams, 1986).

This design is presented with the understanding that the construction of natural streams is inexact, and construction variability should be expected and even encouraged within certain parameters. Certain design parameters are more critical than others. For the purpose of this design, we have attributed three levels of priority for construction accuracy: very high, high and moderate. Note there is no low priority. The proposed stream lengths, the upstream and downstream streambed elevations, and the stream and floodplain gradients are very critical elements to each stream reach. These parameters have a very high construction accuracy priority and should be strictly adhered to during construction. The cross-sectional area and width of the bankfull channels also have a very high priority and should be constructed accordingly.

Although the final shape of the channel cross section has a high priority, the channel cross section shape should be adjusted during construction to appear natural. The proposed meander geometries are intended to vary within the estimated ranges, and are given a moderate priority to encourage variability during construction. The meander patterns depicted in the reach-specific plans and profile sheets are provided as graphic examples and should be adjusted within the specified ranges during construction. Floodplain gradients along each reach are a very high priority. Undulations and variability in floodplain cross sections, however, are encouraged, and accuracy is given a moderate priority.

Watershed conditions, discharges and sediment flows are variable from season to season and from year to year. Stream channels are expected to adjust and accommodate these variations. Natural stream systems are also dynamic and are intended to meander throughout the floodplain over time. Designing for dynamic equilibrium simply attempts to balance the relative rates of lateral erosion, sedimentation and channel migration. However, deep vertical erosion, also known as headcutting or incision, is not desirable and should be managed appropriately. The proposed stream designs will require proper monitoring and maintenance to ensure that they are responding as intended.

3.4.2 Stream Design

Conditions of the historical Ball Creek channel were estimated from topography and aerial photographs (Appendix C, Sheet 3.1). Sinuous channel scars roughly 50 to 75 feet wide are visible cutting across the Kootenai River floodplain both in aerial photographs and detailed LiDAR-based topography. These channel scars originate near the existing outlet of Ball Creek and are presumed to have been formed by Ball Creek prior to human channel modifications. From these interpretations, it is estimated that the channel flowed across the greater Kootenai River floodplain for a distance of roughly 3.5 miles with an average sinuosity of 1.34 and an overall slope of 0.3 percent.

When Ball Creek historically flooded, it would deposit most of its sediment load near the channel, creating a naturally perched condition. Therefore, when looking at the topography of the floodplain, portions of the historical Ball Creek alignment are topographically higher than the Kootenai River floodplain. Following the historical stream channel would be advisable if the entire historical channel, including its confluence with the Kootenai River, could be utilized. This would mimic historical conditions and is therefore the most desirable alternative. Unfortunately, like many restoration projects, the location of the alignment and associated flooding is constrained by geomorphic and anthropogenic conditions. Because of these constraints, the proposed channel alignment has been located in the topographic low areas of the floodplain adjacent to the perched portions of the historical channel.

To facilitate the stream design, the proposed alignment was divided into nine distinct reaches. The locations of these reaches are presented on Sheet 5 in Appendix C. The proposed stream alignment generally follows the historical alignment in Reaches 6 through 9 and then relies upon the relatively higher elevation of the creek's historical banks, the Kootenai River floodplain and proposed excavation spoils to limit flooding extents in Reaches 2 through 5. The flood extents are contained along Reaches 2 through 5 to maintain the creek's alignment along the desired route and to reduce the potential of channel piracy and large-scale avulsions into the Kootenai River. Additionally, channel excavation was significantly reduced by locating the proposed alignment in the topographically low area east of the historical creek alignment. Reach 1, the most-downstream reach, is essentially the existing backwater area off the Kootenai River into which the water from Ditch A is pumped.

We used visual evidence from the DEM and 1934 aerial photographs to develop the plan view and slope of the proposed project reach, following existing contours and historical evidence of the stream's former location. Using the DEM, we were able to analyze the planform of other historical tributary alignments on the Kootenai floodplain to obtain targets and reference reaches for the proposed alignment. These reference targets were then utilized within our proprietary computer program to achieve the balance in our proposed stream designs as discussed above. The geomorphic parameters of the nine design reaches were calculated and averaged into an overall restoration plan. Each reach is designed for form, process and function then classified in accordance with the Rosgen Stream Classification System (Rosgen, 1996). Sheet 8.1 in Appendix C summarizes the proposed stream sizes, geometries and range of meander geometries. Subsequent sheets in the Stream Restoration Construction Bid Documents in Appendix C display the proposed stream and floodplain enhancements in greater detail.

3.5 DESIGN DISCHARGES

In seven out of the nine reaches on Ball Creek, the bankfull channel of the proposed stream has been designed to convey the bankfull discharge, which has a return frequency of approximately once every 1.25 years in this hydrologic region (Castro et al., 2001). Discharges in excess of the bankfull discharge will initiate flow in the adjacent floodplains. Reaches 4 and 6, which are wetland meadows, have been designed with a bankfull channel capable of conveying a discharge that has a return frequency of approximately once every year. That will result in floodplain inundation at flows greater than the 1-year recurrence interval, rather than 1.25-year recurrence interval as with the other design reaches. More frequent floodplain inundation will better maintain the wetland/meadow form and function of the reach.

Federal and county standards require that floodplains safely convey the 100-year discharge, at a minimum. The proposed floodplain is designed to safely convey discharges in excess of the 100-year discharge (2,364 cfs) with and without 100-year backwater conditions from the Kootenai River. This excess capacity is provided to accommodate riparian habitat on the floodplains, fish and animal passage, natural stream movement and episodic sediment pulses.

3.6 HYDRAULIC MODELING

GeoEngineers developed a hydraulic model of the stream corridor throughout Ball Creek Ranch for the proposed site conditions. The proposed conditions model was used to define the bankfull and 100-year floodplain, with and without any backwater flooding conditions from the Kootenai River. The model was also used to confirm and refine the stream enhancement designs. Version 4.0 of the USACE HEC-RAS hydraulic computer model was used to model the proposed conditions of Ball Creek (USACE, 2006). Multiple scenarios were modeled to estimate a variety of hydrologic conditions. Various flood frequency return intervals were modeled without any backwater conditions from the Kootenai River, and they were also modeled with backwater conditions from the Kootenai River. The backwater conditions on the

Kootenai River are based on the 100-year flood elevation at the point where the levee will be breached. The bankfull condition without any backwater effects from the Kootenai River and the 100-year floodplain with backwater effects from the Kootenai River as defined by GeoEngineers are presented on Sheet 4.2 in Appendix C.

3.7 IN-STREAM HABITAT STRUCTURES

In-stream habitat structures are naturally appearing, naturally functioning tree or rock structures placed in the stream, stream banks and floodplains. In addition to creating and maintaining in-stream and riparian habitat, these structures help stabilize the stream channel over time.

Every proposed structure dissipates energy, stabilizes the stream banks and bed, and creates localized habitat benefits. Each individual structure performs very specific functions such as protecting banks, directing stream flow, scouring pools or sorting gravel based on known hydraulic forces and the design intention. Knowledge of hydraulic forces throughout the enhancement reaches improves, creates and maintains habitat features including vegetated banks, pools, riffles, eddys and undercut banks, which help create habitat complexity and cool water temperatures, and provide cover for protection and a source for food. These features, in turn, enhance and diversify habitat for fish spawning, rearing, refuge and migration. Additional benefits to macroinvertebrates, amphibians and other aquatic and upland species results as well from well planned and established in-stream habitat structures.

Habitat structures associated with the stream reaches and the floodplains provide initial erosion protection and stream stability while the newly constructed stream stabilizes overtime with vegetation and substrate sorting. As the stream banks and floodplains are reinforced with vegetation and roots, the tree structures will simply decay or naturally recruit more wood from the stream for continual protection and habitat maintenance. The rock, gravel and/or cobble structures will simply become worked into the streambed substrate and blend into the bed. These temporary controls are consistent with overall geomorphic design of the streams and enable the stream channels to adjust, fluctuate and migrate over time.

Proposed structure locations are shown in Appendix C, Sheets 7.1 through 7.12. Typical details are shown on Sheets 9.1 through 9.5, and they show the typical habitat structures proposed for this project as well as their intended use and purpose. It should be noted that these structures are presented as “typical” details, and necessitate site-specific field adjustments during construction.

3.8 CHANNEL STABILITY AND STREAM SUBSTRATE

Downstream of West Side Road, Ball Creek was channelized, resulting in a steep, narrow, incised, transport-dominated channel where previously a naturally broad, depositional alluvial fan had been. The historical alluvial fan formed where Ball Creek emerged from the steep and narrow confines of the Selkirk Mountains and could spread out onto the broad floodplain of the Kootenai River. Substrate grain sizes decrease in the downstream direction, ranging from large-cobble/small boulder with an estimated mean diameter (D50) of 300 millimeters, to gravel sizes and smaller, with a D50 of less than 90 millimeters. The decreasing substrate size and relatively high width-to-depth ratio is characteristic of alluvial fans where channel character changes from transport-dominated to depositional in the downstream direction. This natural continuum from transport to deposition is, however, being limited by anthropogenic channelization. The bridge on West Side Road and other human-related channel confinements have effectively eliminated Ball Creek’s ability to spread out and dissipate energy across the alluvial fan. Instead, the confined, high-energy flow persists further downstream, resulting in bank erosion and channel incision. During high discharge on the Kootenai River, Ball Creek is influenced by Kootenai River backwater. The high-energy of Ball Creek is largely dissipated only upon encountering this backwater from the Kootenai River.

Because the existing alignment of Ball Creek has been diverted from its historical location, the proposed channel will be reconfigured into a meandering channel across the Kootenai River floodplain, approximating the general character and pattern of the historical Ball Creek channel. The proposed stream channel has been designed to be stable in the existing sand and silt substrate located on the floodplain. Additionally, specifically located grade-control structures composed of cobbles and boulders will be used to limit potential scour and headcutting. The sizes and gradations of the proposed grade-control structures vary depending upon site-specific requirements, site vulnerabilities, velocities, shear stresses, intended use and aesthetics. Stream scour and bedload sorting will occur naturally (within the limits of the grade-control structures), while the channel establishes and maintains its necessary configuration.

Proposed substrate sizes were calculated by employing a sediment transport analysis using two different methods. These methods included a shear stress analysis for incipient motion, using Shields' Equation (Shields, 1936), and a velocity analysis using Neill's Equation (Neill, 1973) and Laursen's Equation (Laursen, 1980). The incipient motion analysis compares the dimensionless shear stress with the boundary Reynold's number for the substrate size in question to estimate what particle sizes will be transported downstream. Particle motion begins to occur when the two parameters are above an empirical envelope of incipient motion. Bedload transport occurs when the criteria for incipient motion are met or exceeded. The velocity analysis is based on a critical transport velocity dependent on substrate size and a relative bed stability factor to determine if the bedload will be transported.

Each of these methods involve inherent errors, and actual values may vary from the calculated values. The calculated values are intended to estimate incipient motion and bedload for the purposes of the design.

3.9 FLOODPLAIN MANAGEMENT AND ACCESS

3.9.1 Floodplain Management

One of the concerns that needed to be addressed for this restoration effort was limiting the inundation extents from Ball Creek and from backwater on the Kootenai River to maintain active agricultural production on the neighboring parcels. Model results based on our proposed stream and floodplain elevations identified two areas that will require fill to limit inundation outside of the proposed active floodplain. These areas and the limited 1.25-year and 100-year floodplains are shown on Sheets 3.4 and 4.2 in the Construction Bid Documents in Appendix C.

Excavated material from construction of the proposed channel and floodplain will be used as fill in low-lying areas to prevent flooding of active agricultural fields. The most significant low-lying areas to be filled are on the perimeter of the proposed floodplain in Reaches 3, 4 and 5. This will elevate these areas above the 100-year Kootenai River elevation of 1,763 feet, decreasing the frequency of flooding of the active agricultural fields. Excess soils will also be utilized to topographically focus the broad floodplains of Reaches 8 and 5 into the relatively narrow floodplains of Reaches 7 and 4, respectively.

3.9.2 Floodplain Access (Geocell Ford)

The proposed alignment of Ball Creek will bisect Ball Creek Ranch and limit access to the property east of the proposed creek alignment. The upstream portion of the property will be accessible over the elevated and armored berm adjacent to Reaches 9 and 8, but further downstream the existing access roads will be bisected by the proposed alignment. It would be difficult and expensive to install a bridge where the proposed alignment breaches the existing downstream levee. Instead, the design includes a gravel-filled geocell low-water ford at the location shown on Sheet 3.4, "Proposed Site Conditions," in

Appendix C. Details of the geocell are presented on Sheet 10.2. Vehicles will be able to access the property east of Ditch B by driving over the backfilled location upstream, parallel to Reach 3.

Geocell low-water fords are applicable in low-traffic areas and are best suited for low-gradient streams such as the proposed Ball Creek alignment. These fords allow for unobstructed passage of water and of fish and other aquatic animals during all times of the year. They are a low-cost, low-maintenance alternative and have proven to be durable by the USACE. However, traffic can cross the ford only during low water, and may not be able to access the eastern portion of the property in the springtime and during other high-water events.

The hardened stream crossing will extend to the top of the floodplain on both sides of Ball Creek. When constructed, the top elevation of the geocell ford will be equal to the stream bed and floodplain elevation to prevent scour and deposition. The geocell shall be Presto Geosystem's Geoweb or equivalent. A non-woven geotextile fabric will be placed beneath the perforated geocell to separate the local fine sand and silt from gravels that will be used to fill and cover the geocells. ATRA[®] anchors, composed of fiberglass bars and clips, will be used to anchor the system in place along with polymeric tendons prior to gravel infill. For ease of vehicle crossing, the relatively steep banks in this reach will be laid back to a 5H:1V (horizontal to vertical) sideslope at the geocell ford. To prevent bank erosion, both banks upstream and downstream of the ford will be armored with vegetated soil reinforced bank protection (that is, burrito wrap). The channel will also be roughened upstream and downstream of the ford to maintain a transport reach and further prevent scour and deposition. The ford is located at a natural floodplain constriction. In combination, the constriction and reinforced geocell create a relatively hardened channel and floodplain cross section, which reduces the potential for the stream to migrate laterally beyond the desired alignment. It will also double as grade control. To promote safety, we strongly recommend that a stream staff gauge be installed at the ford so people can estimate the depth of the water flowing over the ford. Additionally, the ford should be inspected for damage after high-flow events and/or yearly at a minimum. Although these types of crossings require less maintenance than bridges, culverts and/or other types of low-water fords, this crossing will likely require some maintenance over the years.

4.0 PROPOSED ENHANCEMENT DESIGNS

As noted above, the proposed alignment has been divided into nine distinct reaches. Each reach was identified based on geomorphic conditions, existing landscape and the proposed landscape. The primary variables considered in defining these reaches included: cost; excavation feasibility; existing and proposed grades; proposed reach function; functional interactions between reaches; habitat; and potential floodplain width. Progressing in an upstream direction, the following summary generally describes the design of each proposed reach.

4.1 REACH 1

4.1.1 Reference Sheets

Reach 1 is the most downstream length of Ball Creek starting from its confluence with the Kootenai River and continuing upstream 1,000 feet (Sta. 10+00 to Sta. 20+00). The enhancements proposed in Reach 1 are graphically depicted on Sheets 6.1, 7.1 and 8.2 in Appendix C. Specifically, the proposed floodplain grading and profile are shown on Sheet 6.1, the vegetation and habitat structures are shown on Sheet 7.1, and a typical cross section is presented on Sheet 8.2.

4.1.2 Existing Conditions

Reach 1 is currently located on the Kootenai River side of the levees and acts like off-channel habitat and slack water on the edge of the Kootenai River. This reach is located in a small cove on the left bank of the Kootenai River, as seen on Sheets 3.3 and 3.4 in Appendix C. It consists of a primarily sand bed with ineffective flowing water during high flows.

4.1.3 Proposed Conditions and Design Considerations

The elevations in the reach are controlled upstream by grade controls in Reach 2 and downstream by the stage of the Kootenai River. The width of the reach is controlled by the existing levees along the Kootenai River. Because of the significant existing hydraulic controls, the Reach 1 design will consist of a relatively simple channel through the existing slack water area, providing positive drainage to the Kootenai River, matching existing grades and establishing riparian vegetation.

4.1.4 Benefits

Establishing riparian vegetation will provide shade, bank stabilization and the potential for future recruitment of large woody debris (LWD) in the Kootenai River and the mouth of Ball Creek. Providing positive drainage all the way to the Kootenai River will provide year-round fish access to Ball Creek and will not isolate or strand fish in Ball Creek.

4.2 REACH 2

4.2.1 Reference Sheets

Reach 2 is located immediately upstream of Reach 1 and is a transition reach through the existing Kootenai levee. This reach is 700 feet long (Sta. 20+00 to Sta. 27+00). The enhancements proposed in Reach 2 are graphically depicted on Sheets 6.1, 6.2, 7.1, 7.2 and 8.2 in Appendix C. Specifically, the proposed floodplain grading and profile are shown on Sheets 6.1 and 6.2, the vegetation and habitat structures are shown on Sheets 7.1 and 7.2, and a typical cross section is presented on Sheet 8.2. A detail of the roughened channel through the levee is presented on Sheet 10.4.

4.2.2 Existing Conditions

Reach 2 is currently a predominately dry reach that is bisected by the Kootenai levee that follows the left bank of the Kootenai River. This reach is composed of silts and sands. The Kootenai River side of the reach is probably inundated at extreme flows in the Kootenai River.

4.2.3 Proposed Conditions and Design Considerations

The proposed conditions for Reach 2 were designed to convey Ball Creek water through the Kootenai River levee. Proposed channel gradient is controlled by the elevation drop from the landward side of the levee to the Kootenai River side, resulting in a relatively steep channel. The overall width of the proposed Reach 2 channel and floodplain was designed as small as possible to minimize potential interference with the levee's flood-control function, yet wide enough to adequately convey a 100-year discharge from Ball Creek. The goal of the design is to permit Ball Creek flood flows to pass through the levee without bed scour and possible headcutting.

Although we anticipate a backwater condition resulting from high water in the Kootenai River during large floods, the possibility of a lag in peak discharge on the Kootenai River may negate the backwater effect. Because the proposed Reach 2 design is relatively steep and narrow, the channel cannot significantly dissipate energy in its adjacent floodplain. As a result, when discharges increase beyond the

bankfull discharge, channel-forming processes continue to increase. For this reason, the Reach 2 design used the 100-year discharge for the bankfull riffle design, rather than the 1.25-year discharge. This more closely mimics the conditions of a narrow, entrenched channel as it passes through the levee given a lag in peak discharge on the Kootenai River.

Sinuosity has also been reduced in Reach 2 to accommodate the steeper gradient. As a result of the relatively steep gradient and narrow floodplain, the transport capacity of Reach 2 is higher than it is upstream in Reach 3. This increases the potential of headcutting. Large rock grade controls, a roughened bed, plunge pools and dense woody vegetation have been added to the design to reduce the potential of headcutting and to increase bank stability.

4.2.4 Benefits

The need to excavate Ball Creek through the Kootenai River levee represents a significant design constraint resulting in a relatively steep channel gradient and a narrow floodplain. The benefit of this design is that it greatly reduces the amount of large-scale excavation required for upstream reaches, while providing adequate channel stability with rock and wood and allowing fish passage through the Kootenai River levee to the newly created habitat upstream.

4.3 REACH 3

4.3.1 Reference Sheets

Reach 3 is located immediately upstream of Reach 2 and is 2,800 feet long (Sta. 27+00 to Sta. 55+00). The enhancements proposed in Reach 3 are graphically depicted on Sheets 6.2, 6.3, 7.2, 7.3 and 8.3 in Appendix C. Specifically, the proposed floodplain grading and profile are shown on Sheets 6.2 and 6.3, the vegetation and habitat structures are shown on Sheets 7.2 and 7.3, and a typical cross section is presented on Sheet 8.3.

4.3.2 Existing Conditions

Reach 3 currently exists as dry agricultural land over silts and sands. The proposed channel crosses back and forth over existing Ditch B.

4.3.3 Proposed Conditions and Design Considerations

Reach 3 has been designed with a steep-banked, narrow, sinuous channel and a broad floodplain. The channel will be constructed in loose sandy soils; therefore, bank stabilization will depend upon the installation of LWD habitat structures and the establishment of riparian vegetation. If the rooting depth of the riparian vegetation is undermined by the channel, the banks will become unstable. For this reason, the depth of the channel was designed not to exceed 4.5 feet.

As with natural sinuous channels, some channel migration is expected; therefore, Reach 3 was designed to allow sufficient in-stream velocity to transport silt and fine sand derived from bank erosion and upstream processes. At the same time, increased channel sinuosity, the addition of in-stream structures and woody debris creating bank friction will reduce the potential for bed scour, headcutting and channel incision. Allowing the transport of incoming sediment through the reach will reduce the amount of in-stream deposition and therefore also reduce the potential formation of sand bars. By limiting bar formation, channel migration rates will be reduced, and riparian vegetation will more likely be able to maintain bank stability. The high in-stream friction and narrow channel designed for Reach 3 will also promote floodplain connectivity. Because of the high sinuosity and possibility for increased overbank

flow, the floodplain design includes an added roughness factor to reduce the chance of floodplain scour and/or avulsion. Roughness elements include woody plantings and scattered woody debris.

4.3.4 Benefits

The appropriate width-to-depth ratio, gradient, sinuosity and added structure all combine to create a naturally functioning, geomorphically stable, self-sustaining channel transitioning flow from the low-gradient wetland/meadow in Reach 4 upstream to the steep gradient of Reach 2 downstream. Additionally, the steep banks, in-stream structure and dense riparian vegetation will provide shade and shelter for fish. Floodplain connectivity at high flows and a highly sinuous channel will also dissipate flood velocities, creating areas of refugia for juvenile fish during floods.

4.4 REACH 4

4.4.1 Reference Sheets

Reach 4 is located immediately upstream of Reach 3 and is 3,500 feet long (Sta. 55+00 to Sta. 90+00). The enhancements proposed in Reach 4 are graphically depicted on Sheets 6.3 through 6.6, Sheets 7.3 through 7.6, and Sheet 8.3 in Appendix C. Specifically, the proposed floodplain grading and profile are shown on Sheets 6.3 through 6.6, the vegetation and habitat structures are shown on Sheets 7.3-7.6, and a typical cross section is presented on Sheet 8.3.

4.4.2 Existing Conditions

Reach 4 currently exists as dry agricultural land over silts and sands. Proceeding in an upstream direction, the proposed channel runs adjacent to existing Ditch B for a short distance then turns west.

4.4.3 Proposed Conditions and Design Considerations

Reach 4 has been designed as a low-gradient wetland/meadow. The design maintains a highly sinuous channel through the center of the wetland/meadow with a channel geometry that will result in floodplain inundation at flows greater than the 1-year recurrence interval, rather than 1.25-year recurrence interval as with most other design reaches. More frequent floodplain inundation will better maintain the wetland/meadow form and function of the reach. Very low gradients result in low channel velocity and will likely result in deposition, particularly in the upper reach where sediment will enter from Reach 5. Deposition will increase the rate of channel migration and possibly small-scale avulsion within the upper reach, which has been accounted for by designing a broad floodplain confined by topographic high points around its perimeter.

4.4.4 Benefits

Low velocity flows through Reach 4 will provide fish rearing, holding and refugia habitat conditions. As such, riparian vegetation has been designed not only to stabilize banks, but also to provide shade and cover for fish. In addition, woody debris structures will provide further cover for fish of all age classes. The designed channel geometry mimics a natural wetland/meadow stream and is intended to provide frequent floodplain connection and raise the local water table, enhancing riparian vegetation and terrestrial habitat. The large floodplain designed for Reach 4 also serves as a detention basin, attenuating peak discharges during floods.

4.5 REACH 5

4.5.1 Reference Sheets

Reach 5 is located immediately upstream of Reach 4 and is 2,000 feet long (Sta. 90+00 to Sta. 110+00). The enhancements proposed in Reach 5 are graphically depicted on Sheets 6.6, 6.7, 7.6, 7.7 and 8.4 in Appendix C. Specifically, the proposed floodplain grading and profile are shown on Sheets 6.6 and 6.7, the vegetation and habitat structures are shown on Sheets 7.6 and 7.7, and a typical cross section is presented on Sheet 8.4.

4.5.2 Existing Conditions

Reach 5 currently exists as dry agricultural land over silts and sands. The proposed channel near its upstream end is located in an old meander of the Kootenai River.

4.5.3 Proposed Conditions and Design Considerations

Reach 5 will be constructed on native sandy soils. As such, the channel banks have been designed with appropriate slopes, dense riparian vegetation and adequate bank armoring along the outsides of bends. If the rooting depth of the riparian vegetation is undermined by the channel, the banks will become unstable. For this reason, the depth of the channel was designed not to exceed 4.5 feet. Some channel migration and erosion of the sandy/silty banks is expected; therefore, the channel has been designed to transport fine sand, maintaining a coarse sand bed and limiting the formation of sand bars. By limiting bar formation, channel migration rates will be limited, and riparian vegetation will more likely be able to maintain bank stabilization.

4.5.4 Benefits

The goal of the design for Reach 5 is to develop a channel with a low-gradient, narrow, sinuous pattern and a relatively narrow floodplain. Maintaining a narrow floodplain will limit the extent of excavation necessary as the channel and floodplain pass through an area of relatively high topography. Additionally, a relatively narrow floodplain will focus the flow back into the main channel from the meadow/wetland reach upstream. It will also facilitate the addition of a ford for vehicle crossings, which will act as a grade control.

4.6 REACH 6

4.6.1 Reference Sheets

Reach 6 is located immediately upstream of Reach 5 and is 3,550 feet long (Sta. 110+00 to Sta. 145+50). The enhancements proposed in Reach 6 are graphically depicted on Sheets 6.7 through 6.9, Sheets 7.7 through 7.9, and Sheet 8.4 in Appendix C. Specifically, the proposed floodplain grading and profile are shown on Sheets 6.7 through 6.9, the vegetation and habitat structures are shown on Sheets 7.7 through 7.9, and a typical cross section is presented on Sheet 8.4.

4.6.2 Existing Conditions

Reach 6 currently exists as dry agricultural land over silts and sands. The proposed channel is located in an old abandoned meander of the Kootenai River.

4.6.3 Proposed Conditions and Design Considerations

Similar to Reach 4, Reach 6 has been designed as a highly sinuous, low-gradient wetland/meadow. The design maintains a sinuous channel through the center of the wetland/meadow with a channel geometry that will result in floodplain inundation at flows greater than the 1-year recurrence interval, rather than 1.25-year recurrence interval as with most other design reaches. More frequent floodplain inundation will better maintain the wetland/meadow form and function of the reach. Very low gradients result in low channel velocity and the potential for deposition, particularly in the upper reach where sediment will enter from Reach 7. Deposition will increase the rates of channel migration and possibly small-scale avulsion (meander cut-off) within the upper reach, which has been accounted for by designing a broad floodplain confined by topographic high points around its perimeter.

4.6.4 Benefits

Low velocity flows through Reach 6 will provide fish rearing, holding and refugia habitat conditions. As such, riparian vegetation has been designed not only to stabilize banks, but also to provide shade and cover for fish. In addition, woody debris structures will provide further cover for fish of all age classes. The designed channel geometry mimics a natural wetland/meadow stream, and is intended to provide frequent floodplain connection and raise the local water table, enhancing riparian vegetation and terrestrial habitat. The large floodplain designed for Reach 6 also serves as a detention basin, attenuating peak discharges during floods.

4.7 REACH 7

4.7.1 Reference Sheets

Reach 7 is located immediately upstream of Reach 6 and is 1,200 feet long (Sta. 145+50 to Sta. 157+50). The enhancements proposed in Reach 7 are graphically depicted on Sheets 6.9, 6.10, 7.9, 7.10 and 8.5 in Appendix C. Specifically, the proposed floodplain grading and profile are shown on Sheets 6.9 and 6.10, the vegetation and habitat structures are shown on Sheets 7.9 and 7.10, and a typical cross section is presented on Sheet 8.5.

4.7.2 Existing Conditions

Reach 7 currently exists as dry agricultural land composed of silts and sands. The proposed channel is located downstream of the distal end of the historical alluvial fan from Ball Creek.

4.7.3 Proposed Conditions and Design Considerations

Reach 7 has been designed to provide a transition from the alluvial fan form of Reach 8 to the meadow/wetland form of Reach 6. Design considerations include channel geometry, sinuosity and gradient sufficient to transport sand and some gravel entering from upstream. Additionally, the floodplain has been designed to be accessible during 1.25-year recurrence interval floods, with dense riparian vegetation and scattered woody debris to dissipate flood energy and promote stability in the main channel. To provide additional bank stability, the channel depth has been designed not to exceed the expected rooting depth of the riparian vegetation along the banks. Furthermore, bank armoring consisting of woody debris and jute matting will be used to promote bank stability, particularly within the first few years after construction while the riparian vegetation becomes established.

4.7.4 Benefits

The gradient, grain sizes and sediment availability in Reach 7 provide the greatest potential for spawning habitat within the Ball Creek project area. To maximize spawning potential, the channel geometry and profile have been designed to maintain a single-threaded channel with a primarily gravel grain-size bed. Wood structures along the banks, particularly on the outside of bends, will not only promote bank stabilization, but also provide channel complexity, including holding and rearing habitat for fish and gravel sorting for spawning.

4.8 REACH 8

4.8.1 Reference Sheets

Reach 8 is located immediately upstream of Reach 7 and is 1,950 feet long (Sta. 157+50 to Sta. 177+00). The enhancements proposed in Reach 8 are graphically depicted on Sheets 6.10 through 6.12, Sheets 7.10 through 7.12, and Sheet 8.5 in Appendix C. Specifically, the proposed floodplain grading and profile are shown on Sheets 6.10 through 6.12, the vegetation and habitat structures are shown on Sheets 7.10 through 7.12, and a typical cross section is presented on Sheet 8.5.

4.8.2 Existing Conditions

Reach 8 currently exists as dry agricultural land over a varying bed of cobbles, boulders, sands and silts. The proposed channel is located on the historical alluvial fan from Ball Creek, and it also bisects an old levee near Station 175+00.

4.8.3 Proposed Conditions and Design Considerations

The channel has been designed as a single main stem with two high-flow side channels and a broad floodplain mimicking the form of an alluvial fan. During high discharges, sediment-rich flows will be spread across a wider floodplain surface, reducing the hydraulic radius of the channel(s), which reduces shear stress, resulting in deposition. On the other hand, during low discharges, which typically do not transport sediment, flows are intended to pass through only the primary channel, maintaining its form by reworking deposited sediment. The potential high volumes of sediment entering Reach 8 along with the depositional design for the reach will create the potential for relatively rapid channel migration and/or small-scale avulsion – similar to a braided reach or an alluvial fan. The design accommodates these processes by utilizing a much broader floodplain than the adjacent reaches and by grading the surrounding topography to contain potential floodwaters and refocus the flow again into a single channel by Reach 7. In-stream complexity will be supplemented by the addition of LWD, as will floodplain complexity by scattering woody debris and densely planting vegetation across the surface of the floodplain.

4.8.4 Benefits

The primary goal of Reach 8 is to accept the sediment load passing through Reach 9 by providing sufficient space for deposition on the floodplain (alluvial fan), then refocusing flows into Reach 7. The placement of woody debris in the channel and floodplain will disrupt potential laminar flow during high discharges, promoting sediment sorting and gravel deposition in the mainstem and side channels for spawning habitat. The combination of a broad floodplain, large quantities of woody debris and dense vegetation across the floodplain all contribute to dissipating energy from high flows and promoting deposition in Reach 8, which provides increased channel stability for downstream reaches.

4.9 REACH 9

4.9.1 Reference Sheets

Reach 9 is located immediately upstream of Reach 8 and is 430 feet long (Sta. 177+00 to Sta. 181+30). The enhancements proposed in Reach 9 are graphically depicted on Sheets 6.12, 7.12 and 8.6 in Appendix C. Specifically, the proposed floodplain grading and profile are shown on Sheet 6.12, the vegetation and habitat structures are shown on Sheet 7.12, and a typical cross section is presented on Sheet 8.6.

4.9.2 Existing Conditions

Reach 9 is a relatively short, steep, entrenched, transport reach located at the distal end of the existing alluvial fan. It appears as though the channel has become incised in recent decades after being redirected into its existing, much shorter and steeper, channel. Channel incision has headcut upstream, entrenching the channel across the longitudinal surface of the existing alluvial fan. Entrenchment has effectively stabilized the alluvial fan by forcing sediment downstream through a deep, narrow channel rather than allowing flow to spread out and deposit sediment across the surface of the fan. As a result, the bed and banks are composed primarily of large alluvial sediment including boulders and cobbles with relatively small amounts of gravel and sand.

4.9.3 Proposed Conditions and Design Considerations

It is assumed that the greatest sediment load is delivered to the stream during very high discharge, and that there is minimal sediment delivery during relatively low discharge. As such, the channel was designed to be relatively wide, and the floodplain was designed to be relatively narrow (entrenched). In this way, flow is shallow and slow in the channel when the sediment load is minimal, and flow is deep and swift across the entire floodplain when the sediment load is greatest. In this way, sediment can be passed through the reach at such times that the potential sediment load is greatest.

Stream power generally decreases when flow overtops the banks, because it can spread out and dissipate energy in the floodplain. Because Reach 9 is fairly entrenched, the channel cannot significantly dissipate energy in the narrow floodplain. As a result, when discharge increases beyond bankfull, channel-forming processes continue to increase. For this reason, the Reach 9 design used the 100-year discharge for bankfull and riffle design, rather than the 1.25-year discharge. This more closely mimics the conditions of an entrenched channel.

4.9.4 Benefits

The goal of the design in Reach 9 is to extend the alluvial fan's transition from transport to deposition farther downstream while maintaining a stable and self-maintaining stream channel. By doing so, most deposition and channel variability associated with deposition will occur downstream of existing infrastructure. Mimicking the existing entrenched condition will minimize the potential for aggradation in Reach 9, which will minimize the potential for bank erosion, channel avulsion and related damage to infrastructure upstream.

5.0 CONSTRUCTION

5.1 CONSTRUCTION SEQUENCING

Construction will occur in a sensitive manner that avoids the disturbance of the existing habitat as much as possible. Where disturbance is necessary, it will be minimized and the disturbed areas will be

replanted and/or mitigated with an overall net benefit to the stream and surrounding environment. A general construction sequencing plan is outlined on Sheets 12.1 and 12.2 in Appendix C. Key elements of the construction plan include:

1. A sensitive design that addresses the overall long-term stability of the stream and riparian areas.
2. A sensitive design that minimizes the extent of disturbance to the stream and riparian habitat as much as possible.
3. A construction sequencing plan that minimizes the duration over which the disturbance occurs.
4. Off-line construction to enable the proposed stream and floodplain enhancements to be constructed away from active streamflow under dry conditions.
5. A BMP Plan that addresses both the temporary, construction-related concerns, as well as the long-term permanent stability concerns of this project.
6. An adjustable temporary diversion at the upstream end of the project that enables the flow in the enhanced stream reaches to be regulated to optimize the establishment of vegetation.
7. A multi-year, phased stream activation plan.
8. A construction safety plan to be completed by the contractor, which includes work schedule and hours of operation. This plan is to be signed and agreed to by all parties on the project site throughout construction.
9. On-site landscape sculpting and soil dispersal.

5.2 CONSTRUCTION QUANTITIES AND COST ESTIMATE

Approximate construction quantities have been generated for each reach, shown on Sheet 12.3 in Appendix C. Cost estimates have also been calculated for each reach. These costs were developed using a single list of standard unit costs based upon our recent project design/construction experience, inquiries to local construction contractors, suppliers and/or agencies, R.S. Means Heavy Construction Cost Data, and other appropriate sources. In addition to unit costs for specific construction quantities, our unit cost basis includes costs and variables to account for inflation, local location adjustment factors, mobilization, incidentals and contingencies. Additional design and permitting fees have not been included in the construction cost estimates. A summary of costs per reach is shown below in Table 3. Calculations regarding cost estimations per reach can be found in Appendix C.

Table 3. Construction Cost Per Reach

Ball Creek Reach	Construction Cost (\$)
Reach 1	\$ 104,487
Reach 2	\$ 583,410
Reach 3	\$ 914,568
Reach 4	\$ 1,185,857
Reach 5	\$ 605,849
Reach 6	\$ 637,963
Reach 7	\$ 176,870
Reach 8	\$ 586,897
Reach 9	\$ 132,747
Total	\$ 4,928,648

5.3 BEST MANAGEMENT PRACTICES (BMPs)

5.3.1 BMP Overview

The IDEQ's catalog of stormwater BMPs for cities and counties (IDEQ, 2005) was used as guidance for the design of this project. The contractor shall design, construct, maintain and removed all the BMPs employed in this restoration project as specified in the catalog. For the brevity of this report, the BMPs in the IDEQ catalog are simply referenced and summarized in Table 4 with the understanding that the design team and the stream construction contractor will have a current copy of this catalog on-site during construction at all times as a reference.

It must be noted that BMP regulations are guided by many factors beyond the control of GeoEngineers, as described in the note below Table 4.

5.3.2 General Construction Site Guidelines (IDEQ BMP Catalog Section 4.3)

The BMPs listed in Table 4 will be employed for this project. The numbers refer to the IDEQ BMP catalog (IDEQ, 2005).

Table 4. Best Management Practices Summary (IDEQ, 2005).

BMP	Necessary and Required	Use If Need Becomes Apparent
1 Construction Timing	X	
2 Construction Staging Areas	X	
3 Preserve Existing Vegetation		X
4 Clearing Limits		X
5 Stabilize Entrance and Roads	X	
6-10 Housekeeping BMPs	X	
11-18 Temporary Slope Protection	X	
19-21 Temporary Channel and Drain Protection		X
22 Check Dams		X
23 Temporary Stream Crossing		X
24 Straw Bales/Biofilter Bags		X
25 Silt Fence	X	
26 Vegetated Buffer Strips		X
27 Sediment Traps	X	
28 Portable Sediment Tanks		X
29 Temporary Swales		X
30 Earth Dikes		X
31 Perimeter Dikes and Swales		X
32 Temporary Berms and Sandbags		X
33 Temporary Storm Drain Diversion		X
34-37 Top Soil, Seeding, Sodding, Planting	X	
38-42 Stormwater Filters		X
43-44 Infiltration Facilities		X
45-51 Detention Facilities		X
52 Oil/Water Separator		X
53 Level Spreader		X

Note:

BMP regulations are guided by many factors beyond the control of GeoEngineers. Despite our best efforts to predict BMPs likely to be required, we recognize site conditions and permitting requirements could substantially change the project as described herein. As a result, the construction contractor must verify applicable regulations and permit requirements and adjust construction techniques and sequencing accordingly. Permit and BMP requirements are ultimately decided by regulatory agencies and supersede any design or report prepared by GeoEngineers.

BMP 1 Construction Timing

After the “permanent” BMPs inherent in the stream design itself, the most important BMP associated with this project is the construction sequencing. The proposed construction sequencing minimizes the overall disturbance to the stream and construction site in terms of both area and duration. Furthermore, it provides the flexibility necessary to construct, test and refine the proposed improvements while managing the stream’s flows with minimal disturbance to the aquatic life in the Kootenai River downstream of the project.

BMP 2 Construction Staging Areas

Construction staging will occur in designated upland areas currently used for agriculture production. The contractor shall comply with all the guidelines for this BMP as specified in the IDEQ BMP catalog (IDEQ, 2005).

BMP 3 Preservation of Existing Vegetation

Because most of the proposed stream restoration will be constructed in an area that currently has no riparian vegetation, the implementation of this BMP will be necessary only at the very upstream- and downstream-most extents of the proposed stream.

BMP 4 Clearing Limits

Because the proposed stream restoration will be aligned through an area that currently is managed for crop and grazing, no forest or natural vegetation exist on-site; therefore, the implementation of this BMP will be minimal.

BMP 5 Stabilization of Construction Entrances, Roads and Driveways

It is anticipated that the primary stream construction equipment will not be entering or exiting the construction site on a frequent basis. Nonetheless, the primary entrances that access public rights-of-way will be stabilized as specified in the IDEQ BMP catalog (IDEQ, 2005). Internal driveways associated with the stream construction will also be stabilized, as necessary, to prevent sediment from entering the stream or sensitive streamside areas. The design team will locate these stabilized areas with the contractors, as necessary, in accordance with all the associated guidelines specified in the IDEQ BMP catalog (IDEQ, 2005).

5.3.3 Housekeeping (IDEQ BMP Section 4.4)

The contractor shall comply with all the associated guidelines for all of the “Housekeeping BMPs” as specified in the IDEQ BMP catalog (IDEQ, 2005). Currently, these BMPs include:

- BMP 6 Dust control
- BMP 7 Covering of materials and equipment
- BMP 8 Spill prevention and control
- BMP 9 Vehicle/equipment washing and maintenance
- BMP 10 Waste management

5.3.4 Slope Protection (IDEQ BMP Section 4.5)

It is anticipated that the temporary slope protection BMPs will be necessary for this project in the vicinity of any levee that is being opened and laid back at any slope greater than 3H:1V. Such slope protection BMPs include:

- BMP 11 Mulching
- BMP 12 Hydraulic mulching
- BMP 13 Geotextiles
- BMP 14 Matting
- BMP 15 Pipe slope drains

- BMP 16 Slope roughening
- BMP 17 Gradient terracing
- BMP 18 Retaining walls

5.3.5 Channel and Storm Drain Protection (IDEQ BMP Section 4.6)

It is not anticipated that the temporary channel and storm drain protection BMPs (will be necessary for this project because the stream channel and associated riparian area will be constructed prior to water introduction. Stormwater conveyance facilities are not included in this project. However, the contractor should note that between the date of this report and the date of construction, regulations might change and more restrictive BMP compliance mandated. It is the contractor's responsibility to obtain fully up-to-date permits prior to construction. Currently, these BMPs include:

- BMP 19 Gabions
- BMP 20 Outlet protection
- BMP 22 Inlet protection

BMP 22 Check Dams

Because the stream channel and associated riparian area will be constructed prior to water introduction, check dams should not be necessary, and therefore this BMP is not likely to be applicable. This BMP could be used during the three-year vegetation time period to periodically check water for supplemental irrigation purposes to aid in establishing a healthy vegetative corridor.

BMP 23 Temporary Stream Crossing

Because stream flow will not be present during construction, stream crossings with heavy equipment will not be necessary.

5.3.6 Sediment Collection and Runoff Diversion (IDEQ BMP Section 4.7)

The following BMPs will be incorporated as noted. The contractor shall comply with all the associated guidelines specified in the IDEQ BMP catalog (IDEQ, 2005) for all of these BMPs, where prescribed.

BMP 24 Straw Bales/Biofilter Bags

It is anticipated that straw bales or biofilter bags will be used on this project as shown in the BMP catalog, as necessary. Silt fence (see BMP 25, below) will be employed for these types of applications. Straw bales may be used for temporary diversion ditches.

BMP 25 Silt Fence

Silt fence will be used to protect the stream from sediment associated with stream construction. Silt fence will also be used to protect the overall stream restoration site from sediment associated with run-on from off-site areas or the adjacent construction activities. The contractor shall comply with all the associated guidelines specified in the IDEQ BMP Catalog (IDEQ, 2005) for the installation of silt fence.

BMP 26 Vegetated Buffer Strips

Vegetated buffer strips will not likely be used on this project because such strips are intended to protect streams from adjacent construction activities, whereas this project involves fully reconstructing the stream and largely replanting new buffer strips.

BMP 27 Sediment Traps

Sediment traps, as described in the IDEQ BMP catalog (IDEQ, 2005), are not likely to be used on this project. It is anticipated that groundwater seeping into the active stream construction areas will be pumped “overboard” to local low points where the water will be infiltrated into the local soils. Should the local ground become saturated, the discharge line will be relocated. Sediment traps, as described in the BMP catalog, might be utilized, if necessary. If utilized, the contractor shall comply with all the associated guidelines specified in the IDEQ BMP catalog (IDEQ, 2005).

BMP 28 Portable Sediment Tanks

It is not anticipated that portable sediment tanks will be utilized on this project. If deemed necessary, however, the contractor shall comply with all the associated guidelines specified in the IDEQ BMP catalog (IDEQ, 2005).

BMP 29 Temporary Swales

Although not specifically required, temporary swales may be used on this project if determined appropriate. If deemed appropriate, the contractor shall comply with all the associated guidelines for this BMP as specified in the IDEQ BMP catalog (IDEQ, 2005).

BMP 30 Earth Dikes

Although not specifically required, earth dikes may be used on this project if determined appropriate. If deemed appropriate, the contractor shall comply with all the associated guidelines for this BMP as specified in the IDEQ BMP catalog (IDEQ, 2005).

BMP 31 Perimeter Dikes and Swales

Although not specifically required, perimeter dikes and swales may be used on this project if determined appropriate. If deemed appropriate, the contractor shall comply with all the associated guidelines for this BMP as specified in the IDEQ BMP catalog (IDEQ, 2005).

BMP 32 Temporary Berms and Sandbags

Although not specifically located on the plans, temporary berms and/or sandbags will likely be used throughout this project where applicable. The contractor shall comply with all the associated guidelines for this BMP as specified in the IDEQ BMP catalog (IDEQ, 2005).

BMP 33 Temporary Storm Drain Diversions

Although not specifically required, temporary storm drain diversions might be used on this project if determined appropriate. If deemed appropriate, the contractor shall comply with all the associated guidelines for this BMP as specified in the IDEQ BMP catalog (IDEQ, 2005).

5.3.7 Slope Protection and Stabilization (IDEQ BMP Section 5.2)

The permanent slope protection and stabilization BMPs are vital to both the short- and long-term success of this project and will be implemented throughout the entire stream restoration site. Currently, these BMPs include:

- BMP 34 Topsoiling
- BMP 35 Seeding
- BMP 36 Sodding
- BMP 37 Planting

5.3.8 Non-Applicable BMPs

These BMPs largely focus on development projects under current regulation and policy application. Because of the nature of this ecosystem restoration project, these BMPs are not considered necessary and are not likely to be utilized for this project element. If determined to be necessary, these BMPs can be implemented. If they are implemented, the contractor shall comply with all the associated guidelines for these BMP as specified in the IDEQ BMP catalog (IDEQ, 2005). These BMPs include:

- BMPs 38-42 Stormwater Filters (IDEQ BMP Section 5.3)
- BMPs 43-44 Infiltration Facilities (IDEQ BMP Section 5.4)
- BMPs 45-51 Detention Facilities (IDEQ BMP Section 5.5)
- BMPs 52-53 Other Structural Controls (IDEQ BMP Section 5.6)

6.0 PLANTING PLAN

6.1 OVERVIEW

The establishment of healthy, self-sustaining native vegetative community throughout the project site is vital to the success of a stream restoration project. Such communities promote short-term and long-term bank stabilization, shade for cooler water, protective cover for fish, habitat for terrestrial wildlife (birds, mammals, amphibians and macroinvertebrates) and will provide woody debris recruitment in the future (FISCR, 2000). The species of plants proposed in this plan vary in relation to the stream's bankfull elevation, with the more hydrophytic plants closer to the stream and the more drought-tolerant species at higher elevations. The proposed vegetation consists of plant species native to the area that are typically found at similar sites within the region. The restoration area is currently managed as agricultural land, thus is lacking shrub and tree vegetative layers. In order to establish both an overstory tree canopy and understory shrub layer, this planting plan proposes to install relatively quick growing early successional species such as black cottonwood (*Populus. trichocarpa*) and willows (*Salix spp.*). Small quantities of late successional species including western red cedar (*Thuja plicata*) are incorporated into this plan as well to provide a seed base for future establishment by volunteers of these species.

The restoration activities will be spaced out over the course of three years as identified on Sheet 12.2 in Appendix C. In the first year, the restoration site will be graded and vegetation will be installed. Because the channel will not contain flowing water at this point, irrigation will be required to promote vigorous growth and increase the likelihood of survival of the planted species. Once the restoration activities have been completed at the site, the restoration area will be supported by near-surface groundwater conditions. However, to help promote plant colonization and root development, the restoration area will have supplemental irrigation by providing a controlled discharge through the new channel for two to three years after the restoration activities are complete. Small check dams will be placed in the new channel to check water to aid in maintaining a high groundwater table.

6.2 PLANTING ZONES AND APPLICATIONS

6.2.1 Overview

Four "Planting Zones" have been identified based on elevations relative to the proposed bankfull elevation of the creek. These zones include the upland transitional zone, riparian floodplain zone, stream bank zone and wet meadow zone (see Sheets 11.1 and 11.2 in Appendix C). Specific plant communities have been chosen for each zone that reflect the anticipated hydrology available for each zone (see Sheet

11.2). Table 5 shows the acreages of each planting zone within the restoration area. Descriptions of each zone and respective plant communities are contained in the following sections.

Table 5. Planting Zones, Approximate Elevations and Sizes

Planting Zone	Approximate Elevation	Size (acres)
Upland Transitional	>2 feet above bankfull elevation	63.8
Riparian Floodplain	0<2 feet above bankfull elevation	122.1
Stream Bank	0<1 feet above bankfull elevation	9.6
Wet Meadow	Bankfull elevation	51.3
Total		246.8

6.2.2 Upland Transitional Vegetation Zone

The upland transitional zone is the driest zone within the restoration area and encompasses approximately 64 acres. The proposed vegetation structure for the upland transitional vegetation zone is intended to provide a forested transition from the lower, wetter riparian floodplain vegetation community up into the higher, dryer agricultural fields. Because the proposed restoration corridor will mainly be floodplain habitat, it is unlikely that the transition to obligate upland vegetation will be complete prior to encountering the remaining agricultural fields. Therefore, the majority of the species used in this zone will be facultative species that thrive in both wetland and upland conditions. However, species with some drought tolerance, such as black cottonwood and western red cedar, will be applicable in the higher, drier areas. The grasses chosen for this zone contain species that tolerate a range of moisture conditions. Grass seed mix should be broadcast throughout the upland transitional zone. Table 6 lists the species and quantities proposed for the upland transitional zone. Sheet 11.2 in Appendix C identifies the recommended planting configurations for nursery stock and cuttings in the upland transitional zone.

Table 6. Planting Table for Upland Transitional Zone

Common Name	Scientific Name	Size	Spacing (On-Center)	Quantity
Trees				
Black cottonwood	<i>Populus trichocarpa</i>	Cuttings	12 ft o.c.	5,786
Western red cedar	<i>Thuja plicata</i>	2 gallon	12 ft o.c.	1,930
Quaking aspen	<i>Populus tremuloides</i>	2 gallon	12 ft o.c.	1,930
Shrubs				
Snowberry	<i>Symphoricarpos albus</i>	1 gallon	6 ft o.c.	7,714
Blue elderberry	<i>Sambucus nigra</i>	1 gallon	6 ft o.c.	7,714
Serviceberry	<i>Amelanchier alnifolia</i>	1 gallon	6 ft o.c.	3,857
Thimbleberry	<i>Rubus parviflorus</i>	1 gallon	6 ft o.c.	3,857
Oceanspray	<i>Holodiscus discolor</i>	1 gallon	6 ft o.c.	3,857
Golden currant	<i>Ribes aureum</i>	1 gallon	6 ft o.c.	7,714
Wood's rose	<i>Rosa woodsii</i>	1 gallon	6 ft o.c.	3,857
Grasses				
Sandberg's bluegrass	<i>Poa secunda</i>	Seed	Broadcast @ 1.6 lb/ac	102 lbs
Bluebunch wheatgrass	<i>Pseudoroegneria spicata</i>	Seed	Broadcast @ 0.4 lb/ac	26 lbs
Slender wheatgrass	<i>Elymus trachycaulus</i>	Seed	Broadcast @ 2.4 lb/ac	153 lbs
Idaho fescue	<i>Festuca idahoensis</i>	Seed	Broadcast @ 1.6 lb/ac	102 lbs

Notes:

ft = feet

o.c. = on-center

lb/ac = pounds per acre

6.2.3 Riparian Floodplain Vegetation Zone

The proposed vegetation structure for the riparian floodplain vegetation zone will consist of a tall, closed to partially open canopy forest, in narrow to wide bands along the stream corridor. This zone will also include a dense shrub understory containing the species listed in Table 7. The proposed vegetation will be applied as a combination of seed mix, nursery stock and live cuttings. The species proposed for the riparian floodplain zone are contained in Table 7, and the recommended planting configuration for this zone is shown on Sheet 11.2 in Appendix C.

Table 7. Planting Table for Riparian Floodplain Zone

Common Name	Scientific Name	Size	Spacing (On-Center)	Quantity
Trees				
Black cottonwood	<i>Populus balsamifera ssp. trichocarpa</i>	Cuttings	12 ft o.c.	11,078
Western red cedar	<i>Thuja plicata</i>	2 gallon	12 ft o.c.	1,846
Engelmann spruce	<i>Picea engelmannii</i>	2 gallon	12 ft o.c.	1,846
Quaking aspen	<i>Populus tremuloides</i>	2 gallon	12 ft o.c.	1,846
Cascara	<i>Rhamnus purshiana</i>	2 gallon	12 ft o.c.	1,846
Shrubs				
Red osier dogwood	<i>Cornus sericea</i>	Cuttings	6 ft o.c.	14,771
Drummonds willow	<i>Salix drummondiana</i>	Cuttings	6 ft o.c.	14,771
Coyote willow	<i>Salix exigua</i>	Cuttings	6 ft o.c.	14,771
Hardhack	<i>Spiraea douglasii</i>	1 gallon	6 ft o.c.	7,386
Mountain Alder	<i>Alnus incana</i>	1 gallon	6 ft o.c.	7,386
Thimbleberry	<i>Rubus parviflorus</i>	1 gallon	6 ft o.c.	7,386
Snowberry	<i>Symphoricarpos albus</i>	1 gallon	6 ft o.c.	7,386
Wood's rose	<i>Rosa woodsii</i>	1 gallon	6 ft o.c.	7,386

6.2.4 Stream Bank Vegetation Zone

Stream bank vegetation will be dominated by a dense shrub community and cottonwood trees with a small amount of western red cedar, as listed in Table 8. The proposed vegetation will consist primarily of live cuttings. The densities of cuttings will vary based on their respective locations along the stream channel. The cuttings should be spaced at 3-foot on-center intervals when located at the outside of channel meanders and further apart (6- to 8-foot on-center intervals) in areas where stream bank protection is less of a concern (for example, the inside of channel meanders and along straight sections). Sheet 11.2 in Appendix C identifies the recommended planting configurations for nursery stock and cuttings in the stream bank zone.

Table 8. Planting Table for Stream Bank Zone

Common Name	Scientific Name	Size	Spacing (On-Center)	Quantity
Trees				
Black cottonwood	<i>Populus balsamifera ssp. trichocarpa</i>	Cuttings	12 ft o.c.	875
Western red cedar	<i>Thuja plicata</i>	2 gallon	12 ft o.c.	146
Shrubs				
Red osier dogwood	<i>Cornus sericea</i>	Cuttings	6 ft o.c.	2,682
Drummonds willow	<i>Salix drummondiana</i>	Cuttings	6 ft o.c.	2,332
Coyote willow	<i>Salix exigua</i>	Cuttings	6 ft o.c.	2,565

6.2.5 Wet Meadow Vegetation Zone

The wet meadow vegetation zone will consist primarily of emergent herbaceous wetland plant species. Several woody shrub species that match species found in naturally occurring wetland habitats characteristic of low-gradient floodplain streams in the lower Kootenai River Basin will also be installed within the wet meadow zone. The proposed vegetation will be applied as wetland seed mixtures, wetland nursery stock and live cuttings. Table 9 lists the species proposed for the wet meadow zone, and Sheet 11.2 in Appendix C identifies the recommended planting configuration for this zone.

Table 9. Planting Table for Wet Meadow Zone

Common Name	Scientific Name	Size	Spacing (On-Center)	Quantity
Shrubs				
Red osier dogwood	<i>Cornus sericea</i>	Cuttings	6 ft o.c.	9,311
Drummonds willow	<i>Salix drummondiana</i>	Cuttings	6 ft o.c.	9,311
Coyote willow	<i>Salix exigua</i>	Cuttings	6 ft o.c.	9,311
Hardhack	<i>Spiraea douglasii</i>	1 gallon	6 ft o.c.	9,311
Sedges, Rushes and Grasses				
Beaked sedge	<i>Carex rostrata</i>	Seed	Broadcast @ 0.8 lb/ac	41 lbs
Creeping spikerush	<i>Eleocharis palustris</i>	Seed	Broadcast @ 0.8 lb/ac	41 lbs
Tufted hairgrass	<i>Deschampsia caespitosa</i>	Seed	Broadcast @ 0.8 lb/ac	41 lbs
Red fescue	<i>Festuca rubra</i>	Seed	Broadcast @ 1.6 lb/ac	82 lbs
Mountain brome	<i>Bromus marginatus</i>	Seed	Broadcast @ 1.6 lb/ac	82 lbs

7.0 RESULTS AND CONCLUSIONS

Restoring a small portion of the Kootenai River floodplain is a step toward restoring a once-thriving ecosystem. Ecosystem productivity, throughout the lower Kootenai River valley, was historically driven by interactions between the mainstem of the river and the floodplain. This project aims to restore local ecosystem processes dependent on floodplain and channel connectivity.

The proposed restoration will improve the degraded condition by reconfiguring the stream and floodplain to include naturally appearing, naturally functioning stream and floodplain processes with limited maintenance. The proposed design utilizes grade controls at key points to address the increased gradient with respect to historic conditions. The restoration of natural physical processes is expected to result in ecological responses such as increased biological production and biodiversity for both aquatic and terrestrial organisms.

The enhancements proposed to achieve these results include:

1. Realignment of Ball Creek into portions of its assumed historical alignment. Stream length will increase from approximately 3,100 feet to 18,000 feet, and the total riparian/floodplain corridor will increase to approximately 182 acres.
2. Sculpting wetlands, pools, riffles, runs and glides and incorporating in-stream wood and boulder structures to direct flows naturally (rather than forcefully resist flows). This enables the stream to maintain itself by proper substrate conveyance and sorting.

3. Utilizing native vegetation for long-term stream bank stability and habitat diversification. Vegetation will be established for at least three years prior to stream flows being introduced into the proposed channel.

The proposed improvements will result in enhancing, expanding and diversifying the function and values of the aquatic and riparian habitat along the stream corridor itself while enhancing the continuity to the larger mosaic of upland habitats. Such enhancements include:

1. Enhancing and increasing in-stream fish habitat to accommodate the full range of fish lifecycles and requirements, including spawning, rearing, holding, feeding, refuge and passage.
2. Enhancing and expanding habitat for a wide range of indigenous wildlife and botanical species.
3. Creating a migration corridor useable by aquatic and terrestrial organisms.
4. Creating an ecosystem that mimics the natural floodplain ecosystem, at all trophic levels.

Construction will occur in a sensitive manner that minimizes the disruption of the existing habitat as much as possible. Where disturbance is necessary, the disturbed areas will be replaced and mitigated with an overall net benefit to the stream and surrounding environment. Examples include:

1. Removing and relocating the fish and amphibians in the reaches to be restored prior to restoration.
2. Protecting, utilizing, reusing and maintaining as much of the existing vegetation as possible before, during and after construction.
3. Limiting the areas of disturbance in terms of both extent and duration by the use of practical construction sequencing plans and BMPs.
4. Conducting a collaborative design/construction effort with the Design Team and an experienced stream restoration contractor to address the nuances of stream restoration.

Restoration project elements will be on property owned and managed by TNC as a nature preserve. An agreement will be established and conveyed so these actions are maintained in perpetuity. A detailed monitoring and maintenance plan has been developed to address the full range of anticipated adjustments that the stream and riparian areas will undergo as they settle into their revised surroundings.

8.0 LIMITATIONS

GeoEngineers has developed this restoration design and prepared this report for use by the Kootenai Tribe of Idaho and their agents specifically for Ball Creek within the limitations of our signed agreement executed on September 4, 2008. Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in the field of stream and river habitat enhancement, stabilization and restoration design engineering in this area at the time this report was prepared. The conclusions, recommendations and opinions presented in this report are based on our professional knowledge, judgment and experience. No warranty or other conditions, express or implied, should be understood.

Any electronic form, facsimile or hard copy of the original document (email, text, table and/or figure), if provided, and any attachments should be considered a copy of the original document. The original document is stored by GeoEngineers, Inc. and will serve as the official document of record.

Please refer to Appendix D titled "Report Limitations and Guidelines for Use" for additional information pertaining to the use of this report.

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APPENDIX A
SUPPORTING HYDROLOGIC CALCULATIONS
(EXCERPTS)

ball creek fkg results

1
 Program PeakFq U. S. GEOLOGICAL SURVEY Seq. 000. 000
 Ver. 5.2 Annual peak flow frequency analysis Run Date / Time
 11/01/2007 following Bulletin 17-B Guidelines 01/27/2009 15:52

--- PROCESSING OPTIONS ---

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

Input files used:
 peaks (ascii) - C:\DOCUMENTS AND
 SETTINGS\JFEALKO\DESKTOP\BALL CREEK.TXT
 specifications - PKFQWPSF.TMP

Output file(s):
 main - C:\DOCUMENTS AND SETTINGS\JFEALKO\DESKTOP\BALL
 CREEK.PRT

1
 Program PeakFq U. S. GEOLOGICAL SURVEY Seq. 001. 001
 Ver. 5.2 Annual peak flow frequency analysis Run Date / Time
 11/01/2007 following Bulletin 17-B Guidelines 01/27/2009 15:52

Station - 12313500 BALL CREEK NR BONNERS FERRY ID

INPUT DATA SUMMARY

Number of peaks in record	=	15
Peaks not used in analysis	=	0
Systematic peaks in analysis	=	15
Historic peaks in analysis	=	0
Years of historic record	=	0
Generalized skew	=	-0.207
Standard error	=	0.550
Mean Square error	=	0.303
Skew option	=	WEIGHTED
Gage base discharge	=	0.0
User supplied high outlier threshold	=	--
User supplied low outlier criterion	=	--
Plotting position parameter	=	0.00

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

WCF134I -NO SYSTEMATIC PEAKS WERE BELOW GAGE BASE.		0.0
WCF162I -SYSTEMATIC PEAKS EXCEEDED HIGH-OUTLIER CRITERION.	1	2087.9
WCF195I -NO LOW OUTLIERS WERE DETECTED BELOW CRITERION.		138.8

1
 Program PeakFq U. S. GEOLOGICAL SURVEY Seq. 001. 002
 Ver. 5.2 Annual peak flow frequency analysis Run Date / Time
 11/01/2007 following Bulletin 17-B Guidelines 01/27/2009 15:52
 Page 1

ball creek fkfq results

Station - 12313500 BALL CREEK NR BONNERS FERRY ID

ANNUAL FREQUENCY CURVE PARAMETERS -- LOG-PEARSON TYPE III

	FLOOD BASE		LOGARITHMIC		
	DISCHARGE	EXCEEDANCE PROBABILITY	MEAN	STANDARD DEVIATION	SKEW
SYSTEMATIC RECORD	0.0	1.0000	2.7311	0.2620	0.660
BULL. 17B ESTIMATE	0.0	1.0000	2.7311	0.2620	0.173

ANNUAL FREQUENCY CURVE -- DISCHARGES AT SELECTED EXCEEDANCE PROBABILITIES

ANNUAL EXCEEDANCE PROBABILITY	BULL. 17B ESTIMATE	SYSTEMATIC RECORD	'EXPECTED PROBABILITY' ESTIMATE	95-PCT CONFIDENCE LIMITS FOR BULL. 17B ESTIMATES	
				LOWER	UPPER
0.9950	125.6	164.8	97.5	60.8	189.8
0.9900	143.0	177.9	117.2	73.0	210.8
0.9500	205.8	226.2	187.2	121.2	284.5
0.9000	251.5	262.6	236.9	159.2	337.6
0.8000	322.6	321.0	312.7	221.3	421.5
0.6667	409.5	395.6	403.9	298.9	529.1
0.5000	529.1	504.0	529.1	403.3	691.5
0.4292	589.4	561.2	592.6	453.7	780.7
0.2000	889.3	869.1	920.6	681.3	1293.0
0.1000	1178.0	1202.0	1264.0	875.2	1876.0
0.0400	1603.0	1751.0	1831.0	1135.0	2860.0
0.0200	1964.0	2273.0	2384.0	1340.0	3796.0
0.0100	2364.0	2908.0	3086.0	1557.0	4928.0
0.0050	2808.0	3680.0	3990.0	1786.0	6287.0
0.0020	3470.0	4958.0	5625.0	2112.0	8493.0

1

Program PeakFq
Ver. 5.2
11/01/2007

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

Seq. 001.003
Run Date / Time
01/27/2009 15:52

Station - 12313500 BALL CREEK NR BONNERS FERRY ID

INPUT DATA LISTING

WATER YEAR	DISCHARGE	CODES	WATER YEAR	DISCHARGE	CODES
1928	418.0		1973	520.0	
1929	393.0		1974	2180.0	
1930	254.0		1975	582.0	
1931	361.0		1976	843.0	
1932	358.0		1977	198.0	
1933	644.0		1978	759.0	
1934	642.0		1979	417.0	
1972	1190.0				

Explanation of peak discharge qualification codes
Page 2

ball creek fkg results

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

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

1

Program PeakFq U. S. GEOLOGICAL SURVEY Seq. 001.004
Ver. 5.2 Annual peak flow frequency analysis Run Date / Time
11/01/2007 following Bulletin 17-B Guidelines 01/27/2009 15:52

Station - 12313500 BALL CREEK NR BONNERS FERRY ID

EMPIRICAL FREQUENCY CURVES -- WEIBULL PLOTTING POSITIONS

WATER YEAR	RANKED DISCHARGE	SYSTEMATIC RECORD	BULL. 17B ESTIMATE
1974	2180.0	0.0625	0.0625
1972	1190.0	0.1250	0.1250
1976	843.0	0.1875	0.1875
1978	759.0	0.2500	0.2500
1933	644.0	0.3125	0.3125
1934	642.0	0.3750	0.3750
1975	582.0	0.4375	0.4375
1973	520.0	0.5000	0.5000
1928	418.0	0.5625	0.5625
1979	417.0	0.6250	0.6250
1929	393.0	0.6875	0.6875
1931	361.0	0.7500	0.7500
1932	358.0	0.8125	0.8125
1930	254.0	0.8750	0.8750
1977	198.0	0.9375	0.9375

1

End PeakFQ analysis.
Stations processed : 1
Number of errors : 0
Stations skipped : 0
Station years : 15

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

For the station below, the following records were ignored:
Page 3

ball creek fkg results

FINISHED PROCESSING STATION: 12313500 USGS BALL CREEK NR BONNERS FERRY I

For the station below, the following records were ignored:

FINISHED PROCESSING STATION:

Ball Creek Channel Design Workbook, Reach 2

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 2

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

Workbook Description

- This workbook is proprietary to GeoEngineers, Inc.
- This workbook contains spreadsheets that facilitate the general design of any given creek.
- This method is based, in part on the "Rosgen" Stream Classification Method.
- This spreadsheet lists the General Project Information that is consistent throughout the workbook.
- It also lists the titles of the spreadsheets contained in this workbook.

Filename: P:\9\9229002 TEMP SPOK\04\Working\Calcs\Stream Design\FINAL\Stream Design 2.xls\General

Sheet Titles:

Ball Creek Channel Design Workbook, Reach 2
Target Parameters
Channel and Floodplain Cross-Section Calculation
Meander Geometry Calculation
Incipient Motion Analysis (Bedload Test)
Incipient Motion Analysis (Riffle Material Design)
Summary Table Of Creek Parameters

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Target Parameters

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 2

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

- This spreadsheet describes the characteristics of the bedload and bank materials, and their respective design parameters.
- These parameters are based upon *Open Channel Hydraulics*, Ven Te Chow, 1959, Table 7-3.
- These numbers provide general design targets and are not considered absolutes.

Bank & Bed Material

Description: Sand with silt
Water Clarity: Clear, low turbidity
Maximum Permissible Velocity (fps) 5.00

**No reference reach - see Stream
Classification Workbook**
Segment 1

**B/F Width
(ft)**
35

**B/F Depth
(ft)**
2

W/D
17.50

Sinuosity
1.2

Ave =

2.00

17.50

Channel and Floodplain Cross-Section Calculation

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 2

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

- This spreadsheet estimates the size of the bankfull channel and floodplain required for a **Targeted** "Rosgen" Stream type.
 - The dimensions calculated below are only approximate, and intended to be a "first estimate". The dimensions calculated below should be input into a hydraulic model (like HEC-RAS) and refined.
 - The calculations are based on Manning's equation, and therefore do not account for any backwater effects. Also, this analysis assumes the flow in the channel remains in the long sinuous channel, while the flow in the floodplain flows along the shorter valley. Also, the cross-sections of the bankfull channel and floodplain are calculated independently.
 - **Only input data into the shaded cells.**

Step #1: Input Desired Stream Classification Data

C4	= Stream Type
2.3	= ER = Entrenchment Ratio (ft/ft)
20.00	= W/D = Width/Depth Ratio (ft/ft)
1.01	= K = Sinuosity (ft/ft)
323	= $Q_{1.25}$ = Bankfull Discharge (cfs)
2364	= Q_{100} = 100-Year Discharge (cfs) (Or any "Design Flood" Discharge)

Step #2: Input Desired Stream and Valley Geometry Data

Bankfull Channel	Floodplain (Valley)	
0.035	0.065	= n = Manning's n Value
2	3	= z = Bank Side-Slopes (H:1V)
700	690.2	= L = Length (ft)
0.01000	0.0101	= G = Gradient (ft/ft)

Channel and Floodplain Design (Output)

- **Step #3:** - Use Microsoft's "Goal Seek" tool twice. Once to calculate the geometry of the bankfull channel and once to calculate the geometry of the floodplain. ("Goal Seek" is a trial-and-error tool, found under the "Tools" menu.)
 - For each Trial, "Set Cell" = "Resulting" Discharge, "To Value" = "Required" Discharge, "By Changing Cells" = "Depth". (See Bold Italics)
 - Calculate the bankfull channel first.

Bankfull Channel	
323	= Required Channel Discharge (cfs)
1.77	= D_{bf} = Bankfull Depth (ft)
35.46	= W_{bf} = Bankfull Width (Top Width) (ft)
28.37	= B = Bottom Width (ft)
56.58	= A = Cross-Sectional Area (sf)
36.30	= P = Wetted Perimeter (ft)
1.56	= R = Hydraulic Radius (ft)
5.71	= V = Velocity (fps)
0.97	= τ = Shear Stress in Channel (lbs/sf)
323.00	= Resulting Channel Discharge (cfs)

Floodplain (Valley)	
2041	= Required Floodplain Discharge (Excludes Channel Q) (cfs)
6.26	= D = Depth of Water in Floodplain (ft)
81.55	= W = Width of Water in Floodplain (Top Width) (ft)
44.00	= B = Bottom Width (ft)
392.93	= A = Cross-Sectional Area (sf)
83.59	= P = Wetted Perimeter (ft)
4.70	= R = Hydraulic Radius (ft)
6.46	= V = Velocity (fps)
117.01	= Overall Floodplain Width (ft)
2539.968	= Resulting Floodplain Discharge (cfs)

Incipient Motion Analysis (Bedload Test)

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 2

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

Spreadsheet Description

- This spreadsheet calculates the critical velocity and critical shear stress for a channel's bed material.
- It also compares the critical velocity and critical shear stress to the values calculated in a hydraulic model of the channel. This comparison is represented in the Relative Bed Stability (RBS) factor. Incipient motion occurs when the RBS is 1.0. If the RBS is < 1.0, the material is mobile. A channel's bed material becomes more stable as the RBS increases (above 1.0).
- The velocity analysis below uses a channel's D_{50} , while the shear stress analysis uses the D_{84} .
- Several equations are used for comparison.
- Note, these equations are generalizations, and should be used with caution and judgement.
- The velocity equations assume the specific gravity of the bed material is 2.65.
- **Only input information into the shaded cells.**
- **This spreadsheet checks to make sure the upstream bedload can be conveyed through the proposed channel.**

Filename: P:\9229002 TEMP SPOK\04\Working\Calcs\Stream Design\FINAL\Stream Design 2.xls\Bedload

Velocity Analysis (Using D_{50})

Direct Input

	<u>mm</u>	<u>cm</u>	<u>in</u>	<u>ft</u>	
Boulder	350.00	35	13.78	1.148	= D_{50} = Mean Diameter of Bed Material
Boulder	425.00	42.5	16.73	1.394	= D_{84}

Input From Cross-Section Spreadsheet

13.6	= V = Q_{100} Velocity (fps)
8.0	= Q_{100} Channel Depth (ft)
3.56	= $t = Q_{100}$ Shear Stress in Channel (lbs/sf)

Results (Neill's Equation)

17.07	= V_c = Critical Velocity (fps)
1.26	= RBS = Relative Bed Stability (dimensionless)

D50 is close to threshold, material may move.

Results (Laursen's Equation)

16.23	= V_c = Critical Velocity (fps)
1.20	= RBS = Relative Bed Stability (dimensionless)

D50 is close to threshold, material may move.

Shear Stress Analysis (Using D_{84})

Typical Constants (Input)

1.148	= D_{50} = Mean Diameter of Bed Material (From Above) (ft)
1.394	= D_{84} = 84th percentile grain size of bed material (ft)
62.400	= γ_w = Specific weight of water (lbs/ft ³)
168.000	= γ_p = Specific Weight of Sediment (lbs/ft ²)

Results (Shield's Equation)

0.070	= τ_* = Shields Number: $\tau_* = 0.0834(D_{84}/D_{50})^{-0.872}$
10.368	= τ_c = Q_{100} Critical Shear Stress: $\tau_c = \tau_*(\gamma_p - \gamma_w)D_{84}$
2.912	= RBS = Relative Bed Stability (dimensionless)

D84 is very stable.

Incipient Motion Analysis (Riffle Material Design)

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 2

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

Spreadsheet Description

- This spreadsheet calculates the critical velocity and critical shear stress for a channel's bed material for the proposed condition **at the fastest average velocity**.
- The bed material tested below should be used as the minimum material size for the riffle cross-sections.
 - It also compares the critical velocity and critical shear stress to the values calculated in a hydraulic model of the channel. This comparison is represented in the Relative Bed Stability (RBS) factor. Incipient motion occurs when the RBS is 1.0. If the RBS is < 1.0, the material is mobile. A channel's bed material becomes more stable as the RBS increases (above 1.0).
 - The velocity analysis below uses a channel's D_{50} , while the shear stress analysis uses the D_{84} .
 - Several equations are used for comparison.
 - Note, these equations are generalizations, and should be used with caution and judgement.
 - The velocity equations assume the specific gravity of the bed material is 2.65.
 - The bed material gradation can be calculated using following 2 methods:
 (1) The 9/10/2001 *Fish Passage Design at Road Culverts* Manual, by WDFW. These ratios are: $D_{84} = 2.5(D_{50})$, $D_{100} = 2.5(D_{84})$,
 $D_{16} = 0.125(D_{84})$ Thickness = D_{100} .
 (2) The AASHTO Method as presented in HEC-23, page DG12.7. These ratios are: $D_{84} = 1.3(D_{50})$, $D_{100} = 1.6(D_{50})$,
 $D_{16} = 0.5(D_{50})$
- Only input information into the shaded cells.

Filename: P:\9229002 TEMP SPOK\04Working\Calcs\Stream Design\FINAL\Stream Design 2.xls\Riffle Design

Velocity Analysis (Using D_{50})

Direct Input

2 = Gradation Method: "1" = WDFW, "2" = AASHTO.

	mm	cm	in	ft	
Cobble	250.0	25.00	9.84	0.82	= D_{16} For Proposed Riffle Bed Material
Boulder	500.0	50.00	19.69	1.64	= D_{50} For Proposed Riffle Bed Material
Boulder	650.0	65.00	25.59	2.13	= D_{84} For Proposed Riffle Bed Material
Boulder	800.0	80.00	31.50	2.62	= D_{100} For Proposed Riffle Bed Material
Boulder	800.0	80.0	31.5	2.6	= Minimum Layer Thickness

Input From Cross-Section Spreadsheet

13.6 = $V = Q_{100}$ Velocity (fps)
 8.0 = Q_{100} Channel Depth (ft)
 3.6 = $t = Q_{100}$ Shear Stress in Channel (lbs/sf)

Results (Neill's Equation)

19.23 = V_c = Critical Velocity (fps)
 1.42 = RBS = Relative Bed Stability (dimensionless)

D50 is close to threshold, material may move.

Results (Laursen's Equation)

18.28 = V_c = Critical Velocity (fps)
 1.35 = RBS = Relative Bed Stability (dimensionless)

D50 is close to threshold, material may move.

Shear Stress Analysis (Using D_{84})

Typical Constants (Input)

1.640 = D_{50} = Mean Diameter of Bed Material (From Above) (ft)
 2.133 = D_{84} = 84th percentile grain size of bed material (ft)
 62.400 = γ_w = Specific weight of water (lbs/ft³)
 168.000 = γ_p = Specific Weight of Sediment (lbs/ft²)

Results (Shield's Equation)

0.066 = τ_* = Shields Number: $\tau_* = 0.0834(D_{84}/D_{50})^{-0.872}$
 14.941 = τ_c = Q_{100} Critical Shear Stress: $\tau_c = \tau_*(\gamma_p - \gamma_w)D_{84}$
 4.196 = RBS = Relative Bed Stability (dimensionless)

D84 is very stable.

Meander Geometry Calculation

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 2

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

- This spreadsheet calculates the range of sizes for the meander features noted.
- **No actual input is required on this sheet.**
- **The input for this sheet (noted below) is based upon the previous cross-section spreadsheet.**
- Three meander geometry equations are used for each meander feature. These equations, and their numbers, are based upon Williams, 1996.
- These equations can also be found on Table 7.7 of "Stream Corridor Restoration, Principles, Processes, and Practices" NRCS Manual, 10/98.
- These equations can also be found on the last two pages of Rosgen's "The Reference reach Field Book", 1998.
- The validity of each equation used is checked below. **Do not use the results of an equation if it is not valid.**
- The results noted below are highly variable, and are independent upon bed and bank material.
- **These results should be measured against an applicable reference reach.**

Input From Previous (Cross-Section) Spreadsheet

1.77 = D_{bf} = Bankfull Depth (ft)
 35.46 = W_{bf} = Bankfull Width (Top Width) (ft)
 56.58 = A = Cross-Sectional Area (sf)
 117.01 = BW = Belt Width = Overall Floodplain Width (ft)

Meander Geometry Calculations

Meander Wave Length			
Equation #	26	30	34
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Meander Wave Length (ft) = L_m =	289	354	308

Channel Length (Along Bend)			
Equation #	27	31	35
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Channel Length (Along Bend) (ft) = L_b =	207	239	205

Belt Width (Floodplain Width)			
Equation #	28	32	36
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Belt Width (ft) = BW =	179	201	191
Maximum BW (ft) =	201		
Minimum BW (ft) =	191		
Previous BW (ft) =	117		
Is Previous BW OK?	No		

Radius Of Curvature			
Equation #	29	33	37
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Radius Of Curvature (ft) = R_c =	56	71	55

Pool To Pool Spacing			
Spacing = 1/2 Meander Wavelength (ft) =	145	177	154
Spacing = 5 to 7 Bankfull Widths (not B3) (ft) =	106	142	177

Summary Table Of Creek Parameters

Project: Kootenai Floodplain Reconnection
 Project Number: 9229-002-04
 Watercourse: Ball Creek Reach 2

Site:
 Analyst:
 Latest Revision:

Ball Creek Ranch
 RDR, JJF
 7/3/2009

Summary Table Of Creek Parameters

35.5	= W_{BF}	= Bankfull Width at Riffles & Pools (ft)	C4	= Rosgen Stream Type
1.77	= D_{BF}	= Bankfull Depth (at Riffle) (ft)	1.01419878	= Sinuosity
4.43	= D_P	= Pool Depth At Bankfull Flow (ft)	20	= Width / Depth Ratio
9.84	= D_{16}	= D_{16} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles	2.3	= Minimum Entrenchment Ratio
19.7	= D_{50}	= D_{50} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles	0.0101	= Average Valley Gradient (ft/ft)
25.6	= D_{84}	= D_{84} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles	0.0100	= Average Creek Gradient (ft/)
31.5	= D_{100}	= D_{100} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles (Largest Rock Size)	323	= Bankfull Discharge (cfs)
289.4 353.7	= WL	= Range of Acceptable Meander Wavelengths (ft)	2364	= 100-Year Flood Discharge (cfs)
205.4 239.4	= BL	= Range of Bend Length (ft)	5.7	= Average Bankfull Velocity (fps)
191.0 201.3	= FP	= Range of Acceptable Minimum Floodplain Widths (ft)		
55 71	= R	= Range of Acceptable Radii of Curvature (ft)		
106 177	= P/P	= Range of Acceptable Pool To Pool Spacing (ft)		

Summary Table Of Creek Parameters

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 2

Site:
Analyst:
Latest Revision:

Ball Creek Ranch
 RDR, JJF
 7/3/2009

Summary Table Of Creek Parameters

C4		= Rosgen Stream Type	
1.014198783		= Sinuosity	
20		= Width / Depth Ratio	
2.3		= Minimum Entrenchment Ratio	
0.0101		= Average Valley Gradient (ft/ft)	
0.0100		= Average Creek Gradient (ft/)	
323		= Bankfull Discharge (cfs)	
2364		= 100-Year Flood Discharge (cfs)	
5.7		= Average Bankfull Velocity (fps)	
35.5		= W_{BF}	= Bankfull Width (ft)
1.8		= D_{BF}	= Bankfull Depth (At Riffle) (ft)
4.4		= D_P	= Pool Depth (ft)
9.8		= D_{16}	= Bed Material Size (in) (16% of material this size or smaller)
19.7		= D_{50}	= Bed Material Size (in) (50% of material this size or smaller)
25.6		= D_{84}	= Bed Material Size (in) (84% of material this size or smaller)
31.5		= D_{100}	= Bed Material Size (in) (100% of material this size or smaller)
289.4	353.7	= WL	= Range of Acceptable Meander Wavelengths (ft)
205.4	239.4	= BL	= Range of Bend Length (ft)
191.0	201.3	= FP	= Range of Acceptable Minimum Floodplain Widths (ft)
55	71	= R	= Range of Acceptable Radii of Curvature (ft)
106	177	= P/P	= Range of Acceptable Pool To Pool Spacing (ft)

Ball Creek Channel Design Workbook, Reach 3

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 3

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

Workbook Description

- This workbook is proprietary to GeoEngineers, Inc.
- This workbook contains spreadsheets that facilitate the general design of any given creek.
- This method is based, in part on the "Rosgen" Stream Classification Method.
- This spreadsheet lists the General Project Information that is consistent throughout the workbook.
- It also lists the titles of the spreadsheets contained in this workbook.

Filename: P:\9\9229002 TEMP SPOK\04\Working\Calcs\Stream Design\FINAL\Stream Design 3.xls\General

Sheet Titles:

Ball Creek Channel Design Workbook, Reach 3
Target Parameters
Channel and Floodplain Cross-Section Calculation
Meander Geometry Calculation
Incipient Motion Analysis (Bedload Test)
Incipient Motion Analysis (Riffle Material Design)
Summary Table Of Creek Parameters

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Target Parameters

Project:

Project Number:

Watercourse:

Kootenai Floodplain Reconnection

9229-002-04

Ball Creek Reach 3

Site:

Analyst:

Latest Revision:

Ball Creek Ranch

RDR, JJF

7/3/2009

- This spreadsheet describes the characteristics of the bedload and bank materials, and their respective design parameters.

- These parameters are based upon *Open Channel Hydraulics*, Ven Te Chow, 1959, Table 7-3.

- These numbers provide general design targets and are not considered absolutes.

Bank & Bed Material

Description:

Water Clarity:

Maximum Permissible Velocity (fps)

Sand with silt

Clear, low turbidity

5.00

No reference reach - see Stream Classification Workbook Segment 1	B/F Width (ft) 35	B/F Depth (ft) 4	W/D 8.75	Sinuosity 1.7
	Ave =	4.00	8.75	

Channel and Floodplain Cross-Section Calculation

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 3

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

- This spreadsheet estimates the size of the bankfull channel and floodplain required for a **Targeted** "Rosgen" Stream type.
 - The dimensions calculated below are only approximate, and intended to be a "first estimate". The dimensions calculated below should be input into a hydraulic model (like HEC-RAS) and refined.
 - The calculations are based on Manning's equation, and therefore do not account for any backwater effects. Also, this analysis assumes the flow in the channel remains in the long sinuous channel, while the flow in the floodplain flows along the shorter valley. Also, the cross-sections of the bankfull channel and floodplain are calculated independently.
 - **Only input data into the shaded cells.**

Step #1: Input Desired Stream Classification Data

E5	= Stream Type
18	= ER = Entrenchment Ratio (ft/ft)
9.00	= W/D = Width/Depth Ratio (ft/ft)
1.62	= K = Sinuosity (ft/ft)
323	= $Q_{1.25}$ = Bankfull Discharge (cfs)
2364	= Q_{100} = 100-Year Discharge (cfs) (Or any "Design Flood" Discharge)

Step #2: Input Desired Stream and Valley Geometry Data

Bankfull Channel	Floodplain (Valley)	
0.032	0.07	= n = Manning's n Value
1.5	5	= z = Bank Side-Slopes (_H:1V)
2800	1733.2	= L = Length (ft)
0.00040	0.0006	= G = Gradient (ft/ft)

Channel and Floodplain Design (Output)

- **Step #3:** - Use Microsoft's "Goal Seek" tool twice. Once to calculate the geometry of the bankfull channel and once to calculate the geometry of the floodplain. ("Goal Seek" is a trial-and-error tool, found under the "Tools" menu.)
 - For each Trial, "Set Cell" = "Resulting" Discharge, "To Value" = "Required" Discharge, "By Changing Cells" = "Depth". (See Bold Italics)
 - Calculate the bankfull channel first.

Bankfull Channel	
323	= Required Channel Discharge (cfs)
4.48	= D_{bf} = Bankfull Depth (ft)
40.35	= W_{bf} = Bankfull Width (Top Width) (ft)
26.90	= B = Bottom Width (ft)
150.78	= A = Cross-Sectional Area (sf)
43.07	= P = Wetted Perimeter (ft)
3.50	= R = Hydraulic Radius (ft)
2.14	= V = Velocity (fps)
0.09	= τ = Shear Stress in Channel (lbs/sf)
323.00	= Resulting Channel Discharge (cfs)

Floodplain (Valley)	
2041	= Required Floodplain Discharge (Excludes Channel Q) (cfs)
2.74	= D = Depth of Water in Floodplain (ft)
726.36	= W = Width of Water in Floodplain (Top Width) (ft)
698.93	= B = Bottom Width (ft)
1955.00	= A = Cross-Sectional Area (sf)
726.91	= P = Wetted Perimeter (ft)
2.69	= R = Hydraulic Radius (ft)
1.04	= V = Velocity (fps)
766.72	= Overall Floodplain Width (ft)
2041	= Resulting Floodplain Discharge (cfs)

Incipient Motion Analysis (Bedload Test)

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 3

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

Spreadsheet Description

- This spreadsheet calculates the critical velocity and critical shear stress for a channel's bed material.
- It also compares the critical velocity and critical shear stress to the values calculated in a hydraulic model of the channel. This comparison is represented in the Relative Bed Stability (RBS) factor. Incipient motion occurs when the RBS is 1.0. If the RBS is < 1.0, the material is mobile. A channel's bed material becomes more stable as the RBS increases (above 1.0).
- The velocity analysis below uses a channel's D_{50} , while the shear stress analysis uses the D_{84} .
- Several equations are used for comparison.
- Note, these equations are generalizations, and should be used with caution and judgement.
- The velocity equations assume the specific gravity of the bed material is 2.65.
- **Only input information into the shaded cells.**
- **This spreadsheet checks to make sure the upstream bedload can be conveyed through the proposed channel.**

Filename: P:\9229002 TEMP SPOK\04\Working\Calcs\Stream Design\FINAL\Stream Design 3.xls\Bedload

Velocity Analysis (Using D_{50})

Direct Input

	<u>mm</u>	<u>cm</u>	<u>in</u>	<u>ft</u>	
Medium Sand	1.00	0.1	0.04	0.003	= D_{50} = Mean Diameter of Bed Material
Medium Sand	1.50	0.15	0.06	0.005	= D_{84}

Input From Cross-Section Spreadsheet

2.1	= V = Mean Bankfull Velocity (fps)
4.5	= D_{bf} = y = Mean Bankfull Water Depth (ft)
0.09	= τ = Shear Stress in Channel (lbs/sf)

Results (Neill's Equation)

2.20	= V_c = Critical Velocity (fps)
1.03	= RBS = Relative Bed Stability (dimensionless)

D50 is close to threshold, material may move.

Results (Laursen's Equation)

2.09	= V_c = Critical Velocity (fps)
0.97	= RBS = Relative Bed Stability (dimensionless)

D50 is mobile.

Shear Stress Analysis (Using D_{84})

Typical Constants (Input)

0.003	= D_{50} = Mean Diameter of Bed Material (From Above) (ft)
0.005	= D_{84} = 84th percentile grain size of bed material (ft)
62.400	= γ_w = Specific weight of water (lbs/ft ³)
168.000	= γ_p = Specific Weight of Sediment (lbs/ft ³)

Results (Shield's Equation)

0.059	= τ_* = Shields Number: $\tau_* = 0.0834(D_{84}/D_{50})^{-0.872}$
0.030	= τ_c = Bankful Critical Shear Stress: $\tau_c = \tau_*(\gamma_p - \gamma_w)D_{84}$
0.348	= RBS = Relative Bed Stability (dimensionless)

D84 is mobile.

Incipient Motion Analysis (Riffle Material Design)

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 3

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

Spreadsheet Description

- This spreadsheet calculates the critical velocity and critical shear stress for a channel's bed material for the proposed condition **at the fastest average velocity**.
- The bed material tested below should be used as the minimum material size for the riffle cross-sections.
 - It also compares the critical velocity and critical shear stress to the values calculated in a hydraulic model of the channel. This comparison is represented in the Relative Bed Stability (RBS) factor. Incipient motion occurs when the RBS is 1.0. If the RBS is < 1.0, the material is mobile. A channel's bed material becomes more stable as the RBS increases (above 1.0).
 - The velocity analysis below uses a channel's D_{50} , while the shear stress analysis uses the D_{84} .
 - Several equations are used for comparison.
 - Note, these equations are generalizations, and should be used with caution and judgement.
 - The velocity equations assume the specific gravity of the bed material is 2.65.
 - The bed material gradation can be calculated using following 2 methods:
 (1) The 9/10/2001 *Fish Passage Design at Road Culverts* Manual, by WDFW. These ratios are: $D_{84} = 2.5(D_{50})$, $D_{100} = 2.5(D_{84})$,
 $D_{16} = 0.125(D_{84})$ Thickness = D_{100} .
 (2) The AASHTO Method as presented in HEC-23, page DG12.7. These ratios are: $D_{84} = 1.3(D_{50})$, $D_{100} = 1.6(D_{50})$,
 $D_{16} = 0.5(D_{50})$
- Only input information into the shaded cells.

Filename: P:\9229002 TEMP SPOK\04Working\Calcs\Stream Design\FINAL\Stream Design 3.xls\Riffle Design

Velocity Analysis (Using D_{50})

Direct Input

2 = Gradation Method: "1" = WDFW, "2" = AASHTO.

	mm	cm	in	ft	
Coarse Sand	4.0	0.40	0.16	0.01	= D_{16} For Proposed Riffle Bed Material
Fine Gravel	8.0	0.80	0.31	0.03	= D_{50} For Proposed Riffle Bed Material
Fine Gravel	10.4	1.04	0.41	0.03	= D_{84} For Proposed Riffle Bed Material
Fine Gravel	12.8	1.28	0.50	0.04	= D_{100} For Proposed Riffle Bed Material
Fine Gravel	12.8	1.3	0.5	0.0	= Minimum Layer Thickness

Input From Cross-Section Spreadsheet

2.1 = V = Mean Bankfull Velocity (fps)
 4.5 = y = Mean Bankfull Water Depth (ft)
 0.1 = t = Shear Stress in Channel (lbs/sf)

Results (Neill's Equation)

4.40 = V_c = Critical Velocity (fps)
 2.05 = RBS = Relative Bed Stability (dimensionless)

D50 is very stable.

Results (Laursen's Equation)

4.18 = V_c = Critical Velocity (fps)
 1.95 = RBS = Relative Bed Stability (dimensionless)

D50 is stable

Shear Stress Analysis (Using D_{84})

Typical Constants (Input)

0.026 = D_{50} = Mean Diameter of Bed Material (From Above) (ft)
 0.034 = D_{84} = 84th percentile grain size of bed material (ft)
 62.400 = γ_w = Specific weight of water (lbs/ft³)
 168.000 = γ_p = Specific Weight of Sediment (lbs/ft²)

Results (Shield's Equation)

0.066 = τ_* = Shields Number: $\tau_* = 0.0834(D_{84}/D_{50})^{-0.872}$
 0.239 = τ_c = Bankfull Critical Shear Stress: $\tau_c = \tau_*(\gamma_p - \gamma_w)D_{84}$
 2.736 = RBS = Relative Bed Stability (dimensionless)

D84 is very stable.

Meander Geometry Calculation

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 3

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

- This spreadsheet calculates the range of sizes for the meander features noted.
- **No actual input is required on this sheet.**
- **The input for this sheet (noted below) is based upon the previous cross-section spreadsheet.**
- Three meander geometry equations are used for each meander feature. These equations, and their numbers, are based upon Williams, 1996.
- These equations can also be found on Table 7.7 of "Stream Corridor Restoration, Principles, Processes, and Practices" NRCS Manual, 10/98.
- These equations can also be found on the last two pages of Rosgen's "The Reference reach Field Book", 1998.
- The validity of each equation used is checked below. **Do not use the results of an equation if it is not valid.**
- The results noted below are highly variable, and are independent upon bed and bank material.
- **These results should be measured against an applicable reference reach.**

Input From Previous (Cross-Section) Spreadsheet

4.48 = D_{bf} = Bankfull Depth (ft)
 40.35 = W_{bf} = Bankfull Width (Top Width) (ft)
 150.78 = A = Cross-Sectional Area (sf)
 766.72 = BW = Belt Width = Overall Floodplain Width (ft)

Meander Geometry Calculations

Meander Wave Length			
Equation #	26	30	34
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Meander Wave Length (ft) = L_m =	547	409	1262

Channel Length (Along Bend)			
Equation #	27	31	35
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Channel Length (Along Bend) (ft) = L_b =	391	277	841

Belt Width (Floodplain Width)			
Equation #	28	32	36
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Belt Width (ft) = BW =	339	233	783
Maximum BW (ft) =	783		
Minimum BW (ft) =	233		
Previous BW (ft) =	767		
Is Previous BW OK?	Yes		

Radius Of Curvature			
Equation #	29	33	37
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Radius Of Curvature (ft) = R_c =	107	82	225

Pool To Pool Spacing			
Spacing = 1/2 Meander Wavelength (ft) =	274	204	631
Spacing = 5 to 7 Bankfull Widths (not B3) (ft) =	121	161	202

Summary Table Of Creek Parameters

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 3

Site:
Analyst:
Latest Revision:

Ball Creek Ranch
 RDR, JJF
 7/3/2009

Summary Table Of Creek Parameters

40.4	= W_{BF}	= Bankfull Width at Riffles & Pools (ft)	E5	= Rosgen Stream Type
4.48	= D_{BF}	= Bankfull Depth (at Riffle) (ft)	1.61550889	= Sinuosity
8.97	= D_P	= Pool Depth At Bankfull Flow (ft)	9	= Width / Depth Ratio
0.16	= D_{16}	= D_{16} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles	18	= Minimum Entrenchment Ratio
0.3	= D_{50}	= D_{50} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles	0.0006	= Average Valley Gradient (ft/ft)
0.4	= D_{84}	= D_{84} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles	0.0004	= Average Creek Gradient (ft/)
0.5	= D_{100}	= D_{100} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles (Largest Rock Size)	323	= Bankfull Discharge (cfs)
408.8 1262.1	= WL	= Range of Acceptable Meander Wavelengths (ft)	2364	= 100-Year Flood Discharge (cfs)
276.7 841.4	= BL	= Range of Bend Length (ft)	2.1	= Average Bankfull Velocity (fps)
232.7 782.7	= FP	= Range of Acceptable Minimum Floodplain Widths (ft)		
82 225	= R	= Range of Acceptable Radii of Curvature (ft)		
121 631	= P/P	= Range of Acceptable Pool To Pool Spacing (ft)		

Summary Table Of Creek Parameters

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 3

Site:
Analyst:
Latest Revision:

Ball Creek Ranch
 RDR, JJF
 7/3/2009

Summary Table Of Creek Parameters

E5		= Rosgen Stream Type	
1.615508885		= Sinuosity	
9		= Width / Depth Ratio	
18		= Minimum Entrenchment Ratio	
0.0006		= Average Valley Gradient (ft/ft	
0.0004		= Average Creek Gradient (ft/)	
323		= Bankfull Discharge (cfs)	
2364		= 100-Year Flood Discharge (cfs)	
2.1		= Average Bankfull Velocity (fps)	
40.4		= W_{BF}	= Bankfull Width (ft)
4.5		= D_{BF}	= Bankfull Depth (At Riffle) (ft)
9.0		= D_P	= Pool Depth (ft)
0.2		= D_{16}	= Bed Material Size (in) (16% of material this size or smaller)
0.3		= D_{50}	= Bed Material Size (in) (50% of material this size or smaller)
0.4		= D_{84}	= Bed Material Size (in) (84% of material this size or smaller)
0.5		= D_{100}	= Bed Material Size (in) (100% of material this size or smaller)
408.8	1262.1	= WL	= Range of Acceptable Meander Wavelengths (ft)
276.7	841.4	= BL	= Range of Bend Length (ft)
232.7	782.7	= FP	= Range of Acceptable Minimum Floodplain Widths (ft)
82	225	= R	= Range of Acceptable Radii of Curvature (ft)
121	631	= P/P	= Range of Acceptable Pool To Pool Spacing (ft)

Ball Creek Channel Design Workbook, Reach 4

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 4

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

Workbook Description

- This workbook is proprietary to GeoEngineers, Inc.
- This workbook contains spreadsheets that facilitate the general design of any given creek.
- This method is based, in part on the "Rosgen" Stream Classification Method.
- This spreadsheet lists the General Project Information that is consistent throughout the workbook.
- It also lists the titles of the spreadsheets contained in this workbook.

Filename: *P:\9\9229002 TEMP SPOK\04\Working\Calcs\Stream Design\FINAL\Stream Design 4.xls\General*

Sheet Titles:

Ball Creek Channel Design Workbook, Reach 4
Target Parameters
Channel and Floodplain Cross-Section Calculation
Meander Geometry Calculation
Incipient Motion Analysis (Bedload Test)
Incipient Motion Analysis (Riffle Material Design)
Summary Table Of Creek Parameters

Disclaimer: Any electronic form, facsimile or hard copy of the original document (email, text, table, and/or figure), if provided, and any attachments are only a copy of the original document. The original document is stored by GeoEngineers, Inc. and will serve as the official document of record.

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Target Parameters

Project:

Project Number:

Watercourse:

Kootenai Floodplain Reconnection

9229-002-04

Ball Creek Reach 4

Site:

Analyst:

Latest Revision:

Ball Creek Ranch

RDR, JJF

7/3/2009

- This spreadsheet describes the characteristics of the bedload and bank materials, and their respective design parameters.

- These parameters are based upon *Open Channel Hydraulics*, Ven Te Chow, 1959, Table 7-3.

- These numbers provide general design targets and are not considered absolutes.

Bank & Bed Material

Description:

Water Clarity:

Maximum Permissible Velocity (fps)

Sand with silt

Clear, low turbidity

5.00

No reference reach - see Stream Classification Workbook	B/F Width (ft)	B/F Depth (ft)	W/D	Sinuosity
Reach 4	25	3.5	7.14	1.9
	Ave =	3.50	7.14	

Channel and Floodplain Cross-Section Calculation

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 4

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

- This spreadsheet estimates the size of the bankfull channel and floodplain required for a **Targeted** "Rosgen" Stream type.
- The dimensions calculated below are only approximate, and intended to be a "first estimate". The dimensions calculated below should be input into a hydraulic model (like HEC-RAS) and refined.
- The calculations are based on Manning's equation, and therefore do not account for any backwater effects. Also, this analysis assumes the flow in the channel remains in the long sinuous channel, while the flow in the floodplain flows along the shorter valley. Also, the cross-sections of the bankfull channel and floodplain are calculated independently.
- **Only input data into the shaded cells.**

Step #1: Input Desired Stream Classification Data

E5	= Stream Type
12	= ER = Entrenchment Ratio (ft/ft)
8.00	= W/D = Width/Depth Ratio (ft/ft)
1.85	= K = Sinuosity (ft/ft)
126	= $Q_{1.01}$ = Bankfull Discharge (cfs) *Bankfull discharge reduced to increase flooding and meadow wetting
2364	= Q_{100} = 100-Year Discharge (cfs) (Or any "Design Flood" Discharge)

Step #2: Input Desired Stream and Valley Geometry Data

Bankfull Channel	Floodplain (Valley)	
0.028	0.065	= n = Manning's n Value
1.25	5	= z = Bank Side-Slopes (_H:1V)
3500	1890	= L = Length (ft)
0.00030	0.0006	= G = Gradient (ft/ft)

Channel and Floodplain Design (Output)

- **Step #3:** - Use Microsoft's "Goal Seek" tool twice. Once to calculate the geometry of the bankfull channel and once to calculate the geometry of the floodplain. ("Goal Seek" is a trial-and-error tool, found under the "Tools" menu.)
- For each Trial, "Set Cell" = "Resulting" Discharge, "To Value" = "Required" Discharge, "By Changing Cells" = "Depth". (See Bold Italics)
- Calculate the bankfull channel first.

Bankfull Channel	
126	= Required Channel Discharge (cfs)
3.30	= D_{bf} = Bankfull Depth (ft)
26.36	= W_{bf} = Bankfull Width (Top Width) (ft)
18.12	= B = Bottom Width (ft)
73.30	= A = Cross-Sectional Area (sf)
28.67	= P = Wetted Perimeter (ft)
2.56	= R = Hydraulic Radius (ft)
1.72	= V = Velocity (fps)
0.05	= τ = Shear Stress in Channel (lbs/sf)
126.00	= Resulting Channel Discharge (cfs)

Floodplain (Valley)	
2238	= Required Floodplain Discharge (Excludes Channel Q) (cfs)
5.10	= D = Depth of Water in Floodplain (ft)
316.34	= W = Width of Water in Floodplain (Top Width) (ft)
265.31	= B = Bottom Width (ft)
1484.29	= A = Cross-Sectional Area (sf)
317.36	= P = Wetted Perimeter (ft)
4.68	= R = Hydraulic Radius (ft)
1.51	= V = Velocity (fps)
342.71	= Overall Floodplain Width (ft)
2238	= Resulting Floodplain Discharge (cfs)

Incipient Motion Analysis (Bedload Test)

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 4

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

Spreadsheet Description

- This spreadsheet calculates the critical velocity and critical shear stress for a channel's bed material.
- It also compares the critical velocity and critical shear stress to the values calculated in a hydraulic model of the channel. This comparison is represented in the Relative Bed Stability (RBS) factor. Incipient motion occurs when the RBS is 1.0. If the RBS is < 1.0, the material is mobile. A channel's bed material becomes more stable as the RBS increases (above 1.0).
- The velocity analysis below uses a channel's D_{50} , while the shear stress analysis uses the D_{84} .
- Several equations are used for comparison.
- Note, these equations are generalizations, and should be used with caution and judgement.
- The velocity equations assume the specific gravity of the bed material is 2.65.
- **Only input information into the shaded cells.**
- **This spreadsheet checks to make sure the upstream bedload can be conveyed through the proposed channel.**

Filename: P:\9229002 TEMP SPOK\04\Working\Calcs\Stream Design\FINAL\Stream Design 4.xls\Bedload

Velocity Analysis (Using D_{50})

Direct Input

	<u>mm</u>	<u>cm</u>	<u>in</u>	<u>ft</u>	
Coarse Sand	2.40	0.24	0.09	0.008	= D_{50} = Mean Diameter of Bed Material
Fine Gravel	6.00	0.6	0.24	0.020	= D_{84}

Input From Cross-Section Spreadsheet

1.7	= V = Q_{bf} Velocity (fps)
8.4	= D_{bf} Channel Depth (ft)
0.09	= $\tau = Q_{1.01}$ Shear Stress in Channel (lbs/sf)

Results (Neill's Equation)

3.27	= V_c = Critical Velocity (fps)
1.90	= RBS = Relative Bed Stability (dimensionless)

D50 is stable

Results (Laursen's Equation)

3.10	= V_c = Critical Velocity (fps)
1.81	= RBS = Relative Bed Stability (dimensionless)

D50 is stable

Shear Stress Analysis (Using D_{84})

Typical Constants (Input)

0.008	= D_{50} = Mean Diameter of Bed Material (From Above) (ft)
0.020	= D_{84} = 84th percentile grain size of bed material (ft)
62.400	= γ_w = Specific weight of water (lbs/ft ³)
168.000	= γ_p = Specific Weight of Sediment (lbs/ft ³)

Results (Shield's Equation)

0.038	= τ_* = Shields Number: $\tau_* = 0.0834(D_{84}/D_{50})^{-0.872}$
0.078	= τ_c = Q_{100} Critical Shear Stress: $\tau_c = \tau_*(\gamma_p - \gamma_w)D_{84}$
0.847	= RBS = Relative Bed Stability (dimensionless)

D84 is mobile.

Incipient Motion Analysis (Riffle Material Design)

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 4

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

Spreadsheet Description

- This spreadsheet calculates the critical velocity and critical shear stress for a channel's bed material for the proposed condition **at the fastest average velocity**.
- The bed material tested below should be used as the minimum material size for the riffle cross-sections.
 - It also compares the critical velocity and critical shear stress to the values calculated in a hydraulic model of the channel. This comparison is represented in the Relative Bed Stability (RBS) factor. Incipient motion occurs when the RBS is 1.0. If the RBS is < 1.0, the material is mobile. A channel's bed material becomes more stable as the RBS increases (above 1.0).
 - The velocity analysis below uses a channel's D_{50} , while the shear stress analysis uses the D_{84} .
 - Several equations are used for comparison.
 - Note, these equations are generalizations, and should be used with caution and judgement.
 - The velocity equations assume the specific gravity of the bed material is 2.65.
 - The bed material gradation can be calculated using following 2 methods:
 (1) The 9/10/2001 *Fish Passage Design at Road Culverts* Manual, by WDFW. These ratios are: $D_{84} = 2.5(D_{50})$, $D_{100} = 2.5(D_{84})$,
 $D_{16} = 0.125(D_{84})$ Thickness = D_{100} .
 (2) The AASHTO Method as presented in HEC-23, page DG12.7. These ratios are: $D_{84} = 1.3(D_{50})$, $D_{100} = 1.6(D_{50})$,
 $D_{16} = 0.5(D_{50})$
- Only input information into the shaded cells.

Filename: P:\9229002 TEMP SPOK\04Working\Calcs\Stream Design\FINAL\Stream Design 4.xls\Riffle Design

Velocity Analysis (Using D_{50})

Direct Input

2 = Gradation Method: "1" = WDFW, "2" = AASHTO.

	mm	cm	in	ft	
Fine Gravel	17.0	1.70	0.67	0.06	= D_{16} For Proposed Riffle Bed Material
Coarse Gravel	34.0	3.40	1.34	0.11	= D_{50} For Proposed Riffle Bed Material
Coarse Gravel	44.2	4.42	1.74	0.15	= D_{84} For Proposed Riffle Bed Material
Coarse Gravel	54.4	5.44	2.14	0.18	= D_{100} For Proposed Riffle Bed Material
Coarse Gravel	54.4	5.4	2.1	0.2	= Minimum Layer Thickness

Input From Cross-Section Spreadsheet

1.7 = $V = Q_{100}$ Velocity (fps)
 8.4 = Q_{100} Channel Depth (ft)
 0.1 = $t = Q_{100}$ Shear Stress in Channel (lbs/sf)

Results (Neill's Equation)

7.91 = V_c = Critical Velocity (fps)
 4.60 = RBS = Relative Bed Stability (dimensionless)

D50 is very stable.

Results (Laursen's Equation)

7.51 = V_c = Critical Velocity (fps)
 4.37 = RBS = Relative Bed Stability (dimensionless)

D50 is very stable.

Shear Stress Analysis (Using D_{84})

Typical Constants (Input)

0.112 = D_{50} = Mean Diameter of Bed Material (From Above) (ft)
 0.145 = D_{84} = 84th percentile grain size of bed material (ft)
 62.400 = γ_w = Specific weight of water (lbs/ft³)
 168.000 = γ_p = Specific Weight of Sediment (lbs/ft²)

Results (Shield's Equation)

0.066 = τ_* = Shields Number: $\tau_* = 0.0834(D_{84}/D_{50})^{-0.872}$
 1.016 = τ_c = Q_{100} Critical Shear Stress: $\tau_c = \tau_*(\gamma_p - \gamma_w)D_{84}$
 11.038 = RBS = Relative Bed Stability (dimensionless)

D84 is very stable.

Meander Geometry Calculation

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 4

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

- This spreadsheet calculates the range of sizes for the meander features noted.
- **No actual input is required on this sheet.**
- **The input for this sheet (noted below) is based upon the previous cross-section spreadsheet.**
- Three meander geometry equations are used for each meander feature. These equations, and their numbers, are based upon Williams, 1996.
- These equations can also be found on Table 7.7 of "Stream Corridor Restoration, Principles, Processes, and Practices" NRCS Manual, 10/98.
- These equations can also be found on the last two pages of Rosgen's "The Reference reach Field Book", 1998.
- The validity of each equation used is checked below. **Do not use the results of an equation if it is not valid.**
- The results noted below are highly variable, and are independent upon bed and bank material.
- **These results should be measured against an applicable reference reach.**

Input From Previous (Cross-Section) Spreadsheet

3.30 = D_{bf} = Bankfull Depth (ft)
 26.36 = W_{bf} = Bankfull Width (Top Width) (ft)
 73.30 = A = Cross-Sectional Area (sf)
 342.71 = BW = Belt Width = Overall Floodplain Width (ft)

Meander Geometry Calculations

Meander Wave Length			
Equation #	26	30	34
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Meander Wave Length (ft) = L_m =	342	254	790

Channel Length (Along Bend)			
Equation #	27	31	35
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Channel Length (Along Bend) (ft) = L_b =	245	172	527

Belt Width (Floodplain Width)			
Equation #	28	32	36
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Belt Width (ft) = BW =	212	144	490
Maximum BW (ft) =	490		
Minimum BW (ft) =	144		
Previous BW (ft) =	343		
Is Previous BW OK?	Yes		

Radius Of Curvature			
Equation #	29	33	37
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Radius Of Curvature (ft) = R_c =	67	51	141

Pool To Pool Spacing			
Spacing = 1/2 Meander Wavelength (ft) =	171	127	395
Spacing = 5 to 7 Bankfull Widths (not B3) (ft) =	79	105	132

Summary Table Of Creek Parameters

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 4

Site:
Analyst:
Latest Revision:

Ball Creek Ranch
 RDR, JJF
 7/3/2009

Summary Table Of Creek Parameters

26.4	= W_{BF}	= Bankfull Width at Riffles & Pools (ft)	E5	= Rosgen Stream Type
3.30	= D_{BF}	= Bankfull Depth (at Riffle) (ft)	1.85185185	= Sinuosity
8.24	= D_P	= Pool Depth At Bankfull Flow (ft)	8	= Width / Depth Ratio
0.67	= D_{16}	= D_{16} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles	12	= Minimum Entrenchment Ratio
1.3	= D_{50}	= D_{50} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles	0.0006	= Average Valley Gradient (ft/ft)
1.7	= D_{84}	= D_{84} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles	0.0003	= Average Creek Gradient (ft/)
2.1	= D_{100}	= D_{100} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles (Largest Rock Size)	126	= Bankfull Discharge (cfs)
253.8 790.3	= WL	= Range of Acceptable Meander Wavelengths (ft)	2364	= 100-Year Flood Discharge (cfs)
171.8 526.9	= BL	= Range of Bend Length (ft)	1.7	= Average Bankfull Velocity (fps)
144.4 490.1	= FP	= Range of Acceptable Minimum Floodplain Widths (ft)		
51 141	= R	= Range of Acceptable Radii of Curvature (ft)		
79 395	= P/P	= Range of Acceptable Pool To Pool Spacing (ft)		

Summary Table Of Creek Parameters

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 4

Site:
Analyst:
Latest Revision:

Ball Creek Ranch
 RDR, JJF
 7/3/2009

Summary Table Of Creek Parameters

E5		= Rosgen Stream Type	
1.851851852		= Sinuosity	
8		= Width / Depth Ratio	
12		= Minimum Entrenchment Ratio	
0.0006		= Average Valley Gradient (ft/ft)	
0.0003		= Average Creek Gradient (ft/)	
126		= Bankfull Discharge (cfs)	
2364		= 100-Year Flood Discharge (cfs)	
1.7		= Average Bankfull Velocity (fps)	
26.4		= W_{BF}	= Bankfull Width (ft)
3.3		= D_{BF}	= Bankfull Depth (At Riffle) (ft)
8.2		= D_P	= Pool Depth (ft)
0.7		= D_{16}	= Bed Material Size (in) (16% of material this size or smaller)
1.3		= D_{50}	= Bed Material Size (in) (50% of material this size or smaller)
1.7		= D_{84}	= Bed Material Size (in) (84% of material this size or smaller)
2.1		= D_{100}	= Bed Material Size (in) (100% of material this size or smaller)
253.8	790.3	= WL	= Range of Acceptable Meander Wavelengths (ft)
171.8	526.9	= BL	= Range of Bend Length (ft)
144.4	490.1	= FP	= Range of Acceptable Minimum Floodplain Widths (ft)
51	141	= R	= Range of Acceptable Radii of Curvature (ft)
79	395	= P/P	= Range of Acceptable Pool To Pool Spacing (ft)

Ball Creek Channel Design Workbook, Reach 5

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 5

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

Workbook Description

- This workbook is proprietary to GeoEngineers, Inc.
- This workbook contains spreadsheets that facilitate the general design of any given creek.
- This method is based, in part on the "Rosgen" Stream Classification Method.
- This spreadsheet lists the General Project Information that is consistent throughout the workbook.
- It also lists the titles of the spreadsheets contained in this workbook.

Filename: P:\9\9229002 TEMP SPOK\04\Working\Calcs\Stream Design\FINAL\Stream Design 5.xls\General

Sheet Titles:

Ball Creek Channel Design Workbook, Reach 5
Target Parameters
Channel and Floodplain Cross-Section Calculation
Meander Geometry Calculation
Incipient Motion Analysis (Bedload Test)
Incipient Motion Analysis (Riffle Material Design)
Summary Table Of Creek Parameters

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Target Parameters

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 5

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

- This spreadsheet describes the characteristics of the bedload and bank materials, and their respective design parameters.
- These parameters are based upon *Open Channel Hydraulics*, Ven Te Chow, 1959, Table 7-3.
- These numbers provide general design targets and are not considered absolutes.

Bank & Bed Material

Description: Sand with silt
Water Clarity: Clear, low turbidity
Maximum Permissible Velocity (fps) 5.00

**No reference reach - see Stream
Classification Workbook**
Segment 1

**B/F Width
(ft)**
35

**B/F Depth
(ft)**
4

W/D
8.75

Sinuosity
1.4

Ave =

4.00

8.75

Channel and Floodplain Cross-Section Calculation

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 5

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

- This spreadsheet estimates the size of the bankfull channel and floodplain required for a **Targeted** "Rosgen" Stream type.
 - The dimensions calculated below are only approximate, and intended to be a "first estimate". The dimensions calculated below should be input into a hydraulic model (like HEC-RAS) and refined.
 - The calculations are based on Manning's equation, and therefore do not account for any backwater effects. Also, this analysis assumes the flow in the channel remains in the long sinuous channel, while the flow in the floodplain flows along the shorter valley. Also, the cross-sections of the bankfull channel and floodplain are calculated independently.
 - **Only input data into the shaded cells.**

Step #1: Input Desired Stream Classification Data

C5c	= Stream Type
6	= ER = Entrenchment Ratio (ft/ft)
10.00	= W/D = Width/Depth Ratio (ft/ft)
1.23	= K = Sinuosity (ft/ft)
323	= $Q_{1.25}$ = Bankfull Discharge (cfs)
2364	= Q_{100} = 100-Year Discharge (cfs) (Or any "Design Flood" Discharge)

Step #2: Input Desired Stream and Valley Geometry Data

Bankfull Channel	Floodplain (Valley)	
0.03	0.07	= n = Manning's n Value
1.5	2	= z = Bank Side-Slopes (_H:1V)
2000	1622	= L = Length (ft)
0.00050	0.0006	= G = Gradient (ft/ft)

Channel and Floodplain Design (Output)

Step #3: - Use Microsoft's "Goal Seek" tool twice. Once to calculate the geometry of the bankfull channel and once to calculate the geometry of the floodplain. ("Goal Seek" is a trial-and-error tool, found under the "Tools" menu.)
 - For each Trial, "Set Cell" = "Resulting" Discharge, "To Value" = "Required" Discharge, "By Changing Cells" = "Depth". (See Bold Italics)
 - Calculate the bankfull channel first.

Bankfull Channel	
323	= Required Channel Discharge (cfs)
3.98	= D_{bf} = Bankfull Depth (ft)
39.79	= W_{bf} = Bankfull Width (Top Width) (ft)
27.85	= B = Bottom Width (ft)
134.56	= A = Cross-Sectional Area (sf)
42.20	= P = Wetted Perimeter (ft)
3.19	= R = Hydraulic Radius (ft)
2.40	= V = Velocity (fps)
0.10	= τ = Shear Stress in Channel (lbs/sf)
323.00	= Resulting Channel Discharge (cfs)

Floodplain (Valley)	
2041	= Required Floodplain Discharge (Excludes Channel Q) (cfs)
5.61	= D = Depth of Water in Floodplain (ft)
238.72	= W = Width of Water in Floodplain (Top Width) (ft)
216.30	= B = Bottom Width (ft)
1275.55	= A = Cross-Sectional Area (sf)
241.37	= P = Wetted Perimeter (ft)
5.28	= R = Hydraulic Radius (ft)
1.60	= V = Velocity (fps)
278.51	= Overall Floodplain Width (ft)
2041	= Resulting Floodplain Discharge (cfs)

Incipient Motion Analysis (Bedload Test)

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 5

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

Spreadsheet Description

- This spreadsheet calculates the critical velocity and critical shear stress for a channel's bed material.
- It also compares the critical velocity and critical shear stress to the values calculated in a hydraulic model of the channel. This comparison is represented in the Relative Bed Stability (RBS) factor. Incipient motion occurs when the RBS is 1.0. If the RBS is < 1.0, the material is mobile. A channel's bed material becomes more stable as the RBS increases (above 1.0).
- The velocity analysis below uses a channel's D_{50} , while the shear stress analysis uses the D_{84} .
- Several equations are used for comparison.
- Note, these equations are generalizations, and should be used with caution and judgement.
- The velocity equations assume the specific gravity of the bed material is 2.65.
- **Only input information into the shaded cells.**
- **This spreadsheet checks to make sure the upstream bedload can be conveyed through the proposed channel.**

Filename: P:\9229002 TEMP SPOK104\Working\Calcs\Stream Design\FINAL\Stream Design 5.xls\Bedload

Velocity Analysis (Using D_{50})

Direct Input

1 = Gradation Method: "1" = WDFW, "2" = AASHTO

	<u>mm</u>	<u>cm</u>	<u>in</u>	<u>ft</u>	
Medium Sand	0.6	0.06	0.02	0.00	= D_{16} For Proposed Riffle Bed Material
Medium Sand	2.0	0.20	0.08	0.01	= D_{50} For Proposed Riffle Bed Material
Fine Gravel	5.0	0.50	0.20	0.02	= D_{84} For Proposed Riffle Bed Material
Fine Gravel	12.5	1.25	0.49	0.04	= D_{100} For Proposed Riffle Bed Material
Fine Gravel	12.5	1.3	0.5	0.0	= Minimum Layer Thickness

Input From Cross-Section Spreadsheet

2.4 = V = Mean Bankfull Velocity (fps)
 4.0 = y = Mean Bankfull Water Depth (ft)
 0.1 = t = Shear Stress in Channel (lbs/sf)

Results (Neill's Equation)

2.71 = V_c = Critical Velocity (fps)
 1.13 = RBS = Relative Bed Stability (dimensionless)

D50 is close to threshold, material may move.

Results (Laursen's Equation)

2.58 = V_c = Critical Velocity (fps)
 1.07 = RBS = Relative Bed Stability (dimensionless)

D50 is close to threshold, material may move.

Shear Stress Analysis (Using D_{84})

Typical Constants (Input)

0.007 = D_{50} = Mean Diameter of Bed Material (From Above) (ft)
 0.016 = D_{84} = 84th percentile grain size of bed material (ft)
 0.000014 = μ = kinematic viscosity of water (ft^2/s)
 62.400 = γ_w = Specific weight of water (lbs/ft^3)
 168.000 = γ_p = Specific Weight of Sediment (lbs/ft^3)
 347.841 = R = Particle Reynolds number (D_{50})

Results (Shield's Equation)

0.053 = τ_* = Shields Number derived from Shields Diagram
 0.092 = τ_c = Bankfull Critical Shear Stress: $\tau_c = \tau_*(\gamma_p - \gamma_w)D_{84}$
 0.930 = RBS = Relative Bed Stability (dimensionless)

D84 is mobile.

Incipient Motion Analysis (Riffle Material Design)

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 5

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

Spreadsheet Description

- This spreadsheet calculates the critical velocity and critical shear stress for a channel's bed material for the proposed condition **at the fastest average velocity**.

- **The bed material tested below should be used as the minimum material size for the riffle cross-sections.**

- It also compares the critical velocity and critical shear stress to the values calculated in a hydraulic model of the channel. This comparison is represented in the Relative Bed Stability (RBS) factor. Incipient motion occurs when the RBS is 1.0. If the RBS is < 1.0, the material is mobile. A channel's bed material becomes more stable as the RBS increases (above 1.0).

- The velocity analysis below uses a channel's D_{50} , while the shear stress analysis uses the D_{84} .

- Several equations are used for comparison.

- Note, these equations are generalizations, and should be used with caution and judgement.

- The velocity equations assume the specific gravity of the bed material is 2.65.

- The bed material gradation can be calculated using following 2 methods:

(1) The 9/10/2001 *Fish Passage Design at Road Culverts Manual*, by WDFW. These ratios are: $D_{84} = 2.5(D_{50})$, $D_{100} = 2.5(D_{84})$, $D_{16} = 0.125(D_{84})$ Thickness = D_{100} .

(2) The AASHTO Method as presented in HEC-23, page DG12.7. These ratios are: $D_{84} = 1.3(D_{50})$, $D_{100} = 1.6(D_{50})$, $D_{16} = 0.5(D_{50})$.

- **Only input information into the shaded cells.**

Filename: P:\9229002 TEMP SPOK\04\Working\Calcs\Stream Design\FINAL\Stream Design 5.xls\Riffle Design

Velocity Analysis (Using D_{50})

Direct Input

	1	= Gradation Method: "1" = WDFW, "2" = AASHTO			
	mm	cm	in	ft	
Medium Sand	0.6	0.06	0.02	0.00	= D_{16} For Proposed Riffle Bed Material
Medium Sand	2.0	0.20	0.08	0.01	= D_{50} For Proposed Riffle Bed Material
Fine Gravel	5.0	0.50	0.20	0.02	= D_{84} For Proposed Riffle Bed Material
Fine Gravel	12.5	1.25	0.49	0.04	= D_{100} For Proposed Riffle Bed Material
Fine Gravel	12.5	1.3	0.5	0.0	= Minimum Layer Thickness

Input From Cross-Section Spreadsheet

3.9 = $V = Q_{100}$ Velocity (fps)
 9.6 = Q_{100} Water Depth (ft)
 0.2 = $t = Q_{100}$ Shear Stress in Channel (lbs/sf)

Results (Neill's Equation)

3.14 = V_c = Critical Velocity (fps)
 0.80 = RBS = Relative Bed Stability (dimensionless)

D50 is mobile.

Results (Laursen's Equation)

2.99 = V_c = Critical Velocity (fps)
 0.76 = RBS = Relative Bed Stability (dimensionless)

D50 is mobile.

Shear Stress Analysis (Using D_{84})

Typical Constants (Input)

0.007 = D_{50} = Mean Diameter of Bed Material (From Above) (ft)
 0.016 = D_{84} = 84th percentile grain size of bed material (ft)
 0.000014 = ν = kinematic viscosity of water (ft²/s)
 62.400 = γ_w = Specific weight of water (lbs/ft³)
 168.000 = γ_p = Specific Weight of Sediment (lbs/ft³)
 347.841 = R = Particle Reynolds number

Results (Shield's Equation)

0.053 = τ_* = Shields Number derived from Shields Diagram
 0.092 = τ_c = Bankfull Critical Shear Stress: $\tau_c = \tau_*(\gamma_p - \gamma_w)D_{84}$
 0.443 = RBS = Relative Bed Stability (dimensionless)

D84 is mobile.

Meander Geometry Calculation

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 5

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

- This spreadsheet calculates the range of sizes for the meander features noted.
- **No actual input is required on this sheet.**
- **The input for this sheet (noted below) is based upon the previous cross-section spreadsheet.**
- Three meander geometry equations are used for each meander feature. These equations, and their numbers, are based upon Williams, 1996.
- These equations can also be found on Table 7.7 of "Stream Corridor Restoration, Principles, Processes, and Practices" NRCS Manual, 10/98.
- These equations can also be found on the last two pages of Rosgen's "The Reference reach Field Book", 1998.
- The validity of each equation used is checked below. **Do not use the results of an equation if it is not valid.**
- The results noted below are highly variable, and are independent upon bed and bank material.
- **These results should be measured against an applicable reference reach.**

Input From Previous (Cross-Section) Spreadsheet

3.98 = D_{bf} = Bankfull Depth (ft)
 39.79 = W_{bf} = Bankfull Width (Top Width) (ft)
 134.56 = A = Cross-Sectional Area (sf)
 278.51 = BW = Belt Width = Overall Floodplain Width (ft)

Meander Geometry Calculations

Meander Wave Length			
Equation #	26	30	34
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Meander Wave Length (ft) = L_m =	508	402	1052

Channel Length (Along Bend)			
Equation #	27	31	35
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Channel Length (Along Bend) (ft) = L_b =	363	272	702

Belt Width (Floodplain Width)			
Equation #	28	32	36
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Belt Width (ft) = BW =	315	229	653
Maximum BW (ft) =	653		
Minimum BW (ft) =	229		
Previous BW (ft) =	279		
Is Previous BW OK?	Yes		

Radius Of Curvature			
Equation #	29	33	37
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Radius Of Curvature (ft) = R_c =	99	80	188

Pool To Pool Spacing			
Spacing = 1/2 Meander Wavelength (ft) =	254	201	526
Spacing = 5 to 7 Bankfull Widths (not B3) (ft) =	119	159	199

Summary Table Of Creek Parameters

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 5

Site:
Analyst:
Latest Revision:

Ball Creek Ranch
 RDR, JJF
 7/3/2009

Summary Table Of Creek Parameters

39.8	= W_{BF}	= Bankfull Width at Riffles & Pools (ft)	C5c	= Rosgen Stream Type
3.98	= D_{BF}	= Bankfull Depth (at Riffle) (ft)	1.23304562	= Sinuosity
9.95	= D_P	= Pool Depth At Bankfull Flow (ft)	10	= Width / Depth Ratio
0.02	= D_{16}	= D_{16} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles	6	= Minimum Entrenchment Ratio
0.1	= D_{50}	= D_{50} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles	0.0006	= Average Valley Gradient (ft/ft)
0.2	= D_{84}	= D_{84} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles	0.0005	= Average Creek Gradient (ft/)
0.5	= D_{100}	= D_{100} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles (Largest Rock Size)	323	= Bankfull Discharge (cfs)
402.4 1052.4	= WL	= Range of Acceptable Meander Wavelengths (ft)	2364	= 100-Year Flood Discharge (cfs)
272.4 701.6	= BL	= Range of Bend Length (ft)	2.4	= Average Bankfull Velocity (fps)
229.0 652.7	= FP	= Range of Acceptable Minimum Floodplain Widths (ft)		
80 188	= R	= Range of Acceptable Radii of Curvature (ft)		
119 526	= P/P	= Range of Acceptable Pool To Pool Spacing (ft)		

Summary Table Of Creek Parameters

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 5

Site:
Analyst:
Latest Revision:

Ball Creek Ranch
 RDR, JJF
 7/3/2009

Summary Table Of Creek Parameters

C5c		= Rosgen Stream Type	
1.233045623		= Sinuosity	
10		= Width / Depth Ratio	
6		= Minimum Entrenchment Ratio	
0.0006		= Average Valley Gradient (ft/ft)	
0.0005		= Average Creek Gradient (ft/)	
323		= Bankfull Discharge (cfs)	
2364		= 100-Year Flood Discharge (cfs)	
2.4		= Average Bankfull Velocity (fps)	
39.8		= W_{BF}	= Bankfull Width (ft)
4.0		= D_{BF}	= Bankfull Depth (At Riffle) (ft)
9.9		= D_P	= Pool Depth (ft)
0.0		= D_{16}	= Bed Material Size (in) (16% of material this size or smaller)
0.1		= D_{50}	= Bed Material Size (in) (50% of material this size or smaller)
0.2		= D_{84}	= Bed Material Size (in) (84% of material this size or smaller)
0.5		= D_{100}	= Bed Material Size (in) (100% of material this size or smaller)
402.4	1052.4	= WL	= Range of Acceptable Meander Wavelengths (ft)
272.4	701.6	= BL	= Range of Bend Length (ft)
229.0	652.7	= FP	= Range of Acceptable Minimum Floodplain Widths (ft)
80	188	= R	= Range of Acceptable Radii of Curvature (ft)
119	526	= P/P	= Range of Acceptable Pool To Pool Spacing (ft)

Ball Creek Channel Design Workbook, Reach 6

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 6

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

Workbook Description

- This workbook is proprietary to GeoEngineers, Inc.
- This workbook contains spreadsheets that facilitate the general design of any given creek.
- This method is based, in part on the "Rosgen" Stream Classification Method.
- This spreadsheet lists the General Project Information that is consistent throughout the workbook.
- It also lists the titles of the spreadsheets contained in this workbook.

Filename: P:\9\9229002 TEMP SPOK\04\Working\Calcs\Stream Design\FINAL\Stream Design 6.xls\General

Sheet Titles:

Ball Creek Channel Design Workbook, Reach 6
Target Parameters
Channel and Floodplain Cross-Section Calculation
Meander Geometry Calculation
Incipient Motion Analysis (Bedload Test)
Incipient Motion Analysis (Riffle Material Design)
Summary Table Of Creek Parameters

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Target Parameters

Project:

Project Number:

Watercourse:

Kootenai Floodplain Reconnection
9229-002-04
Ball Creek Reach 6

Site:

Analyst:

Latest Revision:

Ball Creek Ranch
RDR, JJF
7/3/2009

- This spreadsheet describes the characteristics of the bedload and bank materials, and their respective design parameters.

- These parameters are based upon *Open Channel Hydraulics*, Ven Te Chow, 1959, Table 7-3.

- These numbers provide general design targets and are not considered absolutes.

Bank & Bed Material

Description:

Water Clarity:

Maximum Permissible Velocity (fps)

Sand with silt
Clear, low turbidity

5.00

No reference reach - see Stream Classification Workbook Reach 6	B/F Width (ft) 25	B/F Depth (ft) 3.5	W/D 7.14	Sinuosity 1.9
	Ave =	3.50	7.14	

Channel and Floodplain Cross-Section Calculation

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 6

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

- This spreadsheet estimates the size of the bankfull channel and floodplain required for a **Targeted** "Rosgen" Stream type.
 - The dimensions calculated below are only approximate, and intended to be a "first estimate". The dimensions calculated below should be input into a hydraulic model (like HEC-RAS) and refined.
 - The calculations are based on Manning's equation, and therefore do not account for any backwater effects. Also, this analysis assumes the flow in the channel remains in the long sinuous channel, while the flow in the floodplain flows along the shorter valley. Also, the cross-sections of the bankfull channel and floodplain are calculated independently.
 - **Only input data into the shaded cells.**

Step #1: Input Desired Stream Classification Data

E5	= Stream Type
23	= ER = Entrenchment Ratio (ft/ft)
8.00	= W/D = Width/Depth Ratio (ft/ft)
1.72	= K = Sinuosity (ft/ft)
30	= Q = Bankfull Discharge (cfs) *Bankfull discharge reduced to increase flooding and meadow wetting
2364	= Q ₁₀₀ = 100-Year Discharge (cfs) (Or any "Design Flood" Discharge)

Step #2: Input Desired Stream and Valley Geometry Data

Bankfull Channel	Floodplain (Valley)	
0.028	0.065	= n = Manning's n Value
1.25	5	= z = Bank Side-Slopes (_H:1V)
3550	2067	= L = Length (ft)
0.0000175	0.00003	= G = Gradient (ft/ft)

Channel and Floodplain Design (Output)

- **Step #3:** - Use Microsoft's "Goal Seek" tool twice. Once to calculate the geometry of the bankfull channel and once to calculate the geometry of the floodplain. ("Goal Seek" is a trial-and-error tool, found under the "Tools" menu.)
 - For each Trial, "Set Cell" = "Resulting" Discharge, "To Value" = "Required" Discharge, "By Changing Cells" = "Depth". (See Bold Italics)
 - Calculate the bankfull channel first.

Bankfull Channel	
30	= Required Channel Discharge (cfs)
3.28	= <i>D_{bf}</i> = Bankfull Depth (ft)
26.23	= W _{bf} = Bankfull Width (Top Width) (ft)
18.03	= B = Bottom Width (ft)
72.57	= A = Cross-Sectional Area (sf)
28.53	= P = Wetted Perimeter (ft)
2.54	= R = Hydraulic Radius (ft)
0.41	= V = Velocity (fps)
0.00	= τ = Shear Stress in Channel (lbs/sf)
30.00	= Resulting Channel Discharge (cfs)

Floodplain (Valley)	
2334	= Required Floodplain Discharge (Excludes Channel Q) (cfs)
8.43	= <i>D</i> = Depth of Water in Floodplain (ft)
603.30	= W = Width of Water in Floodplain (Top Width) (ft)
519.02	= B = Bottom Width (ft)
4729.06	= A = Cross-Sectional Area (sf)
604.97	= P = Wetted Perimeter (ft)
7.82	= R = Hydraulic Radius (ft)
0.49	= V = Velocity (fps)
629.53	= Overall Floodplain Width (ft)
2334	= Resulting Floodplain Discharge (cfs)

Incipient Motion Analysis (Bedload Test)

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 6

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

Spreadsheet Description

- This spreadsheet calculates the critical velocity and critical shear stress for a channel's bed material.
- It also compares the critical velocity and critical shear stress to the values calculated in a hydraulic model of the channel. This comparison is represented in the Relative Bed Stability (RBS) factor. Incipient motion occurs when the RBS is 1.0. If the RBS is < 1.0, the material is mobile. A channel's bed material becomes more stable as the RBS increases (above 1.0).
- The velocity analysis below uses a channel's D_{50} , while the shear stress analysis uses the D_{84} .
- Several equations are used for comparison.
- Note, these equations are generalizations, and should be used with caution and judgement.
- The velocity equations assume the specific gravity of the bed material is 2.65.
- **Only input information into the shaded cells.**
- **This spreadsheet checks to make sure the upstream bedload can be conveyed through the proposed channel.**

Filename: P:\9229002 TEMP SPOK104\Working\Calcs\Stream Design\FINAL\Stream Design 6.xls\Bedload

Velocity Analysis (Using D_{50})

Direct Input

	<u>mm</u>	<u>cm</u>	<u>in</u>	<u>ft</u>	
Fine Sand	0.50	0.05	0.02	0.002	= D_{50} = Mean Diameter of Bed Material
Fine Sand	0.70	0.07	0.03	0.002	= D_{84}

Input From Cross-Section Spreadsheet

0.4	= V = Q_{bf} Velocity (fps)
11.7	= D_{bf} Channel Depth (ft)
0.01	= $t = Q_{100}$ Shear Stress in Channel (lbs/sf)

Results (Neill's Equation)

2.05	= V_c = Critical Velocity (fps)
4.95	= RBS = Relative Bed Stability (dimensionless)

D50 is very stable.

Results (Laursen's Equation)

1.95	= V_c = Critical Velocity (fps)
4.71	= RBS = Relative Bed Stability (dimensionless)

D50 is very stable.

Shear Stress Analysis (Using D_{84})

Typical Constants (Input)

0.002	= D_{50} = Mean Diameter of Bed Material (From Above) (ft)
0.002	= D_{84} = 84th percentile grain size of bed material (ft)
62.400	= γ_w = Specific weight of water (lbs/ft ³)
168.000	= γ_p = Specific Weight of Sediment (lbs/ft ²)

Results (Shield's Equation)

0.062	= τ_* = Shields Number: $\tau_* = 0.0834(D_{84}/D_{50})^{-0.872}$
0.015	= τ_c = Q_{100} Critical Shear Stress: $\tau_c = \tau_*(\gamma_p - \gamma_w)D_{84}$
1.696	= RBS = Relative Bed Stability (dimensionless)

D84 is stable

Incipient Motion Analysis (Riffle Material Design)

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 6

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

Spreadsheet Description

- This spreadsheet calculates the critical velocity and critical shear stress for a channel's bed material for the proposed condition **at the fastest average velocity**.
- The bed material tested below should be used as the minimum material size for the riffle cross-sections.
 - It also compares the critical velocity and critical shear stress to the values calculated in a hydraulic model of the channel. This comparison is represented in the Relative Bed Stability (RBS) factor. Incipient motion occurs when the RBS is 1.0. If the RBS is < 1.0, the material is mobile. A channel's bed material becomes more stable as the RBS increases (above 1.0).
 - The velocity analysis below uses a channel's D_{50} , while the shear stress analysis uses the D_{84} .
 - Several equations are used for comparison.
 - Note, these equations are generalizations, and should be used with caution and judgement.
 - The velocity equations assume the specific gravity of the bed material is 2.65.
 - The bed material gradation can be calculated using following 2 methods:
 (1) The 9/10/2001 *Fish Passage Design at Road Culverts* Manual, by WDFW. These ratios are: $D_{84} = 2.5(D_{50})$, $D_{100} = 2.5(D_{84})$,
 $D_{16} = 0.125(D_{84})$ Thickness = D_{100} .
 (2) The AASHTO Method as presented in HEC-23, page DG12.7. These ratios are: $D_{84} = 1.3(D_{50})$, $D_{100} = 1.6(D_{50})$,
 $D_{16} = 0.5(D_{50})$
- Only input information into the shaded cells.

Filename: P:\9229002 TEMP SPOK\04Working\Calcs\Stream Design\FINAL\Stream Design 6.xls\Riffle Design

Velocity Analysis (Using D_{50})

Direct Input

2 = Gradation Method: "1" = WDFW, "2" = AASHTO.

	mm	cm	in	ft	
Medium Sand	1.5	0.15	0.06	0.00	= D_{16} For Proposed Riffle Bed Material
Coarse Sand	3.0	0.30	0.12	0.01	= D_{50} For Proposed Riffle Bed Material
Coarse Sand	3.9	0.39	0.15	0.01	= D_{84} For Proposed Riffle Bed Material
Fine Gravel	4.8	0.48	0.19	0.02	= D_{100} For Proposed Riffle Bed Material
Fine Gravel	4.8	0.5	0.2	0.0	= Minimum Layer Thickness

Input From Cross-Section Spreadsheet

0.4 = $V = Q_{100}$ Velocity (fps)
 11.7 = Q_{100} Channel Depth (ft)
 0.0 = $t = Q_{100}$ Shear Stress in Channel (lbs/sf)

Results (Neill's Equation)

3.72 = V_c = Critical Velocity (fps)
 9.00 = RBS = Relative Bed Stability (dimensionless)

D50 is very stable.

Results (Laursen's Equation)

3.53 = V_c = Critical Velocity (fps)
 8.55 = RBS = Relative Bed Stability (dimensionless)

D50 is very stable.

Shear Stress Analysis (Using D_{84})

Typical Constants (Input)

0.010 = D_{50} = Mean Diameter of Bed Material (From Above) (ft)
 0.013 = D_{84} = 84th percentile grain size of bed material (ft)
 62.400 = γ_w = Specific weight of water (lbs/ft³)
 168.000 = γ_p = Specific Weight of Sediment (lbs/ft³)

Results (Shield's Equation)

0.066 = τ_* = Shields Number: $\tau_* = 0.0834(D_{84}/D_{50})^{-0.872}$
 0.090 = τ_c = Q_{100} Critical Shear Stress: $\tau_c = \tau_*(\gamma_p - \gamma_w)D_{84}$
 10.077 = RBS = Relative Bed Stability (dimensionless)

D84 is very stable.

Meander Geometry Calculation

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 6

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

- This spreadsheet calculates the range of sizes for the meander features noted.
- **No actual input is required on this sheet.**
- **The input for this sheet (noted below) is based upon the previous cross-section spreadsheet.**
- Three meander geometry equations are used for each meander feature. These equations, and their numbers, are based upon Williams, 1996.
- These equations can also be found on Table 7.7 of "Stream Corridor Restoration, Principles, Processes, and Practices" NRCS Manual, 10/98.
- These equations can also be found on the last two pages of Rosgen's "The Reference reach Field Book", 1998.
- The validity of each equation used is checked below. **Do not use the results of an equation if it is not valid.**
- The results noted below are highly variable, and are independent upon bed and bank material.
- **These results should be measured against an applicable reference reach.**

Input From Previous (Cross-Section) Spreadsheet

3.28 = D_{bf} = Bankfull Depth (ft)
 26.23 = W_{bf} = Bankfull Width (Top Width) (ft)
 72.57 = A = Cross-Sectional Area (sf)
 629.53 = BW = Belt Width = Overall Floodplain Width (ft)

Meander Geometry Calculations

Meander Wave Length			
Equation #	26	30	34
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Meander Wave Length (ft) = L_m =	340	252	784

Channel Length (Along Bend)			
Equation #	27	31	35
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Channel Length (Along Bend) (ft) = L_b =	243	171	523

Belt Width (Floodplain Width)			
Equation #	28	32	36
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Belt Width (ft) = BW =	211	144	486
Maximum BW (ft) =	486		
Minimum BW (ft) =	144		
Previous BW (ft) =	630		
Is Previous BW OK?	No		

Radius Of Curvature			
Equation #	29	33	37
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Radius Of Curvature (ft) = R_c =	66	50	140

Pool To Pool Spacing			
Spacing = 1/2 Meander Wavelength (ft) =	170	126	392
Spacing = 5 to 7 Bankfull Widths (not B3) (ft) =	79	105	131

Summary Table Of Creek Parameters

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 6

Site:
Analyst:
Latest Revision:

Ball Creek Ranch
 RDR, JJF
 7/3/2009

Summary Table Of Creek Parameters

26.2	= W_{BF}	= Bankfull Width at Riffles & Pools (ft)	E5	= Rosgen Stream Type	
3.28	= D_{BF}	= Bankfull Depth (at Riffle) (ft)	1.71746493	= Sinuosity	
8.20	= D_P	= Pool Depth At Bankfull Flow (ft)	8	= Width / Depth Ratio	
0.06	= D_{16}	= D_{16} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles	23	= Minimum Entrenchment Ratio	
0.1	= D_{50}	= D_{50} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles	0.0000	= Average Valley Gradient (ft/ft)	
0.2	= D_{84}	= D_{84} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles	0.0000	= Average Creek Gradient (ft/)	
0.2	= D_{100}	= D_{100} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles (Largest Rock Size)	30	= Bankfull Discharge (cfs)	
252.3	784.3	= WL	= Range of Acceptable Meander Wavelengths (ft)	2364	= 100-Year Flood Discharge (cfs)
170.8	522.9	= BL	= Range of Bend Length (ft)	0.4	= Average Bankfull Velocity (fps)
143.6	486.4	= FP	= Range of Acceptable Minimum Floodplain Widths (ft)		
50	140	= R	= Range of Acceptable Radii of Curvature (ft)		
79	392	= P/P	= Range of Acceptable Pool To Pool Spacing (ft)		

Summary Table Of Creek Parameters

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 6

Site:
Analyst:
Latest Revision:

Ball Creek Ranch
 RDR, JJF
 7/3/2009

Summary Table Of Creek Parameters

E5		= Rosgen Stream Type	
1.717464925		= Sinuosity	
8		= Width / Depth Ratio	
23		= Minimum Entrenchment Ratio	
0.000030		= Average Valley Gradient (ft/ft)	
0.000017		= Average Creek Gradient (ft/)	
30		= Bankfull Discharge (cfs)	
2364		= 100-Year Flood Discharge (cfs)	
0.4		= Average Bankfull Velocity (fps)	
26.2		= W_{BF}	= Bankfull Width (ft)
3.3		= D_{BF}	= Bankfull Depth (At Riffle) (ft)
8.2		= D_P	= Pool Depth (ft)
0.1		= D_{16}	= Bed Material Size (in) (16% of material this size or smaller)
0.1		= D_{50}	= Bed Material Size (in) (50% of material this size or smaller)
0.2		= D_{84}	= Bed Material Size (in) (84% of material this size or smaller)
0.2		= D_{100}	= Bed Material Size (in) (100% of material this size or smaller)
252.3	784.3	= WL	= Range of Acceptable Meander Wavelengths (ft)
170.8	522.9	= BL	= Range of Bend Length (ft)
143.6	486.4	= FP	= Range of Acceptable Minimum Floodplain Widths (ft)
50	140	= R	= Range of Acceptable Radii of Curvature (ft)
79	392	= P/P	= Range of Acceptable Pool To Pool Spacing (ft)

Ball Creek Channel Design Workbook, Reach 7

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 7

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

Workbook Description

- This workbook is proprietary to GeoEngineers, Inc.
- This workbook contains spreadsheets that facilitate the general design of any given creek.
- This method is based, in part on the "Rosgen" Stream Classification Method.
- This spreadsheet lists the General Project Information that is consistent throughout the workbook.
- It also lists the titles of the spreadsheets contained in this workbook.

Filename: P:\9\9229002 TEMP SPOK\04\Working\Calcs\Stream Design\FINAL\Stream Design 7.xls\General

Sheet Titles:

Ball Creek Channel Design Workbook, Reach 7
Target Parameters
Channel and Floodplain Cross-Section Calculation
Meander Geometry Calculation
Incipient Motion Analysis (Bedload Test)
Incipient Motion Analysis (Riffle Material Design)
Summary Table Of Creek Parameters

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Target Parameters

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 7

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

- This spreadsheet describes the characteristics of the bedload and bank materials, and their respective design parameters.
- These parameters are based upon *Open Channel Hydraulics*, Ven Te Chow, 1959, Table 7-3.
- These numbers provide general design targets and are not considered absolutes.

Bank & Bed Material

Description: Graded silts to Cobbles when colloidal
Water Clarity: Colloidal silts
Maximum Permissible Velocity (fps) 5.00

**No Reference Reaches - Use Stream
Classification Workbook**
Segment 2

**B/F Width
(ft)**
50

**B/F Depth
(ft)**
3

W/D
16.67

Sinuosity
1.2

Ave =

3.00

16.67

Channel and Floodplain Cross-Section Calculation

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 7

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

- This spreadsheet estimates the size of the bankfull channel and floodplain required for a **Targeted** "Rosgen" Stream type.
 - The dimensions calculated below are only approximate, and intended to be a "first estimate". The dimensions calculated below should be input into a hydraulic model (like HEC-RAS) and refined.
 - The calculations are based on Manning's equation, and therefore do not account for any backwater effects. Also, this analysis assumes the flow in the channel remains in the long sinuous channel, while the flow in the floodplain flows along the shorter valley. Also, the cross-sections of the bankfull channel and floodplain are calculated independently.
 - **Only input data into the shaded cells.**

Step #1: Input Desired Stream Classification Data

C4	= Stream Type
5	= ER = Entrenchment Ratio (ft/ft)
10.00	= W/D = Width/Depth Ratio (ft/ft) *This was reduced to create the bankfull condition near existing grade.
1.22	= K = Sinuosity (ft/ft)
323	= $Q_{1.25}$ = Bankfull Discharge (cfs)
2364	= Q_{100} = 100-Year Discharge (cfs) (Or any "Design Flood" Discharge)

Step #2: Input Desired Stream and Valley Geometry Data

Bankfull Channel	Floodplain (Valley)	
0.032	0.07	= n = Manning's n Value
2	5	= z = Bank Side-Slopes (_H:1V)
1200	981	= L = Length (ft)
0.00300	0.0037	= G = Gradient (ft/ft)

Channel and Floodplain Design (Output)

- **Step #3:** - Use Microsoft's "Goal Seek" tool twice. Once to calculate the geometry of the bankfull channel and once to calculate the geometry of the floodplain. ("Goal Seek" is a trial-and-error tool, found under the "Tools" menu.)
 - For each Trial, "Set Cell" = "Resulting" Discharge, "To Value" = "Required" Discharge, "By Changing Cells" = "Depth". (See Bold Italics)
 - Calculate the bankfull channel first.

Bankfull Channel	
323	= Required Channel Discharge (cfs)
3.02	= D_{bf} = Bankfull Depth (ft)
30.16	= W_{bf} = Bankfull Width (Top Width) (ft)
18.10	= B = Bottom Width (ft)
72.78	= A = Cross-Sectional Area (sf)
31.59	= P = Wetted Perimeter (ft)
2.30	= R = Hydraulic Radius (ft)
4.44	= V = Velocity (fps)
0.431	= τ = Shear Stress in Channel (lbs/sf)
323.0	= Resulting Channel Discharge (cfs)

Floodplain (Valley)	
2041	= Required Floodplain Discharge (Excludes Channel Q) (cfs)
4.92	= D = Depth of Water in Floodplain (ft)
150.81	= W = Width of Water in Floodplain (Top Width) (ft)
101.65	= B = Bottom Width (ft)
620.48	= A = Cross-Sectional Area (sf)
151.78	= P = Wetted Perimeter (ft)
4.09	= R = Hydraulic Radius (ft)
3.29	= V = Velocity (fps)
180.97	= Overall Floodplain Width (ft)
2041	= Resulting Floodplain Discharge (cfs)

Incipient Motion Analysis (Bedload Test)

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 7

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

Spreadsheet Description

- This spreadsheet calculates the critical velocity and critical shear stress for a channel's bed material.
- It also compares the critical velocity and critical shear stress to the values calculated in a hydraulic model of the channel. This comparison is represented in the Relative Bed Stability (RBS) factor. Incipient motion occurs when the RBS is 1.0. If the RBS is < 1.0, the material is mobile. A channel's bed material becomes more stable as the RBS increases (above 1.0).
- The velocity analysis below uses a channel's D_{50} , while the shear stress analysis uses the D_{84} .
- Several equations are used for comparison.
- Note, these equations are generalizations, and should be used with caution and judgement.
- The velocity equations assume the specific gravity of the bed material is 2.65.
- **Only input information into the shaded cells.**
- **This spreadsheet checks to make sure the upstream bedload can be conveyed through the proposed channel.**

Filename: P:\9229002 TEMP SPOK\04\Working\Calcs\Stream Design\FINAL\Stream Design 7.xls\Bedload

Velocity Analysis (Using D_{50})

Direct Input

	<u>mm</u>	<u>cm</u>	<u>in</u>	<u>ft</u>	
Fine Gravel	12.00	1.2	0.47	0.039	= D_{50} = Mean Diameter of Bed Material
Fine Gravel	16.00	1.6	0.63	0.052	= D_{84}

Input From Cross-Section Spreadsheet

4.4	= V = Mean Bankfull Velocity (fps)
3.0	= D_{bf} = y = Mean Bankfull Water Depth (ft)
0.43	= t = Shear Stress in Channel (lbs/sf)

Results (Neill's Equation)

4.71	= V_c = Critical Velocity (fps)
1.06	= RBS = Relative Bed Stability (dimensionless)

D50 is close to threshold, material may move.

Results (Laursen's Equation)

4.48	= V_c = Critical Velocity (fps)
1.01	= RBS = Relative Bed Stability (dimensionless)

D50 is close to threshold, material may move.

Shear Stress Analysis (Using D_{84})

Typical Constants (Input)

0.039	= D_{50} = Mean Diameter of Bed Material (From Above) (ft)
0.052	= D_{84} = 84th percentile grain size of bed material (ft)
62.400	= γ_w = Specific weight of water (lbs/ft ³)
168.000	= γ_p = Specific Weight of Sediment (lbs/ft ²)

Results (Shield's Equation)

0.065	= τ_* = Shields Number: $\tau_* = 0.0834(D_{84}/D_{50})^{-0.872}$
0.360	= τ_c = Bankfull Critical Shear Stress: $\tau_c = \tau_*(\gamma_p - \gamma_w)D_{84}$
0.834	= RBS = Relative Bed Stability (dimensionless)

D84 is mobile.

Incipient Motion Analysis (Riffle Material Design)

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 7

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

Spreadsheet Description

- This spreadsheet calculates the critical velocity and critical shear stress for a channel's bed material for the proposed condition **at the fastest average velocity**.
- The bed material tested below should be used as the minimum material size for the riffle cross-sections.
 - It also compares the critical velocity and critical shear stress to the values calculated in a hydraulic model of the channel. This comparison is represented in the Relative Bed Stability (RBS) factor. Incipient motion occurs when the RBS is 1.0. If the RBS is < 1.0, the material is mobile. A channel's bed material becomes more stable as the RBS increases (above 1.0).
 - The velocity analysis below uses a channel's D_{50} , while the shear stress analysis uses the D_{84} .
 - Several equations are used for comparison.
 - Note, these equations are generalizations, and should be used with caution and judgement.
 - The velocity equations assume the specific gravity of the bed material is 2.65.
 - The bed material gradation can be calculated using following 2 methods:
 (1) The 9/10/2001 *Fish Passage Design at Road Culverts* Manual, by WDFW. These ratios are: $D_{84} = 2.5(D_{50})$, $D_{100} = 2.5(D_{84})$,
 $D_{16} = 0.125(D_{84})$ Thickness = D_{100} .
 (2) The AASHTO Method as presented in HEC-23, page DG12.7. These ratios are: $D_{84} = 1.3(D_{50})$, $D_{100} = 1.6(D_{50})$,
 $D_{16} = 0.5(D_{50})$
- Only input information into the shaded cells.

Filename: P:\9229002 TEMP SPOK\04Working\Calcs\Stream Design\FINAL\Stream Design 7.xls\Riffle Design

Velocity Analysis (Using D_{50})

Direct Input

2 = Gradation Method: "1" = WDFW, "2" = AASHTO.

	mm	cm	in	ft	
Coarse Gravel	25.0	2.50	0.98	0.08	= D_{16} For Proposed Riffle Bed Material
Coarse Gravel	50.0	5.00	1.97	0.16	= D_{50} For Proposed Riffle Bed Material
Coarse Gravel	65.0	6.50	2.56	0.21	= D_{84} For Proposed Riffle Bed Material
Cobble	80.0	8.00	3.15	0.26	= D_{100} For Proposed Riffle Bed Material
Cobble	80.0	8.0	3.1	0.3	= Minimum Layer Thickness

Input From Cross-Section Spreadsheet

4.4 = V = Mean Bankfull Velocity (fps)
 3.0 = y = Mean Bankfull Water Depth (ft)
 0.4 = t = Shear Stress in Channel (lbs/sf)

Results (Neill's Equation)

7.58 = V_c = Critical Velocity (fps)
 1.71 = RBS = Relative Bed Stability (dimensionless)

D50 is stable

Results (Laursen's Equation)

7.20 = V_c = Critical Velocity (fps)
 1.62 = RBS = Relative Bed Stability (dimensionless)

D50 is stable

Shear Stress Analysis (Using D_{84})

Typical Constants (Input)

0.164 = D_{50} = Mean Diameter of Bed Material (From Above) (ft)
 0.213 = D_{84} = 84th percentile grain size of bed material (ft)
 62.400 = γ_w = Specific weight of water (lbs/ft³)
 168.000 = γ_p = Specific Weight of Sediment (lbs/ft²)

Results (Shield's Equation)

0.066 = τ_* = Shields Number: $\tau_* = 0.0834(D_{84}/D_{50})^{-0.872}$
 1.494 = τ_c = Bankfull Critical Shear Stress: $\tau_c = \tau_*(\gamma_p - \gamma_w)D_{84}$
 3.464 = RBS = Relative Bed Stability (dimensionless)

D84 is very stable.

Meander Geometry Calculation

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 7

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

- This spreadsheet calculates the range of sizes for the meander features noted.
- **No actual input is required on this sheet.**
- **The input for this sheet (noted below) is based upon the previous cross-section spreadsheet.**
- Three meander geometry equations are used for each meander feature. These equations, and their numbers, are based upon Williams, 1996.
- These equations can also be found on Table 7.7 of "Stream Corridor Restoration, Principles, Processes, and Practices" NRCS Manual, 10/98.
- These equations can also be found on the last two pages of Rosgen's "The Reference reach Field Book", 1998.
- The validity of each equation used is checked below. **Do not use the results of an equation if it is not valid.**
- The results noted below are highly variable, and are independent upon bed and bank material.
- **These results should be measured against an applicable reference reach.**

Input From Previous (Cross-Section) Spreadsheet

3.02 = D_{bf} = Bankfull Depth (ft)
 30.16 = W_{bf} = Bankfull Width (Top Width) (ft)
 72.78 = A = Cross-Sectional Area (sf)
 180.97 = BW = Belt Width = Overall Floodplain Width (ft)

Meander Geometry Calculations

Meander Wave Length			
Equation #	26	30	34
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Meander Wave Length (ft) = L_m =	341	295	691

Channel Length (Along Bend)			
Equation #	27	31	35
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Channel Length (Along Bend) (ft) = L_b =	243	200	461

Belt Width (Floodplain Width)			
Equation #	28	32	36
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Belt Width (ft) = BW =	211	168	428
Maximum BW (ft) =	428		
Minimum BW (ft) =	168		
Previous BW (ft) =	181		
Is Previous BW OK?	Yes		

Radius Of Curvature			
Equation #	29	33	37
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Radius Of Curvature (ft) = R_c =	67	59	123

Pool To Pool Spacing			
Spacing = 1/2 Meander Wavelength (ft) =	170	148	345
Spacing = 5 to 7 Bankfull Widths (not B3) (ft) =	90	121	151

Summary Table Of Creek Parameters

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 7

Site:
Analyst:
Latest Revision:

Ball Creek Ranch
 RDR, JJF
 7/3/2009

Summary Table Of Creek Parameters

30.2	= W_{BF}	= Bankfull Width at Riffles & Pools (ft)	C4	= Rosgen Stream Type
3.02	= D_{BF}	= Bankfull Depth (at Riffle) (ft)	1.22324159	= Sinuosity
7.54	= D_P	= Pool Depth At Bankfull Flow (ft)	10	= Width / Depth Ratio
0.98	= D_{16}	= D_{16} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles	5	= Minimum Entrenchment Ratio
2.0	= D_{50}	= D_{50} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles	0.0037	= Average Valley Gradient (ft/ft)
2.6	= D_{84}	= D_{84} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles	0.0030	= Average Creek Gradient (ft/)
3.1	= D_{100}	= D_{100} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles (Largest Rock Size)	323	= Bankfull Discharge (cfs)
295.0 690.8	= WL	= Range of Acceptable Meander Wavelengths (ft)	2364	= 100-Year Flood Discharge (cfs)
199.7 460.5	= BL	= Range of Bend Length (ft)	4.4	= Average Bankfull Velocity (fps)
168.0 428.4	= FP	= Range of Acceptable Minimum Floodplain Widths (ft)		
59 123	= R	= Range of Acceptable Radii of Curvature (ft)		
90 345	= P/P	= Range of Acceptable Pool To Pool Spacing (ft)		

Summary Table Of Creek Parameters

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 7

Site:
Analyst:
Latest Revision:

Ball Creek Ranch
 RDR, JJF
 7/3/2009

Summary Table Of Creek Parameters

C4		= Rosgen Stream Type	
1.22324159		= Sinuosity	
10		= Width / Depth Ratio	
5		= Minimum Entrenchment Ratio	
0.0037		= Average Valley Gradient (ft/ft)	
0.0030		= Average Creek Gradient (ft/)	
323		= Bankfull Discharge (cfs)	
2364		= 100-Year Flood Discharge (cfs)	
4.4		= Average Bankfull Velocity (fps)	
30.2		= W _{BF}	= Bankfull Width (ft)
3.0		= D _{BF}	= Bankfull Depth (At Riffle) (ft)
7.5		= D _P	= Pool Depth (ft)
1.0		= D ₁₆	= Bed Material Size (in) (16% of material this size or smaller)
2.0		= D ₅₀	= Bed Material Size (in) (50% of material this size or smaller)
2.6		= D ₈₄	= Bed Material Size (in) (84% of material this size or smaller)
3.1		= D ₁₀₀	= Bed Material Size (in) (100% of material this size or smaller)
295.0	690.8	= WL	= Range of Acceptable Meander Wavelengths (ft)
199.7	460.5	= BL	= Range of Bend Length (ft)
168.0	428.4	= FP	= Range of Acceptable Minimum Floodplain Widths (ft)
59	123	= R	= Range of Acceptable Radii of Curvature (ft)
90	345	= P/P	= Range of Acceptable Pool To Pool Spacing (ft)

Ball Creek Channel Design Workbook, Reach 8

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-03
Watercourse: Ball Creek Reach 8

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

Workbook Description

- This workbook is proprietary to GeoEngineers, Inc.
- This workbook contains spreadsheets that facilitate the general design of any given creek.
- This method is based, in part on the "Rosgen" Stream Classification Method.
- This spreadsheet lists the General Project Information that is consistent throughout the workbook.
- It also lists the titles of the spreadsheets contained in this workbook.

Filename: *P:\9\9229002 TEMP SPOK\04\Working\Calcs\Stream Design\FINAL\Stream Design 8 main.xls\General*

Sheet Titles:

Ball Creek Channel Design Workbook, Reach 8
Target Parameters
Channel and Floodplain Cross-Section Calculation
Meander Geometry Calculation
Incipient Motion Analysis (Bedload Test)
Incipient Motion Analysis (Riffle Material Design)
Summary Table Of Creek Parameters

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Target Parameters

Project:

Project Number:

Watercourse:

Kootenai Floodplain Reconnection

9229-002-03

Ball Creek Reach 8

Site:

Analyst:

Latest Revision:

Ball Creek Ranch

RDR, JJF

7/3/2009

- This spreadsheet describes the characteristics of the bedload and bank materials, and their respective design parameters.

- These parameters are based upon *Open Channel Hydraulics*, Ven Te Chow, 1959, Table 7-3.

- These numbers provide general design targets and are not considered absolutes.

Bank & Bed Material

Description:

Water Clarity:

Maximum Permissible Velocity (fps)

Graded silts to Cobbles when colloidal

Colloidal silts

5.00

No Reference Reaches - Use Stream Classification Workbook	B/F Width (ft)	B/F Depth (ft)	W/D	Sinuosity
Segment 2	35	2.75	12.73	1.1
	Ave =	2.75	12.73	

Channel and Floodplain Cross-Section Calculation

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-03
Watercourse: Ball Creek Reach 8

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

- This spreadsheet estimates the size of the bankfull channel and floodplain required for a **Targeted** "Rosgen" Stream type.
 - The dimensions calculated below are only approximate, and intended to be a "first estimate". The dimensions calculated below should be input into a hydraulic model (like HEC-RAS) and refined.
 - The calculations are based on Manning's equation, and therefore do not account for any backwater effects. Also, this analysis assumes the flow in the channel remains in the long sinuous channel, while the flow in the floodplain flows along the shorter valley. Also, the cross-sections of the bankfull channel and floodplain are calculated independently.
 - **Only input data into the shaded cells.**

Step #1: Input Desired Stream Classification Data

D4	= Stream Type
17	= ER = Entrenchment Ratio (ft/ft)
15.00	= W/D = Width/Depth Ratio (ft/ft)
1.03	= K = Sinuosity (ft/ft)
206	= $Q_{1.25}$ = Bankfull Discharge (cfs) *Design of D channel main channel design discharge is 206 cfs of the 323 cfs
2364	= Q_{100} = 100-Year Discharge (cfs) (Or any "Design Flood" Discharge)

Step #2: Input Desired Stream and Valley Geometry Data

Bankfull Channel	Floodplain (Valley)	
0.032	0.07	= n = Manning's n Value
1.75	5	= z = Bank Side-Slopes (_H:1V)
1952.88	1896	= L = Length (ft)
0.00500	0.0052	= G = Gradient (ft/ft)

Channel and Floodplain Design (Output)

- **Step #3:** - Use Microsoft's "Goal Seek" tool twice. Once to calculate the geometry of the bankfull channel and once to calculate the geometry of the floodplain. ("Goal Seek" is a trial-and-error tool, found under the "Tools" menu.)
 - For each Trial, "Set Cell" = "Resulting" Discharge, "To Value" = "Required" Discharge, "By Changing Cells" = "Depth". (See Bold Italics)
 - Calculate the bankfull channel first.

Bankfull Channel	
206	= Required Channel Discharge (cfs)
1.86	= D_{bf} = Bankfull Depth (ft)
27.96	= W_{bf} = Bankfull Width (Top Width) (ft)
21.44	= B = Bottom Width (ft)
46.04	= A = Cross-Sectional Area (sf)
28.95	= P = Wetted Perimeter (ft)
1.59	= R = Hydraulic Radius (ft)
4.47	= V = Velocity (fps)
0.496164421	= τ = Shear Stress in Channel (lbs/sf)
206.0000014	= Resulting Channel Discharge (cfs)

Floodplain (Valley)	
2041	= Required Floodplain Discharge (Excludes Channel Q) (cfs)
1.90	= D = Depth of Water in Floodplain (ft)
475.33	= W = Width of Water in Floodplain (Top Width) (ft)
456.33	= B = Bottom Width (ft)
885.31	= A = Cross-Sectional Area (sf)
475.71	= P = Wetted Perimeter (ft)
1.86	= R = Hydraulic Radius (ft)
2.31	= V = Velocity (fps)
503.29	= Overall Floodplain Width (ft)
2041	= Resulting Floodplain Discharge (cfs)

Incipient Motion Analysis (Bedload Test)

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-03
Watercourse: Ball Creek Reach 8

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

Spreadsheet Description

- This spreadsheet calculates the critical velocity and critical shear stress for a channel's bed material.
- It also compares the critical velocity and critical shear stress to the values calculated in a hydraulic model of the channel. This comparison is represented in the Relative Bed Stability (RBS) factor. Incipient motion occurs when the RBS is 1.0. If the RBS is < 1.0, the material is mobile. A channel's bed material becomes more stable as the RBS increases (above 1.0).
- The velocity analysis below uses a channel's D_{50} , while the shear stress analysis uses the D_{84} .
- Several equations are used for comparison.
- Note, these equations are generalizations, and should be used with caution and judgement.
- The velocity equations assume the specific gravity of the bed material is 2.65.
- **Only input information into the shaded cells.**
- **This spreadsheet checks to make sure the upstream bedload can be conveyed through the proposed channel.**

Filename: P:\9229002 TEMP SPOK104\Working\Calcs\Stream Design\FINAL\Stream Design 8 main.xls\Bedload

Velocity Analysis (Using D_{50})

Direct Input

	<u>mm</u>	<u>cm</u>	<u>in</u>	<u>ft</u>	
Fine Gravel	15.00	1.5	0.59	0.049	= D_{50} = Mean Diameter of Bed Material
Coarse Gravel	20.00	2	0.79	0.066	= D_{84}

Input From Cross-Section Spreadsheet

4.5	= V = Mean Bankfull Velocity (fps)
1.9	= D_{bf} = y = Mean Bankfull Water Depth (ft)
0.50	= t = Shear Stress in Channel (lbs/sf)

Results (Neill's Equation)

4.68	= Vc = Critical Velocity (fps)
1.05	= RBS = Relative Bed Stability (dimensionless)

D50 is close to threshold, material may move.

Results (Laursen's Equation)

4.45	= Vc = Critical Velocity (fps)
0.99	= RBS = Relative Bed Stability (dimensionless)

D50 is mobile.

Shear Stress Analysis (Using D_{84})

Typical Constants (Input)

0.049	= D_{50} = Mean Diameter of Bed Material (From Above) (ft)
0.066	= D_{84} = 84th percentile grain size of bed material (ft)
62.400	= γ_w = Specific weight of water (lbs/ft ³)
168.000	= γ_p = Specific Weight of Sediment (lbs/ft ³)

Results (Shield's Equation)

0.065	= τ_* = Shields Number: $\tau_* = 0.0834(D_{84}/D_{50})^{-0.872}$
0.450	= τ_c = Bankfull Critical Shear Stress: $\tau_c = \tau_*(\gamma_p - \gamma_w)D_{84}$
0.906	= RBS = Relative Bed Stability (dimensionless)

D84 is mobile.

Incipient Motion Analysis (Riffle Material Design)

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-03
Watercourse: Ball Creek Reach 8

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

Spreadsheet Description

- This spreadsheet calculates the critical velocity and critical shear stress for a channel's bed material for the proposed condition **at the fastest average velocity**.
- The bed material tested below should be used as the minimum material size for the riffle cross-sections.
 - It also compares the critical velocity and critical shear stress to the values calculated in a hydraulic model of the channel. This comparison is represented in the Relative Bed Stability (RBS) factor. Incipient motion occurs when the RBS is 1.0. If the RBS is < 1.0, the material is mobile. A channel's bed material becomes more stable as the RBS increases (above 1.0).
 - The velocity analysis below uses a channel's D_{50} , while the shear stress analysis uses the D_{84} .
 - Several equations are used for comparison.
 - Note, these equations are generalizations, and should be used with caution and judgement.
 - The velocity equations assume the specific gravity of the bed material is 2.65.
 - The bed material gradation can be calculated using following 2 methods:
 (1) The 9/10/2001 *Fish Passage Design at Road Culverts* Manual, by WDFW. These ratios are: $D_{84} = 2.5(D_{50})$, $D_{100} = 2.5(D_{84})$,
 $D_{16} = 0.125(D_{84})$ Thickness = D_{100} .
 (2) The AASHTO Method as presented in HEC-23, page DG12.7. These ratios are: $D_{84} = 1.3(D_{50})$, $D_{100} = 1.6(D_{50})$,
 $D_{16} = 0.5(D_{50})$
- Only input information into the shaded cells.

Filename: P:\9229002 TEMP SPOK\04Working\Calcs\Stream Design\FINAL\Stream Design 8 main.xls\Riffle Design

Velocity Analysis (Using D_{50})

Direct Input

2 = Gradation Method: "1" = WDFW, "2" = AASHTO.

	mm	cm	in	ft	
Coarse Gravel	30.0	3.00	1.18	0.10	= D_{16} For Proposed Riffle Bed Material
Coarse Gravel	60.0	6.00	2.36	0.20	= D_{50} For Proposed Riffle Bed Material
Cobble	78.0	7.80	3.07	0.26	= D_{84} For Proposed Riffle Bed Material
Cobble	96.0	9.60	3.78	0.31	= D_{100} For Proposed Riffle Bed Material
Cobble	96.0	9.6	3.8	0.3	= Minimum Layer Thickness

Input From Cross-Section Spreadsheet

4.5 = V = Mean Bankfull Velocity (fps)
 1.9 = y = Mean Bankfull Water Depth (ft)
 0.5 = t = Shear Stress in Channel (lbs/sf)

Results (Neill's Equation)

7.43 = V_c = Critical Velocity (fps)
 1.66 = RBS = Relative Bed Stability (dimensionless)

D50 is stable

Results (Laursen's Equation)

7.07 = V_c = Critical Velocity (fps)
 1.58 = RBS = Relative Bed Stability (dimensionless)

D50 is close to threshold, material may move.

Shear Stress Analysis (Using D_{84})

Typical Constants (Input)

0.197 = D_{50} = Mean Diameter of Bed Material (From Above) (ft)
 0.256 = D_{84} = 84th percentile grain size of bed material (ft)
 62.400 = γ_w = Specific weight of water (lbs/ft³)
 168.000 = γ_p = Specific Weight of Sediment (lbs/ft²)

Results (Shield's Equation)

0.066 = τ_* = Shields Number: $\tau_* = 0.0834(D_{84}/D_{50})^{-0.872}$
 1.793 = τ_c = Bankfull Critical Shear Stress: $\tau_c = \tau_*(\gamma_p - \gamma_w)D_{84}$
 3.613 = RBS = Relative Bed Stability (dimensionless)

D84 is very stable.

Meander Geometry Calculation

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-03
Watercourse: Ball Creek Reach 8

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

- This spreadsheet calculates the range of sizes for the meander features noted.
- **No actual input is required on this sheet.**
- **The input for this sheet (noted below) is based upon the previous cross-section spreadsheet.**
- Three meander geometry equations are used for each meander feature. These equations, and their numbers, are based upon Williams, 1996.
- These equations can also be found on Table 7.7 of "Stream Corridor Restoration, Principles, Processes, and Practices" NRCS Manual, 10/98.
- These equations can also be found on the last two pages of Rosgen's "The Reference reach Field Book", 1998.
- The validity of each equation used is checked below. **Do not use the results of an equation if it is not valid.**
- The results noted below are highly variable, and are independent upon bed and bank material.
- **These results should be measured against an applicable reference reach.**

Input From Previous (Cross-Section) Spreadsheet

1.86 = D_{bf} = Bankfull Depth (ft)
 27.96 = W_{bf} = Bankfull Width (Top Width) (ft)
 46.04 = A = Cross-Sectional Area (sf)
 503.29 = BW = Belt Width = Overall Floodplain Width (ft)

Meander Geometry Calculations

Meander Wave Length			
Equation #	26	30	34
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Meander Wave Length (ft) = L_m =	253	271	332

Channel Length (Along Bend)			
Equation #	27	31	35
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Channel Length (Along Bend) (ft) = L_b =	181	183	222

Belt Width (Floodplain Width)			
Equation #	28	32	36
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Belt Width (ft) = BW =	157	154	206
Maximum BW (ft) =	206		
Minimum BW (ft) =	154		
Previous BW (ft) =	503		
Is Previous BW OK?	No		

Radius Of Curvature			
Equation #	29	33	37
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Radius Of Curvature (ft) = R_c =	49	54	59

Pool To Pool Spacing			
Spacing = 1/2 Meander Wavelength (ft) =	127	136	166
Spacing = 5 to 7 Bankfull Widths (not B3) (ft) =	84	112	140

Summary Table Of Creek Parameters

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-03
Watercourse: Ball Creek Reach 8

Site:
Analyst:
Latest Revision:

Ball Creek Ranch
 RDR, JJF
 7/3/2009

Summary Table Of Creek Parameters

28.0	= W_{BF}	= Bankfull Width at Riffles & Pools (ft)	D4	= Rosgen Stream Type
1.86	= D_{BF}	= Bankfull Depth (at Riffle) (ft)	1.03	= Sinuosity
4.66	= D_P	= Pool Depth At Bankfull Flow (ft)	15	= Width / Depth Ratio
1.18	= D_{16}	= D_{16} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles	17	= Minimum Entrenchment Ratio
2.4	= D_{50}	= D_{50} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles	0.0052	= Average Valley Gradient (ft/ft)
3.1	= D_{84}	= D_{84} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles	0.0050	= Average Creek Gradient (ft/)
3.8	= D_{100}	= D_{100} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles (Largest Rock Size)	206	= Bankfull Discharge (cfs)
253.1 332.4	= WL	= Range of Acceptable Meander Wavelengths (ft)	2364	= 100-Year Flood Discharge (cfs)
180.8 221.6	= BL	= Range of Bend Length (ft)	4.5	= Average Bankfull Velocity (fps)
154.3 206.2	= FP	= Range of Acceptable Minimum Floodplain Widths (ft)		
49 59	= R	= Range of Acceptable Radii of Curvature (ft)		
84 166	= P/P	= Range of Acceptable Pool To Pool Spacing (ft)		

Summary Table Of Creek Parameters

Project: Kootenai Floodplain Reconnection
 Project Number: 9229-002-03
 Watercourse: Ball Creek Reach 8

Site:
 Analyst:
 Latest Revision:

Ball Creek Ranch
 RDR, JJF
 7/3/2009

Summary Table Of Creek Parameters

D4		= Rosgen Stream Type	
1.03		= Sinuosity	
15		= Width / Depth Ratio	
17		= Minimum Entrenchment Ratio	
0.0052		= Average Valley Gradient (ft/ft)	
0.0050		= Average Creek Gradient (ft/)	
206		= Bankfull Discharge (cfs)	
2364		= 100-Year Flood Discharge (cfs)	
4.5		= Average Bankfull Velocity (fps)	
28.0		= W_{BF}	= Bankfull Width (ft)
1.9		= D_{BF}	= Bankfull Depth (At Riffle) (ft)
4.7		= D_P	= Pool Depth (ft)
1.2		= D_{16}	= Bed Material Size (in) (16% of material this size or smaller)
2.4		= D_{50}	= Bed Material Size (in) (50% of material this size or smaller)
3.1		= D_{84}	= Bed Material Size (in) (84% of material this size or smaller)
3.8		= D_{100}	= Bed Material Size (in) (100% of material this size or smaller)
253.1	332.4	= WL	= Range of Acceptable Meander Wavelengths (ft)
180.8	221.6	= BL	= Range of Bend Length (ft)
154.3	206.2	= FP	= Range of Acceptable Minimum Floodplain Widths (ft)
49	59	= R	= Range of Acceptable Radii of Curvature (ft)
84	166	= P/P	= Range of Acceptable Pool To Pool Spacing (ft)

Ball Creek Channel Design Workbook, Reach 8

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-03
Watercourse: Ball Creek Reach 8

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

Workbook Description

- This workbook is proprietary to GeoEngineers, Inc.
- This workbook contains spreadsheets that facilitate the general design of any given creek.
- This method is based, in part on the "Rosgen" Stream Classification Method.
- This spreadsheet lists the General Project Information that is consistent throughout the workbook.
- It also lists the titles of the spreadsheets contained in this workbook.

Filename: *P:\9\9229002 TEMP SPOK\04\Working\Calcs\Stream Design\FINAL\Stream Design 8 side.xls\General*

Sheet Titles:

Ball Creek Channel Design Workbook, Reach 8
Target Parameters
Channel and Floodplain Cross-Section Calculation
Meander Geometry Calculation
Incipient Motion Analysis (Bedload Test)
Incipient Motion Analysis (Riffle Material Design)
Summary Table Of Creek Parameters

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Target Parameters

Project:

Project Number:

Watercourse:

Kootenai Floodplain Reconnection

9229-002-03

Ball Creek Reach 8

Site:

Analyst:

Latest Revision:

Ball Creek Ranch

RDR, JJF

7/3/2009

- This spreadsheet describes the characteristics of the bedload and bank materials, and their respective design parameters.

- These parameters are based upon *Open Channel Hydraulics*, Ven Te Chow, 1959, Table 7-3.

- These numbers provide general design targets and are not considered absolutes.

Bank & Bed Material

Description:

Water Clarity:

Maximum Permissible Velocity (fps)

Graded silts to Cobbles when colloidal

Colloidal silts

5.00

No Reference Reaches - Use Stream Classification Workbook	B/F Width (ft)	B/F Depth (ft)	W/D	Sinuosity
Segment 2	35	2.75	12.73	1.1
	Ave =	2.75	12.73	

Channel and Floodplain Cross-Section Calculation

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-03
Watercourse: Ball Creek Reach 8

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

- This spreadsheet estimates the size of the bankfull channel and floodplain required for a **Targeted** "Rosgen" Stream type.
 - The dimensions calculated below are only approximate, and intended to be a "first estimate". The dimensions calculated below should be input into a hydraulic model (like HEC-RAS) and refined.
 - The calculations are based on Manning's equation, and therefore do not account for any backwater effects. Also, this analysis assumes the flow in the channel remains in the long sinuous channel, while the flow in the floodplain flows along the shorter valley. Also, the cross-sections of the bankfull channel and floodplain are calculated independently.
 - **Only input data into the shaded cells.**

Step #1: Input Desired Stream Classification Data

D4	= Stream Type
28	= ER = Entrenchment Ratio (ft/ft)
15.00	= W/D = Width/Depth Ratio (ft/ft)
1.03	= K = Sinuosity (ft/ft) *Rosgen allows sinuosity variance by plus or minus 0.2 units
58.5	= $Q_{1.25}$ = Bankfull Discharge (cfs) *Design of D channel side channel design discharge is 59 cfs for each side of the 323 cfs
2364	= Q_{100} = 100-Year Discharge (cfs) (Or any "Design Flood" Discharge)

Step #2: Input Desired Stream and Valley Geometry Data

Bankfull Channel	Floodplain (Valley)	
0.032	0.07	= n = Manning's n Value
1.75	5	= z = Bank Side-Slopes (_H:1V)
1952.88	1896	= L = Length (ft)
0.00500	0.0052	= G = Gradient (ft/ft)

Channel and Floodplain Design (Output)

- **Step #3:** - Use Microsoft's "Goal Seek" tool twice. Once to calculate the geometry of the bankfull channel and once to calculate the geometry of the floodplain. ("Goal Seek" is a trial-and-error tool, found under the "Tools" menu.)
 - For each Trial, "Set Cell" = "Resulting" Discharge, "To Value" = "Required" Discharge, "By Changing Cells" = "Depth". (See Bold Italics)
 - Calculate the bankfull channel first.

Bankfull Channel	
58.5	= Required Channel Discharge (cfs)
1.16	= D_{bf} = Bankfull Depth (ft)
17.44	= W_{bf} = Bankfull Width (Top Width) (ft)
13.37	= B = Bottom Width (ft)
17.91	= A = Cross-Sectional Area (sf)
18.06	= P = Wetted Perimeter (ft)
0.99	= R = Hydraulic Radius (ft)
3.27	= V = Velocity (fps)
0.309481426	= τ = Shear Stress in Channel (lbs/sf)
58.50003824	= Resulting Channel Discharge (cfs)

Floodplain (Valley)	
2041	= Required Floodplain Discharge (Excludes Channel Q) (cfs)
1.87	= D = Depth of Water in Floodplain (ft)
488.33	= W = Width of Water in Floodplain (Top Width) (ft)
469.65	= B = Bottom Width (ft)
894.90	= A = Cross-Sectional Area (sf)
488.70	= P = Wetted Perimeter (ft)
1.83	= R = Hydraulic Radius (ft)
2.28	= V = Velocity (fps)
505.77	= Overall Floodplain Width (ft)
2041	= Resulting Floodplain Discharge (cfs)

Incipient Motion Analysis (Bedload Test)

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-03
Watercourse: Ball Creek Reach 8

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

Spreadsheet Description

- This spreadsheet calculates the critical velocity and critical shear stress for a channel's bed material.
- It also compares the critical velocity and critical shear stress to the values calculated in a hydraulic model of the channel. This comparison is represented in the Relative Bed Stability (RBS) factor. Incipient motion occurs when the RBS is 1.0. If the RBS is < 1.0, the material is mobile. A channel's bed material becomes more stable as the RBS increases (above 1.0).
- The velocity analysis below uses a channel's D_{50} , while the shear stress analysis uses the D_{84} .
- Several equations are used for comparison.
- Note, these equations are generalizations, and should be used with caution and judgement.
- The velocity equations assume the specific gravity of the bed material is 2.65.
- **Only input information into the shaded cells.**
- **This spreadsheet checks to make sure the upstream bedload can be conveyed through the proposed channel.**

Filename: P:\9229002 TEMP SPOK\04\Working\Calcs\Stream Design\FINAL\Stream Design 8 side.xls\Bedload

Velocity Analysis (Using D_{50})

Direct Input

	<u>mm</u>	<u>cm</u>	<u>in</u>	<u>ft</u>	
Fine Gravel	8.00	0.8	0.31	0.026	= D_{50} = Mean Diameter of Bed Material
Fine Gravel	12.00	1.2	0.47	0.039	= D_{84}

Input From Cross-Section Spreadsheet

3.3	= V = Mean Bankfull Velocity (fps)
1.2	= D_{bf} = y = Mean Bankfull Water Depth (ft)
0.31	= t = Shear Stress in Channel (lbs/sf)

Results (Neill's Equation)

3.51	= V_c = Critical Velocity (fps)
1.07	= RBS = Relative Bed Stability (dimensionless)

D50 is close to threshold, material may move.

Results (Laursen's Equation)

3.34	= V_c = Critical Velocity (fps)
1.02	= RBS = Relative Bed Stability (dimensionless)

D50 is close to threshold, material may move.

Shear Stress Analysis (Using D_{84})

Typical Constants (Input)

0.026	= D_{50} = Mean Diameter of Bed Material (From Above) (ft)
0.039	= D_{84} = 84th percentile grain size of bed material (ft)
62.400	= γ_w = Specific weight of water (lbs/ft ³)
168.000	= γ_p = Specific Weight of Sediment (lbs/ft ³)

Results (Shield's Equation)

0.059	= τ_* = Shields Number: $\tau_* = 0.0834(D_{84}/D_{50})^{-0.872}$
0.243	= τ_c = Bankfull Critical Shear Stress: $\tau_c = \tau_*(\gamma_p - \gamma_w)D_{84}$
0.787	= RBS = Relative Bed Stability (dimensionless)

D84 is mobile.

Incipient Motion Analysis (Riffle Material Design)

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-03
Watercourse: Ball Creek Reach 8

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

Spreadsheet Description

- This spreadsheet calculates the critical velocity and critical shear stress for a channel's bed material for the proposed condition **at the fastest average velocity**.
- The bed material tested below should be used as the minimum material size for the riffle cross-sections.
 - It also compares the critical velocity and critical shear stress to the values calculated in a hydraulic model of the channel. This comparison is represented in the Relative Bed Stability (RBS) factor. Incipient motion occurs when the RBS is 1.0. If the RBS is < 1.0, the material is mobile. A channel's bed material becomes more stable as the RBS increases (above 1.0).
 - The velocity analysis below uses a channel's D_{50} , while the shear stress analysis uses the D_{84} .
 - Several equations are used for comparison.
 - Note, these equations are generalizations, and should be used with caution and judgement.
 - The velocity equations assume the specific gravity of the bed material is 2.65.
 - The bed material gradation can be calculated using following 2 methods:
 (1) The 9/10/2001 *Fish Passage Design at Road Culverts* Manual, by WDFW. These ratios are: $D_{84} = 2.5(D_{50})$, $D_{100} = 2.5(D_{84})$,
 $D_{16} = 0.125(D_{84})$ Thickness = D_{100} .
 (2) The AASHTO Method as presented in HEC-23, page DG12.7. These ratios are: $D_{84} = 1.3(D_{50})$, $D_{100} = 1.6(D_{50})$,
 $D_{16} = 0.5(D_{50})$
- Only input information into the shaded cells.

Filename: P:\9229002 TEMP SPOK\04Working\Calcs\Stream Design\FINAL\Stream Design 8 side.xls\Riffle Design

Velocity Analysis (Using D_{50})

Direct Input

2 = Gradation Method: "1" = WDFW, "2" = AASHTO.

	mm	cm	in	ft	
Coarse Gravel	30.0	3.00	1.18	0.10	= D_{16} For Proposed Riffle Bed Material
Coarse Gravel	60.0	6.00	2.36	0.20	= D_{50} For Proposed Riffle Bed Material
Cobble	78.0	7.80	3.07	0.26	= D_{84} For Proposed Riffle Bed Material
Cobble	96.0	9.60	3.78	0.31	= D_{100} For Proposed Riffle Bed Material
Cobble	96.0	9.6	3.8	0.3	= Minimum Layer Thickness

Input From Cross-Section Spreadsheet

3.3 = V = Mean Bankfull Velocity (fps)
 1.2 = y = Mean Bankfull Water Depth (ft)
 0.3 = t = Shear Stress in Channel (lbs/sf)

Results (Neill's Equation)

6.87 = V_c = Critical Velocity (fps)
 2.10 = RBS = Relative Bed Stability (dimensionless)

D50 is very stable.

Results (Laursen's Equation)

6.53 = V_c = Critical Velocity (fps)
 2.00 = RBS = Relative Bed Stability (dimensionless)

D50 is stable

Shear Stress Analysis (Using D_{84})

Typical Constants (Input)

0.197 = D_{50} = Mean Diameter of Bed Material (From Above) (ft)
 0.256 = D_{84} = 84th percentile grain size of bed material (ft)
 62.400 = γ_w = Specific weight of water (lbs/ft³)
 168.000 = γ_p = Specific Weight of Sediment (lbs/ft²)

Results (Shield's Equation)

0.066 = τ_* = Shields Number: $\tau_* = 0.0834(D_{84}/D_{50})^{-0.872}$
 1.793 = τ_c = Bankfull Critical Shear Stress: $\tau_c = \tau_*(\gamma_p - \gamma_w)D_{84}$
 5.793 = RBS = Relative Bed Stability (dimensionless)

D84 is very stable.

Meander Geometry Calculation

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-03
Watercourse: Ball Creek Reach 8

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

- This spreadsheet calculates the range of sizes for the meander features noted.
- **No actual input is required on this sheet.**
- **The input for this sheet (noted below) is based upon the previous cross-section spreadsheet.**
- Three meander geometry equations are used for each meander feature. These equations, and their numbers, are based upon Williams, 1996.
- These equations can also be found on Table 7.7 of "Stream Corridor Restoration, Principles, Processes, and Practices" NRCS Manual, 10/98.
- These equations can also be found on the last two pages of Rosgen's "The Reference reach Field Book", 1998.
- The validity of each equation used is checked below. **Do not use the results of an equation if it is not valid.**
- The results noted below are highly variable, and are independent upon bed and bank material.
- **These results should be measured against an applicable reference reach.**

Input From Previous (Cross-Section) Spreadsheet

1.16 = D_{bf} = Bankfull Depth (ft)
 17.44 = W_{bf} = Bankfull Width (Top Width) (ft)
 17.91 = A = Cross-Sectional Area (sf)
 505.77 = BW = Belt Width = Overall Floodplain Width (ft)

Meander Geometry Calculations

Meander Wave Length			
Equation #	26	30	34
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Meander Wave Length (ft) = L_m =	137	160	162

Channel Length (Along Bend)			
Equation #	27	31	35
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Channel Length (Along Bend) (ft) = L_b =	98	108	108

Belt Width (Floodplain Width)			
Equation #	28	32	36
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Belt Width (ft) = BW =	85	91	101
Maximum BW (ft) =	101		
Minimum BW (ft) =	91		
Previous BW (ft) =	506		
Is Previous BW OK?	No		

Radius Of Curvature			
Equation #	29	33	37
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Radius Of Curvature (ft) = R_c =	27	32	29

Pool To Pool Spacing			
Spacing = 1/2 Meander Wavelength (ft) =	69	80	81
Spacing = 5 to 7 Bankfull Widths (not B3) (ft) =	52	70	87

Summary Table Of Creek Parameters

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-03
Watercourse: Ball Creek Reach 8

Site:
Analyst:
Latest Revision:

Ball Creek Ranch
 RDR, JJF
 7/3/2009

Summary Table Of Creek Parameters

17.4	= W_{BF}	= Bankfull Width at Riffles & Pools (ft)	D4	= Rosgen Stream Type	
1.16	= D_{BF}	= Bankfull Depth (at Riffle) (ft)	1.03	= Sinuosity	
2.91	= D_P	= Pool Depth At Bankfull Flow (ft)	15	= Width / Depth Ratio	
1.18	= D_{16}	= D_{16} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles	28	= Minimum Entrenchment Ratio	
2.4	= D_{50}	= D_{50} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles	0.0052	= Average Valley Gradient (ft/ft)	
3.1	= D_{84}	= D_{84} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles	0.0050	= Average Creek Gradient (ft/)	
3.8	= D_{100}	= D_{100} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles (Largest Rock Size)	58.5	= Bankfull Discharge (cfs)	
137.0	162.2	= WL	= Range of Acceptable Meander Wavelengths (ft)	2364	= 100-Year Flood Discharge (cfs)
97.9	108.1	= BL	= Range of Bend Length (ft)	3.3	= Average Bankfull Velocity (fps)
90.9	100.6	= FP	= Range of Acceptable Minimum Floodplain Widths (ft)		
27	32	= R	= Range of Acceptable Radii of Curvature (ft)		
52	87	= P/P	= Range of Acceptable Pool To Pool Spacing (ft)		

Summary Table Of Creek Parameters

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-03
Watercourse: Ball Creek Reach 8

Site:
Analyst:
Latest Revision:

Ball Creek Ranch
 RDR, JJF
 7/3/2009

Summary Table Of Creek Parameters

D4		= Rosgen Stream Type	
1.03		= Sinuosity	
15		= Width / Depth Ratio	
28		= Minimum Entrenchment Ratio	
0.0052		= Average Valley Gradient (ft/ft)	
0.0050		= Average Creek Gradient (ft/)	
58.5		= Bankfull Discharge (cfs)	
2364		= 100-Year Flood Discharge (cfs)	
3.3		= Average Bankfull Velocity (fps)	
17.4		= W_{BF}	= Bankfull Width (ft)
1.2		= D_{BF}	= Bankfull Depth (At Riffle) (ft)
2.9		= D_P	= Pool Depth (ft)
1.2		= D_{16}	= Bed Material Size (in) (16% of material this size or smaller)
2.4		= D_{50}	= Bed Material Size (in) (50% of material this size or smaller)
3.1		= D_{84}	= Bed Material Size (in) (84% of material this size or smaller)
3.8		= D_{100}	= Bed Material Size (in) (100% of material this size or smaller)
137.0	162.2	= WL	= Range of Acceptable Meander Wavelengths (ft)
97.9	108.1	= BL	= Range of Bend Length (ft)
90.9	100.6	= FP	= Range of Acceptable Minimum Floodplain Widths (ft)
27	32	= R	= Range of Acceptable Radii of Curvature (ft)
52	87	= P/P	= Range of Acceptable Pool To Pool Spacing (ft)

Ball Creek Channel Design Workbook, Reach 9

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 9

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

Workbook Description

- This workbook is proprietary to GeoEngineers, Inc.
- This workbook contains spreadsheets that facilitate the general design of any given creek.
- This method is based, in part on the "Rosgen" Stream Classification Method.
- This spreadsheet lists the General Project Information that is consistent throughout the workbook.
- It also lists the titles of the spreadsheets contained in this workbook.

Filename: P:\9\9229002 TEMP SPOK\04\Working\Calcs\Stream Design\FINAL\Stream Design 9.xls\General

Sheet Titles:

Ball Creek Channel Design Workbook, Reach 9
Target Parameters
Channel and Floodplain Cross-Section Calculation
Meander Geometry Calculation
Incipient Motion Analysis (Bedload Test)
Incipient Motion Analysis (Riffle Material Design)
Summary Table Of Creek Parameters

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Target Parameters

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 9

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

- This spreadsheet describes the characteristics of the bedload and bank materials, and their respective design parameters.
- These parameters are based upon *Open Channel Hydraulics*, Ven Te Chow, 1959, Table 7-3.
- These numbers provide general design targets and are not considered absolutes.

Bank & Bed Material

Description: Cobbles and boulders
Water Clarity: Clear, low turbidity
Maximum Permissible Velocity (fps) 5.00

**No reference reach - see Stream
Classification Workbook**
Segment 1

**B/F Width
(ft)**
50

**B/F Depth
(ft)**
2

W/D
25.00

Sinuosity
1.14

Ave =

2.00

25.00

Channel and Floodplain Cross-Section Calculation

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 9

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

- This spreadsheet estimates the size of the bankfull channel and floodplain required for a **Targeted** "Rosgen" Stream type.
 - The dimensions calculated below are only approximate, and intended to be a "first estimate". The dimensions calculated below should be input into a hydraulic model (like HEC-RAS) and refined.
 - The calculations are based on Manning's equation, and therefore do not account for any backwater effects. Also, this analysis assumes the flow in the channel remains in the long sinuous channel, while the flow in the floodplain flows along the shorter valley. Also, the cross-sections of the bankfull channel and floodplain are calculated independently.
 - **Only input data into the shaded cells.**

Step #1: Input Desired Stream Classification Data

C3	= Stream Type
3.3	= ER = Entrenchment Ratio (ft/ft)
20.00	= W/D = Width/Depth Ratio (ft/ft)
1.01	= K = Sinuosity (ft/ft) *Rosgen allows sinuosity variance by plus or minus 0.2 units
323	= $Q_{1.25}$ = Bankfull Discharge (cfs)
2364	= Q_{100} = 100-Year Discharge (cfs) (Or any "Design Flood" Discharge)

Step #2: Input Desired Stream and Valley Geometry Data

Bankfull Channel	Floodplain (Valley)	
0.037	0.06	= n = Manning's n Value
2	3	= z = Bank Side-Slopes (_H:1V)
386.83	383	= L = Length (ft)
0.01500	0.0152	= G = Gradient (ft/ft)

Channel and Floodplain Design (Output)

- **Step #3:** - Use Microsoft's "Goal Seek" tool twice. Once to calculate the geometry of the bankfull channel and once to calculate the geometry of the floodplain. ("Goal Seek" is a trial-and-error tool, found under the "Tools" menu.)
 - For each Trial, "Set Cell" = "Resulting" Discharge, "To Value" = "Required" Discharge, "By Changing Cells" = "Depth". (See Bold Italics)
 - Calculate the bankfull channel first.

Bankfull Channel	
323	= Required Channel Discharge (cfs)
1.68	= D_{bf} = Bankfull Depth (ft)
33.57	= W_{bf} = Bankfull Width (Top Width) (ft)
26.86	= B = Bottom Width (ft)
50.73	= A = Cross-Sectional Area (sf)
34.37	= P = Wetted Perimeter (ft)
1.48	= R = Hydraulic Radius (ft)
6.38	= V = Velocity (fps)
1.38	= τ = Shear Stress in Channel (lbs/sf)
323	= Resulting Channel Discharge (cfs)

Floodplain (Valley)	
2041	= Required Floodplain Discharge (Excludes Channel Q) (cfs)
3.24	= D = Depth of Water in Floodplain (ft)
110.80	= W = Width of Water in Floodplain (Top Width) (ft)
91.37	= B = Bottom Width (ft)
327.20	= A = Cross-Sectional Area (sf)
111.85	= P = Wetted Perimeter (ft)
2.93	= R = Hydraulic Radius (ft)
6.24	= V = Velocity (fps)
144.37	= Overall Floodplain Width (ft)
2041	= Resulting Floodplain Discharge (cfs)

Incipient Motion Analysis (Bedload Test)

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 9

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

Spreadsheet Description

- This spreadsheet calculates the critical velocity and critical shear stress for a channel's bed material.
- It also compares the critical velocity and critical shear stress to the values calculated in a hydraulic model of the channel. This comparison is represented in the Relative Bed Stability (RBS) factor. Incipient motion occurs when the RBS is 1.0. If the RBS is < 1.0, the material is mobile. A channel's bed material becomes more stable as the RBS increases (above 1.0).
- The velocity analysis below uses a channel's D_{50} , while the shear stress analysis uses the D_{84} .
- Several equations are used for comparison.
- The velocity equations assume the specific gravity of the bed material is 2.65.
- Note, these equations are generalizations, and should be used with caution and judgement.
- **Only input information into the shaded cells.**
- **This spreadsheet checks to make sure the upstream bedload can be conveyed through the proposed channel.**

Filename: P:\9229002 TEMP SPOK104\Working\Calcs\Stream Design\FINAL\Stream Design 9.xls\Bedload-BF

Velocity Analysis (Using D_{50})

Direct Input

	<u>mm</u>	<u>cm</u>	<u>in</u>	<u>ft</u>	
Coarse Gravel	50.00	5	1.97	0.164	= D_{50} = Mean Diameter of Bed Material
Coarse Gravel	75.00	7.5	2.95	0.246	= D_{84}

Input From Cross-Section Spreadsheet

6.4	= $V = Q_{1.25}$ Velocity (fps)
1.7	= $Q_{1.25}$ Channel Depth (ft)
1.38	= $t = Q_{1.25}$ Shear Stress in Channel (lbs/sf)

Results (Neill's Equation)

6.87	= V_c = Critical Velocity (fps)
1.08	= RBS = Relative Bed Stability (dimensionless)

D50 is close to threshold, material may move.

Results (Laursen's Equation)

6.53	= V_c = Critical Velocity (fps)
1.02	= RBS = Relative Bed Stability (dimensionless)

D50 is close to threshold, material may move.

Shear Stress Analysis (Using D_{84})

Typical Constants (Input)

0.164	= D_{50} = Mean Diameter of Bed Material (From Above) (ft)
0.246	= D_{84} = 84th percentile grain size of bed material (ft)
62.400	= γ_w = Specific weight of water (lbs/ft ³)
168.000	= γ_p = Specific Weight of Sediment (lbs/ft ³)

Results (Shield's Equation)

0.059	= τ_* = Shields Number: $\tau_* = 0.0834(D_{84}/D_{50})^{-0.872}$
1.522	= τ_c = Q_{100} Critical Shear Stress: $\tau_c = \tau_*(\gamma_p - \gamma_w)D_{84}$
1.101	= RBS = Relative Bed Stability (dimensionless)

D84 is close to threshold, material may move.

Incipient Motion Analysis (Bedload Test)

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 9

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

Spreadsheet Description

- This spreadsheet calculates the critical velocity and critical shear stress for a channel's bed material.
- It also compares the critical velocity and critical shear stress to the values calculated in a hydraulic model of the channel. This comparison is represented in the Relative Bed Stability (RBS) factor. Incipient motion occurs when the RBS is 1.0. If the RBS is < 1.0, the material is mobile. A channel's bed material becomes more stable as the RBS increases (above 1.0).
- The velocity analysis below uses a channel's D_{50} , while the shear stress analysis uses the D_{84} .
- Several equations are used for comparison.
- The velocity equations assume the specific gravity of the bed material is 2.65.
- Note, these equations are generalizations, and should be used with caution and judgement.
- **Only input information into the shaded cells.**
- **This spreadsheet checks to make sure the upstream bedload can be conveyed through the proposed channel.**

Filename: P:\9229002 TEMP SPOK\04\Working\Calcs\Stream Design\FINAL\Stream Design 9.xls\Bedload-100yr

Velocity Analysis (Using D_{50})

Direct Input

	<u>mm</u>	<u>cm</u>	<u>in</u>	<u>ft</u>	
Cobble	300.00	30	11.81	0.984	= D_{50} = Mean Diameter of Bed Material
Boulder	390.00	39	15.35	1.280	= D_{84}

Input From Cross-Section Spreadsheet

13.7	= V = Q_{100} Velocity (fps)
4.9	= Q_{100} Channel Depth (ft)
4.34	= $t = Q_{100}$ Shear Stress in Channel (lbs/sf)

Results (Neill's Equation)

14.94	= V_c = Critical Velocity (fps)
1.09	= RBS = Relative Bed Stability (dimensionless)

D50 is close to threshold, material may move.

Results (Laursen's Equation)

14.20	= V_c = Critical Velocity (fps)
1.04	= RBS = Relative Bed Stability (dimensionless)

D50 is close to threshold, material may move.

Shear Stress Analysis (Using D_{84})

Typical Constants (Input)

0.984	= D_{50} = Mean Diameter of Bed Material (From Above) (ft)
1.280	= D_{84} = 84th percentile grain size of bed material (ft)
62.400	= γ_w = Specific weight of water (lbs/ft ³)
168.000	= γ_p = Specific Weight of Sediment (lbs/ft ²)

Results (Shield's Equation)

0.066	= τ_* = Shields Number: $\tau_* = 0.0834(D_{84}/D_{50})^{-0.872}$
8.964	= τ_c = Q_{100} Critical Shear Stress: $\tau_c = \tau_*(\gamma_p - \gamma_w)D_{84}$
2.065	= RBS = Relative Bed Stability (dimensionless)

D84 is very stable.

Incipient Motion Analysis (Riffle Material Design)

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 9

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

Spreadsheet Description

- This spreadsheet calculates the critical velocity and critical shear stress for a channel's bed material for the proposed condition **at the fastest average velocity**.
- The bed material tested below should be used as the minimum material size for the riffle cross-sections.
 - It also compares the critical velocity and critical shear stress to the values calculated in a hydraulic model of the channel. This comparison is represented in the Relative Bed Stability (RBS) factor. Incipient motion occurs when the RBS is 1.0. If the RBS is < 1.0, the material is mobile. A channel's bed material becomes more stable as the RBS increases (above 1.0).
 - The velocity analysis below uses a channel's D_{50} , while the shear stress analysis uses the D_{84} .
 - Several equations are used for comparison.
 - Note, these equations are generalizations, and should be used with caution and judgement.
 - The velocity equations assume the specific gravity of the bed material is 2.65.
 - The bed material gradation can be calculated using following 2 methods:
 (1) The 9/10/2001 *Fish Passage Design at Road Culverts* Manual, by WDFW. These ratios are: $D_{84} = 2.5(D_{50})$, $D_{100} = 2.5(D_{84})$,
 $D_{16} = 0.125(D_{84})$ Thickness = D_{100} .
 (2) The AASHTO Method as presented in HEC-23, page DG12.7. These ratios are: $D_{84} = 1.3(D_{50})$, $D_{100} = 1.6(D_{50})$,
 $D_{16} = 0.5(D_{50})$
- Only input information into the shaded cells.

Filename: P:\9229002 TEMP SPOK\04Working\Calcs\Stream Design\FINAL\Stream Design 9.xls\Riffle Design

Velocity Analysis (Using D_{50})

Direct Input

2 = Gradation Method: "1" = WDFW, "2" = AASHTO.

	mm	cm	in	ft	
Cobble	250.0	25.00	9.84	0.82	= D_{16} For Proposed Riffle Bed Material
Boulder	500.0	50.00	19.69	1.64	= D_{50} For Proposed Riffle Bed Material
Boulder	650.0	65.00	25.59	2.13	= D_{84} For Proposed Riffle Bed Material
Boulder	800.0	80.00	31.50	2.62	= D_{100} For Proposed Riffle Bed Material
Boulder	800.0	80.0	31.5	2.6	= Minimum Layer Thickness

Input From Cross-Section Spreadsheet

13.7 = $V = Q_{100}$ Velocity (fps)
 4.9 = Q_{100} Channel Depth (ft)
 4.3 = $t = Q_{100}$ Shear Stress in Channel (lbs/sf)

Results (Neill's Equation)

17.72 = V_c = Critical Velocity (fps)
 1.29 = RBS = Relative Bed Stability (dimensionless)

D50 is close to threshold, material may move.

Results (Laursen's Equation)

16.84 = V_c = Critical Velocity (fps)
 1.23 = RBS = Relative Bed Stability (dimensionless)

D50 is close to threshold, material may move.

Shear Stress Analysis (Using D_{84})

Typical Constants (Input)

1.640 = D_{50} = Mean Diameter of Bed Material (From Above) (ft)
 2.133 = D_{84} = 84th percentile grain size of bed material (ft)
 62.400 = γ_w = Specific weight of water (lbs/ft³)
 168.000 = γ_p = Specific Weight of Sediment (lbs/ft²)

Results (Shield's Equation)

0.066 = τ_* = Shields Number: $\tau_* = 0.0834(D_{84}/D_{50})^{-0.872}$
 14.941 = τ_c = Q_{100} Critical Shear Stress: $\tau_c = \tau_*(\gamma_p - \gamma_w)D_{84}$
 3.441 = RBS = Relative Bed Stability (dimensionless)

D84 is very stable.

Meander Geometry Calculation

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 9

Site: Ball Creek Ranch
Analyst: RDR, JJF
Latest Revision: 7/3/2009

- This spreadsheet calculates the range of sizes for the meander features noted.
- **No actual input is required on this sheet.**
- **The input for this sheet (noted below) is based upon the previous cross-section spreadsheet.**
- Three meander geometry equations are used for each meander feature. These equations, and their numbers, are based upon Williams, 1996.
- These equations can also be found on Table 7.7 of "Stream Corridor Restoration, Principles, Processes, and Practices" NRCS Manual, 10/98.
- These equations can also be found on the last two pages of Rosgen's "The Reference reach Field Book", 1998.
- The validity of each equation used is checked below. **Do not use the results of an equation if it is not valid.**
- The results noted below are highly variable, and are independent upon bed and bank material.
- **These results should be measured against an applicable reference reach.**

Input From Previous (Cross-Section) Spreadsheet

1.68 = D_{bf} = Bankfull Depth (ft)
 33.57 = W_{bf} = Bankfull Width (Top Width) (ft)
 50.73 = A = Cross-Sectional Area (sf)
 144.37 = BW = Belt Width = Overall Floodplain Width (ft)

Meander Geometry Calculations

Meander Wave Length			
Equation #	26	30	34
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Meander Wave Length (ft) = L_m =	270	333	284

Channel Length (Along Bend)			
Equation #	27	31	35
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Channel Length (Along Bend) (ft) = L_b =	193	225	189

Belt Width (Floodplain Width)			
Equation #	28	32	36
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Belt Width (ft) = BW =	167	189	176
Maximum BW (ft) =	189		
Minimum BW (ft) =	176		
Previous BW (ft) =	144		
Is Previous BW OK?	No		

Radius Of Curvature			
Equation #	29	33	37
Equation Dependent On	A	W_{bf}	D_{bf}
Equation Range Valid?	Yes	Yes	Yes
Radius Of Curvature (ft) = R_c =	53	67	51

Pool To Pool Spacing			
Spacing = 1/2 Meander Wavelength (ft) =	135	166	142
Spacing = 5 to 7 Bankfull Widths (not B3) (ft) =	101	134	168

Summary Table Of Creek Parameters

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 9

Site:
Analyst:
Latest Revision:

Ball Creek Ranch
 RDR, JJF
 7/3/2009

Summary Table Of Creek Parameters

33.6	= W_{BF}	= Bankfull Width at Riffles & Pools (ft)	C3	= Rosgen Stream Type
1.68	= D_{BF}	= Bankfull Depth (at Riffle) (ft)	1.01	= Sinuosity
4.20	= D_P	= Pool Depth At Bankfull Flow (ft)	20	= Width / Depth Ratio
9.84	= D_{16}	= D_{16} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles	3.3	= Minimum Entrenchment Ratio
19.7	= D_{50}	= D_{50} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles	0.0152	= Average Valley Gradient (ft/ft)
25.6	= D_{84}	= D_{84} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles	0.0150	= Average Creek Gradient (ft/)
31.5	= D_{100}	= D_{100} (in) of Gravel & Cobble Bed Material To Be Installed In Riffles (Largest Rock Size)	323	= Bankfull Discharge (cfs)
269.5 332.7	= WL	= Range of Acceptable Meander Wavelengths (ft)	2364	= 100-Year Flood Discharge (cfs)
189.0 225.2	= BL	= Range of Bend Length (ft)	6.4	= Average Bankfull Velocity (fps)
175.8 189.4	= FP	= Range of Acceptable Minimum Floodplain Widths (ft)		
51 67	= R	= Range of Acceptable Radii of Curvature (ft)		
101 168	= P/P	= Range of Acceptable Pool To Pool Spacing (ft)		

Summary Table Of Creek Parameters

Project: Kootenai Floodplain Reconnection
Project Number: 9229-002-04
Watercourse: Ball Creek Reach 9

Site:
Analyst:
Latest Revision:

Ball Creek Ranch
 RDR, JJF
 7/3/2009

Summary Table Of Creek Parameters

C3		= Rosgen Stream Type	
1.01		= Sinuosity	
20		= Width / Depth Ratio	
3.3		= Minimum Entrenchment Ratio	
0.0152		= Average Valley Gradient (ft/ft)	
0.0150		= Average Creek Gradient (ft/)	
323		= Bankfull Discharge (cfs)	
2364		= 100-Year Flood Discharge (cfs)	
6.4		= Average Bankfull Velocity (fps)	
33.6		= W_{BF}	= Bankfull Width (ft)
1.7		= D_{BF}	= Bankfull Depth (At Riffle) (ft)
4.2		= D_P	= Pool Depth (ft)
9.8		= D_{16}	= Bed Material Size (in) (16% of material this size or smaller)
19.7		= D_{50}	= Bed Material Size (in) (50% of material this size or smaller)
25.6		= D_{84}	= Bed Material Size (in) (84% of material this size or smaller)
31.5		= D_{100}	= Bed Material Size (in) (100% of material this size or smaller)
269.5	332.7	= WL	= Range of Acceptable Meander Wavelengths (ft)
189.0	225.2	= BL	= Range of Bend Length (ft)
175.8	189.4	= FP	= Range of Acceptable Minimum Floodplain Widths (ft)
51	67	= R	= Range of Acceptable Radii of Curvature (ft)
101	168	= P/P	= Range of Acceptable Pool To Pool Spacing (ft)

**Comparison of Mean Daily Flows of Kootenai River (at Porthill) and Ball Creek (x 100)
for the Concurrent Period of Record
Jan 1, 1972 through October 4, 1979**

**Ball Creek Hydrograph vs. Kootenai River
Hydrograph Timing**

Kootenai River Floodplain Reconnection
Bonners Ferry, Idaho

GEOENGINEERS

Figure A-1

Map Revised: April 30, 2008 (MGR)

Path: P:\9229002 TEMP SPOK03\GIS\MXD\922900203-FA2.mxd

Office Location: BOIS

Reference: Topographic map provided by ArcWeb Services, download June 20, 2007.
Based on National Geographic TOPO! 1:100,000 map.

Watershed Boundary

Notes:

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Ball Creek Watershed

Kootenai River Floodplain Reconnection
Bonners Ferry, Idaho

Figure A-2

100 Year Floodplain Map in the Vicinity of Ball Creek Ranch

Kootenai River Floodplain Reconnection
Bonners Ferry, Idaho

GEOENGINEERS

Figure A-3

APPENDIX B
SUPPORTING COST ESTIMATION CALCULATIONS

Restoration Cost Workbook

Project: Kootenai River Floodplain Reconnection
Project Number: 9229-002-04

Analyst: J. J. Fealko
Latest Revision: 07/03/09

Workbook Description

- This workbook contains spreadsheets that facilitate the analysis and/or design of this project.
- This spreadsheet lists the general project and workbook information that is consistent throughout the workbook.
- It also lists the titles of the spreadsheets contained in this workbook.
- This workbook is intended for use with ENGLISH UNITS.

Filename: W:\Spokane\Projects\9\9229002\04\Working\Ball Creek Design\922900204_Cost Estimate.xls]Intro

Sheet Titles:

Restoration Cost Workbook
Unit Costs
Summary of Restoration Costs
Summary Table
Comparison of Restoration Costs
Reach 1
Reach 2
Reach 3
Reach 4
Reach 5
Reach 6
Reach 7
Reach 8

Unit Costs

Project:

Kootenai River Floodplain Reconnection

Analyst: J. J. Fealko

Project Number:

9229-002-04

Latest Revision: 7/3/2009

- This spreadsheet calculates the costs associated with site preparation. Unit costs include materials, labor, equipment, overhead and contractor profit.
 - Reference used for "unit costs" include:
 (1) R.S. Means Heavy Construction Cost Data Manual, 2004 (Means)
 (2) Engineering Experience & Recent Similar Projects
 (3) Contractor or Supplier
 - Inflation adjustment is a rough estimate using the Consumer Price Index average between 1999 and 2004.
 - Additional adjustments are based on engineering judgement, experience and site-specific degree of difficulty.
 - Blank rows are provided at the bottom for additional items. Add new items & unit costs on this sheet, if necessary. These will be used to calculate costs on subsequent sheets.

12 = Adjustment for inflation from to 2004 to 2009 (Construction) (%) (consumer price index calculator http://www.bls.gov/data/inflation_calculator.htm)
 -6.5 = Location Factor (Spokane, WA) (%) (Adjustment from national average)
 -3.5 = Additional Location Factor (Bonners Ferry) (%)

Item #	Item Description	Ref. ID	Ref. #	Page #	Units	Unit Cost (\$)	Inflation & Location Adjustments (%)	Additional Adjustments (%)	Adjusted Unit Price (\$)
1	Groundwater Dewatering	2			LS	10,000.00	0	0	10000.00
2	Floodplain Excavation (short and long haul)	1 2	02315-452-0150	51	CY	5.25	0	0	5.25
3	Floodplain Grading	1	02310-100-010	45	Acre	3,000.00	2	0	3060.00
4	Stream Excavation	2	02300-424-0300 02315-490-0320	49 53	CY	5.25	0	0	5.25
5	Stream Grading	1	02310-100-010	45	Acre	3,000.00	2	150	7560.00
6	Boulders, cobbles, gravel placed in stream	2			CY	50.00	0	0	50.00
7	Large Woody Debris (acquisition, haul & installation)	2 (3)			Per Piece	600.00	0	0	600.00
8	Riprap	1	02370-450-0100	57	CY	42.00	2	10	47.04
9	Local Grading of Excavated Material	1	02310-100-0100 02315-310-5700	45 47	Acre	4,350.00	2	0	4437.00
10	Tidegate	3			Each	500.00	0	0	500.00
11	24" HDPE Corrugated Pipe (acquired, installed, drilled)	1	02500-770-3080 02445-300-0500	77 62	LF	360.00	2	0	367.20
12	Geogrid Crossing	3			LS	18,386.00	0	0	18386.00
13	BMP's (Jute mat, silt fence, staked hay bales)	1	02370-700-0020 02370-700-1100	57 58	LS	1,250.00	0	0	1250.00
14	Wetland and Riparian Planting	3			LS	1.00	0	0	1.00
15	Irrigation/Backwater Berms				EA	262.50	0	0	262.50
16	Diversion Structure	3			LS	41,930.00	0	0	41930.00
17	Fascine Bundle	3			LS	1,000.00	0	0	1000.00
18	Burrito Wrap	3			LS	1,000.00	0	0	1000.00
19	Jute Mat Bank	3			LS	1,000.00	0	0	1000.00
101	Mobilization (as % of Construction Sub-Total)							1.5	
102	Taxes (as % of Construction Sub-Total)							0	
103	Incidentals not included in items above (as % of Construction Sub-Total)							5	
104	Contingency (as % of Construction Sub-Total)							5	
105	Permitting & Design (as % of Construction Sub-Total)							0	
106	Other (as % of Construction Sub-Total)							0	

Summary of Restoration Costs

Project: Kootenai River Floodplain Reconnection
Project No: 9229-002-04

Analyst: J. J. Fealko
Latest Revision: 7/3/2009

- This spreadsheet summarizes the costs for all design components and alternatives considered.

Summary Table	
Reach	Total Cost (\$)
1	\$104,487
2	\$583,410
3	\$914,568
4	\$1,185,857
5	\$605,849
6	\$637,963
7	\$176,870
8	\$586,897
9	\$132,747
Total	\$4,928,647

Comparison of Restoration Costs

Project: Kootenai River Floodplain Reconnection
Project No: 9229-002-04

Analyst: J. J. Fealko
Latest Revision: 7/3/2009

- This spreadsheet compares the Alternatives and Design Components for the values noted.
- These values are summarized in the tabl on the preceeding spreadhseet.

Reach 1

Project: Kootenai River Floodplain Reconnection

Analyst: J. J. Fealko

Project No: 9229-002-04

Latest Revision: 7/3/2009

- This spreadsheet calculates the costs for the items noted. Item # references the Item # on the Unit Cost sheet.
- The unit costs are based upon those listed & calculated on the Unit Cost sheet.
- Blue cells represent cells that require input.

Item #	Item Description	Units	Adjusted Unit Cost (\$)	No. of Units	Cost per Item (\$)
1	Groundwater Dewatering	LS	10000.00	1.0	10,000
2	Floodplain Excavation (short and long haul)	CY	5.25	3,700.0	19,425
3	Floodplain Grading	Acre	3060.00	2.3	6,977
4	Stream Excavation	CY	5.25	1,111.0	5,833
5	Stream Grading	Acre	7560.00	0.7	5,216
6	Boulders, cobbles, gravel placed in stream	CY	50.00	100.0	5,000
7	Large Woody Debris (acquisition, haul & installation)	Per Piece	600.00	0.0	0
8	Riprap	CY	47.04	0.0	0
9	Local Grading of Excavated Material	Acre	4437.00	1.4	6,212
10	Tidegate	Each	500.00	1.0	500
11	24" HDPE Corrugated Pipe (acquired, installed, drilled)	LF	367.20	60.0	22,032
12	Geogrid Crossing	LS	18386.00	0.0	0
13	BMP's (Jute mat, silt fence, staked hay bales)	LS	1250.00	1.0	1,250
14	Wetland and Riparian Planting	LS	1.00	4,067.2	4,067
15	Irrigation/Backwater Berms	EA	262.50	1.0	263
16	Diversion Structure	LS	41930.00	0.0	0
17	Fascine Bundle	LS	1000.00	6.9	6,936
18	Burrito Wrap	LS	1000.00	0.0	0
19	Jute Mat Bank	LS	1000.00	0.0	0
Construction Sub-Total					93,710
101	Mobilization (as % of Construction Sub-Total)			1.5%	1,406
102	Taxes (as % of Construction Sub-Total)			0.0%	0
103	Incidentals not included in items above (as % of Construction Sub-Total)			5.0%	4,686
104	Contingency (as % of Construction Sub-Total)			5.0%	4,686
105	Permitting & Design (as % of Construction Sub-Total)			0.0%	0
106	Other (as % of Construction Sub-Total)			0.0%	0
Final Construction Cost					104,487

Reach 2

Project: Kootenai River Floodplain Reconnection

Analyst: J. J. Fealko

Project No: 9229-002-04

Latest Revision: 7/3/2009

- This spreadsheet calculates the costs for the items noted. Item # references the Item # on the Unit Cost sheet.
 - The unit costs are based upon those listed & calculated on the Unit Cost sheet.
 - Blue cells represent cells that require input.

Item #	Item Description	Units	Adjusted Unit Cost (\$)	No. of Units	Cost per Item (\$)
1	Groundwater Dewatering	LS	10000.00	1.0	10,000
2	Floodplain Excavation (short and long haul)	CY	5.25	31,692	166,384
3	Floodplain Grading	Acre	3060.00	3.2	9,884
4	Stream Excavation	CY	5.25	1,467	7,701
5	Stream Grading	Acre	7560.00	0.6	4,308
6	Boulders, cobbles, gravel placed in stream	CY	50.00	5,325.0	266,250
7	Large Woody Debris (acquisition, haul & installation)	Per Piece	600.00	8.0	4,800
8	Riprap	CY	47.04	0.0	0
9	Local Grading of Excavated Material	Acre	4437.00	0.0	0
10	Tidegate	Each	500.00	0.0	0
11	24" HDPE Corrugated Pipe (acquired, installed, drilled)	LF	367.20	0.0	0
12	Geogrid Crossing	LS	18386.00	0.0	0
13	BMP's (Jute mat, silt fence, staked hay bales)	LS	1250.00	1.0	1,250
14	Wetland and Riparian Planting	LS	1.00	3,237.9	3,238
15	Irrigation/Backwater Berms	EA	262.50	1.0	263
16	Diversion Structure	LS	41930.00	0.0	0
17	Fascine Bundle	LS	1000.00	31.9	31,890
18	Burrito Wrap	LS	1000.00	0.0	0
19	Jute Mat Bank	LS	1000.00	17.3	17,270
Construction Sub-Total					523,237
101	Mobilization (as % of Construction Sub-Total)			1.5%	7,849
102	Taxes (as % of Construction Sub-Total)			0.0%	0
103	Incidentals not included in items above (as % of Construction Sub-Total)			5.0%	26,162
104	Contingency (as % of Construction Sub-Total)			5.0%	26,162
105	Permitting & Design (as % of Construction Sub-Total)			0.0%	0
106	Other (as % of Construction Sub-Total)			0.0%	0
Final Construction Cost					583,410

Reach 3

Project: Kootenai River Floodplain Reconnection

Analyst: J. J. Fealko

Project No: 9229-002-04

Latest Revision: 7/3/2009

- This spreadsheet calculates the costs for the items noted. Item # references the Item # on the Unit Cost sheet.
- The unit costs are based upon those listed & calculated on the Unit Cost sheet.
- Blue cells represent cells that require input.

Item #	Item Description	Units	Adjusted Unit Cost (\$)	No. of Units	Cost per Item (\$)
1	Groundwater Dewatering	LS	10000.00	1.0	10,000
2	Floodplain Excavation (short and long haul)	CY	5.25	45,503.6	238,894
3	Floodplain Grading	Acre	3060.00	18.9	57,898
4	Stream Excavation	CY	5.25	15,636.4	82,091
5	Stream Grading	Acre	7560.00	2.8	21,009
6	Boulders, cobbles, gravel placed in stream	CY	50.00	0.0	0
7	Large Woody Debris (acquisition, haul & installation)	Per Piece	600.00	55.0	33,000
8	Riprap	CY	47.04	0.0	0
9	Local Grading of Excavated Material	Acre	4437.00	61.8	274,207
10	Tidegate	Each	500.00	0.0	0
11	24" HDPE Corrugated Pipe (acquired, installed, drilled)	LF	367.20	0.0	0
12	Geogrid Crossing	LS	18386.00	0.0	0
13	BMP's (Jute mat, silt fence, staked hay bales)	LS	1250.00	1.0	1,250
14	Wetland and Riparian Planting	LS	1.00	86,379.8	86,380
15	Irrigation/Backwater Berms	EA	262.50	3.0	788
16	Diversion Structure	LS	41930.00	0.0	0
17	Fascine Bundle	LS	1000.00	10.1	10,052
18	Burrito Wrap	LS	1000.00	4.0	3,962
19	Jute Mat Bank	LS	1000.00	0.7	711
	Construction Sub-Total				820,240
101	Mobilization (as % of Construction Sub-Total)			1.5%	12,304
102	Taxes (as % of Construction Sub-Total)			0.0%	0
103	Incidentals not included in items above (as % of Construction Sub-Total)			5.0%	41,012
104	Contingency (as % of Construction Sub-Total)			5.0%	41,012
105	Permitting & Design (as % of Construction Sub-Total)			0.0%	0
106	Other (as % of Construction Sub-Total)			0.0%	0
	Final Construction Cost				914,568

Reach 4

Project: Kootenai River Floodplain Reconnection

Analyst: J. J. Fealko

Project No: 9229-002-04

Latest Revision: 7/3/2009

- This spreadsheet calculates the costs for the items noted. Item # references the Item # on the Unit Cost sheet.
- The unit costs are based upon those listed & calculated on the Unit Cost sheet.
- Blue cells represent cells that require input.

Item #	Item Description	Units	Adjusted Unit Cost (\$)	No. of Units	Cost per Item (\$)
1	Groundwater Dewatering	LS	10000.00	1.0	10,000
2	Floodplain Excavation (short and long haul)	CY	5.25	115,617.1	606,990
3	Floodplain Grading	Acre	3060.00	25.0	76,429
4	Stream Excavation	CY	5.25	8,670.9	45,522
5	Stream Grading	Acre	7560.00	2.0	15,295
6	Boulders, cobbles, gravel placed in stream	CY	50.00	0.0	0
7	Large Woody Debris (acquisition, haul & installation)	Per Piece	600.00	57.0	34,200
8	Riprap	CY	47.04	0.0	0
9	Local Grading of Excavated Material	Acre	4437.00	39.3	174,374
10	Tidegate	Each	500.00	1.0	500
11	24" HDPE Corrugated Pipe (acquired, installed, drilled)	LF	367.20	0.0	0
12	Geogrid Crossing	LS	18386.00	0.0	0
13	BMP's (Jute mat, silt fence, staked hay bales)	LS	1250.00	1.0	1,250
14	Wetland and Riparian Planting	LS	1.00	89,633.9	89,634
15	Irrigation/Backwater Berms	EA	262.50	3.0	788
16	Diversion Structure	LS	41930.00	0.0	0
17	Fascine Bundle	LS	1000.00	3.3	3,304
18	Burrito Wrap	LS	1000.00	3.0	3,023
19	Jute Mat Bank	LS	1000.00	2.2	2,240
Construction Sub-Total					1,063,549
101	Mobilization (as % of Construction Sub-Total)			1.5%	15,953
102	Taxes (as % of Construction Sub-Total)			0.0%	0
103	Incidentals not included in items above (as % of Construction Sub-Total)			5.0%	53,177
104	Contingency (as % of Construction Sub-Total)			5.0%	53,177
105	Permitting & Design (as % of Construction Sub-Total)			0.0%	0
106	Other (as % of Construction Sub-Total)			0.0%	0
Final Construction Cost					1,185,857

Reach 5

Project: Kootenai River Floodplain Reconnection

Analyst: J. J. Fealko

Project No: 9229-002-04

Latest Revision: 7/3/2009

- This spreadsheet calculates the costs for the items noted. Item # references the Item # on the Unit Cost sheet.
- The unit costs are based upon those listed & calculated on the Unit Cost sheet.
- Blue cells represent cells that require input.

Item #	Item Description	Units	Adjusted Unit Cost (\$)	No. of Units	Cost per Item (\$)
1	Groundwater Dewatering	LS	10000.00	1.0	10,000
2	Floodplain Excavation (short and long haul)	CY	5.25	64,811.6	340,261
3	Floodplain Grading	Acre	3060.00	7.4	22,562
4	Stream Excavation	CY	5.25	9,967.4	52,329
5	Stream Grading	Acre	7560.00	1.8	13,811
6	Boulders, cobbles, gravel placed in stream	CY	50.00	160.0	8,000
7	Large Woody Debris (acquisition, haul & installation)	Per Piece	600.00	55.0	33,000
8	Riprap	CY	47.04	0.0	0
9	Local Grading of Excavated Material	Acre	4437.00	0.0	0
10	Tidegate	Each	500.00	0.0	0
11	24" HDPE Corrugated Pipe (acquired, installed, drilled)	LF	367.20	0.0	0
12	Geogrid Crossing	LS	18386.00	1.0	18,386
13	BMP's (Jute mat, silt fence, staked hay bales)	LS	1250.00	1.0	1,250
14	Wetland and Riparian Planting	LS	1.00	26,872.8	26,873
15	Irrigation/Backwater Berms	EA	262.50	4.0	1,050
16	Diversion Structure	LS	41930.00	0.0	0
17	Fascine Bundle	LS	1000.00	0.0	0
18	Burrito Wrap	LS	1000.00	15.8	15,840
19	Jute Mat Bank	LS	1000.00	0.0	0
Construction Sub-Total					543,362
101	Mobilization (as % of Construction Sub-Total)			1.5%	8,150
102	Taxes (as % of Construction Sub-Total)			0.0%	0
103	Incidentals not included in items above (as % of Construction Sub-Total)			5.0%	27,168
104	Contingency (as % of Construction Sub-Total)			5.0%	27,168
105	Permitting & Design (as % of Construction Sub-Total)			0.0%	0
106	Other (as % of Construction Sub-Total)			0.0%	0
Final Construction Cost					605,849

Reach 6

Project: Kootenai River Floodplain Reconnection

Analyst: J. J. Fealko

Project No: 9229-002-04

Latest Revision: 7/3/2009

- This spreadsheet calculates the costs for the items noted. Item # references the Item # on the Unit Cost sheet.
- The unit costs are based upon those listed & calculated on the Unit Cost sheet.
- Blue cells represent cells that require input.

Item #	Item Description	Units	Adjusted Unit Cost (\$)	No. of Units	Cost per Item (\$)
1	Groundwater Dewatering	LS	10000.00	1.0	10,000
2	Floodplain Excavation (short and long haul)	CY	5.25	23,005.4	120,778
3	Floodplain Grading	Acre	3060.00	9.6	29,278
4	Stream Excavation	CY	5.25	10,667.6	56,005
5	Stream Grading	Acre	7560.00	2.3	17,629
6	Boulders, cobbles, gravel placed in stream	CY	50.00	3.0	150
7	Large Woody Debris (acquisition, haul & installation)	Per Piece	600.00	173.0	103,800
8	Riprap	CY	47.04	0.0	0
9	Local Grading of Excavated Material	Acre	4437.00	0.0	0
10	Tidegate	Each	500.00	0.0	0
11	24" HDPE Corrugated Pipe (acquired, installed, drilled)	LF	367.20	0.0	0
12	Geogrid Crossing	LS	18386.00	0.0	0
13	BMP's (Jute mat, silt fence, staked hay bales)	LS	1250.00	1.0	1,250
14	Wetland and Riparian Planting	LS	1.00	222,210.1	222,210
15	Irrigation/Backwater Berms	EA	262.50	3.0	788
16	Diversion Structure	LS	41930.00	0.0	0
17	Fascine Bundle	LS	1000.00	0.0	0
18	Burrito Wrap	LS	1000.00	8.6	8,641
19	Jute Mat Bank	LS	1000.00	1.6	1,635
Construction Sub-Total					572,165
101	Mobilization (as % of Construction Sub-Total)			1.5%	8,582
102	Taxes (as % of Construction Sub-Total)			0.0%	0
103	Incidentals not included in items above (as % of Construction Sub-Total)			5.0%	28,608
104	Contingency (as % of Construction Sub-Total)			5.0%	28,608
105	Permitting & Design (as % of Construction Sub-Total)			0.0%	0
106	Other (as % of Construction Sub-Total)			0.0%	0
Final Construction Cost					637,963

Reach 7

Project: Kootenai River Floodplain Reconnection

Analyst: J. J. Fealko

Project No: 9229-002-04

Latest Revision: 7/3/2009

- This spreadsheet calculates the costs for the items noted. Item # references the Item # on the Unit Cost sheet.
- The unit costs are based upon those listed & calculated on the Unit Cost sheet.
- Blue cells represent cells that require input.

Item #	Item Description	Units	Adjusted Unit Cost (\$)	No. of Units	Cost per Item (\$)
1	Groundwater Dewatering	LS	10000.00	0.0	0
2	Floodplain Excavation (short and long haul)	CY	5.25	2,471.3	12,975
3	Floodplain Grading	Acre	3060.00	3.0	9,086
4	Stream Excavation	CY	5.25	3,234.7	16,982
5	Stream Grading	Acre	7560.00	0.8	6,281
6	Boulders, cobbles, gravel placed in stream	CY	50.00	0.0	0
7	Large Woody Debris (acquisition, haul & installation)	Per Piece	600.00	55.0	33,000
8	Riprap	CY	47.04	0.0	0
9	Local Grading of Excavated Material	Acre	4437.00	0.0	0
10	Tidegate	Each	500.00	0.0	0
11	24" HDPE Corrugated Pipe (acquired, installed, drilled)	LF	367.20	0.0	0
12	Geogrid Crossing	LS	18386.00	0.0	0
13	BMP's (Jute mat, silt fence, staked hay bales)	LS	1250.00	1.0	1,250
14	Wetland and Riparian Planting	LS	1.00	76,414.3	76,414
15	Irrigation/Backwater Berms	EA	262.50	2.0	525
16	Diversion Structure	LS	41930.00	0.0	0
17	Fascine Bundle	LS	1000.00	2.1	2,115
18	Burrito Wrap	LS	1000.00	0.0	0
19	Jute Mat Bank	LS	1000.00	0.0	0
Construction Sub-Total					158,628
101	Mobilization (as % of Construction Sub-Total)			1.5%	2,379
102	Taxes (as % of Construction Sub-Total)			0.0%	0
103	Incidentals not included in items above (as % of Construction Sub-Total)			5.0%	7,931
104	Contingency (as % of Construction Sub-Total)			5.0%	7,931
105	Permitting & Design (as % of Construction Sub-Total)			0.0%	0
106	Other (as % of Construction Sub-Total)			0.0%	0
Final Construction Cost					176,870

Reach 8

Project: Kootenai River Floodplain Reconnection

Analyst: J. J. Fealko

Project No: 9229-002-04

Latest Revision: 7/3/2009

- This spreadsheet calculates the costs for the items noted. Item # references the Item # on the Unit Cost sheet.
- The unit costs are based upon those listed & calculated on the Unit Cost sheet.
- Blue cells represent cells that require input.

Item #	Item Description	Units	Adjusted Unit Cost (\$)	No. of Units	Cost per Item (\$)
1	Groundwater Dewatering	LS	10000.00	0.0	0
2	Floodplain Excavation (short and long haul)	CY	5.25	23,026.9	120,891
3	Floodplain Grading	Acre	3060.00	21.3	65,138
4	Stream Excavation	CY	5.25	5,912.1	31,039
5	Stream Grading	Acre	7560.00	2.8	21,267
6	Boulders, cobbles, gravel placed in stream	CY	50.00	6.0	300
7	Large Woody Debris (acquisition, haul & installation)	Per Piece	600.00	140.0	84,000
8	Riprap	CY	47.04	0.0	0
9	Local Grading of Excavated Material	Acre	4437.00	21.4	95,085
10	Tidegate	Each	500.00	0.0	0
11	24" HDPE Corrugated Pipe (acquired, installed, drilled)	LF	367.20	0.0	0
12	Geogrid Crossing	LS	18386.00	0.0	0
13	BMP's (Jute mat, silt fence, staked hay bales)	LS	1250.00	1.0	1,250
14	Wetland and Riparian Planting	LS	1.00	106,345.1	106,345
15	Irrigation/Backwater Berms	EA	262.50	4.0	1,050
16	Diversion Structure	LS	41930.00	0.0	0
17	Fascine Bundle	LS	1000.00	0.0	0
18	Burrito Wrap	LS	1000.00	0.0	0
19	Jute Mat Bank	LS	1000.00	0.0	0
Construction Sub-Total					526,365
101	Mobilization (as % of Construction Sub-Total)			1.5%	7,895
102	Taxes (as % of Construction Sub-Total)			0.0%	0
103	Incidentals not included in items above (as % of Construction Sub-Total)			5.0%	26,318
104	Contingency (as % of Construction Sub-Total)			5.0%	26,318
105	Permitting & Design (as % of Construction Sub-Total)			0.0%	0
106	Other (as % of Construction Sub-Total)			0.0%	0
Final Construction Cost					586,897

Reach 9

Project: Kootenai River Floodplain Reconnection

Analyst: J. J. Fealko

Project No: 9229-002-04

Latest Revision: 7/3/2009

- This spreadsheet calculates the costs for the items noted. Item # references the Item # on the Unit Cost sheet.
- The unit costs are based upon those listed & calculated on the Unit Cost sheet.
- Blue cells represent cells that require input.

Item #	Item Description	Units	Adjusted Unit Cost (\$)	No. of Units	Cost per Item (\$)
1	Groundwater Dewatering	LS	10000.00	0.0	0
2	Floodplain Excavation (short and long haul)	CY	5.25	1,085.1	5,697
3	Floodplain Grading	Acre	3060.00	0.6	1,740
4	Stream Excavation	CY	5.25	807.9	4,242
5	Stream Grading	Acre	7560.00	0.3	2,505
6	Boulders, cobbles, gravel placed in stream	CY	50.00	6.0	300
7	Large Woody Debris (acquisition, haul & installation)	Per Piece	600.00	23.0	13,800
8	Riprap	CY	47.04	0.0	0
9	Local Grading of Excavated Material	Acre	4437.00	6.5	28,841
10	Tidegate	Each	500.00	0.0	0
11	24" HDPE Corrugated Pipe (acquired, installed, drilled)	LF	367.20	0.0	0
12	Geogrid Crossing	LS	18386.00	0.0	0
13	BMP's (Jute mat, silt fence, staked hay bales)	LS	1250.00	1.0	1,250
14	Wetland and Riparian Planting	LS	1.00	18,489.1	18,489
15	Irrigation/Backwater Berms	EA	262.50	1.0	263
16	Diversion Structure	LS	41930.00	1.0	41,930
17	Fascine Bundle	LS	1000.00	0.0	0
18	Burrito Wrap	LS	1000.00	0.0	0
19	Jute Mat Bank	LS	1000.00	0.0	0
Construction Sub-Total					119,056
101	Mobilization (as % of Construction Sub-Total)			1.5%	1,786
102	Taxes (as % of Construction Sub-Total)			0.0%	0
103	Incidentals not included in items above (as % of Construction Sub-Total)			5.0%	5,953
104	Contingency (as % of Construction Sub-Total)			5.0%	5,953
105	Permitting & Design (as % of Construction Sub-Total)			0.0%	0
106	Other (as % of Construction Sub-Total)			0.0%	0
Final Construction Cost					132,747

APPENDIX C
STREAM RESTORATION CONSTRUCTION BID
DOCUMENTS

KOOTENAI RIVER FLOODPLAIN RECONNECTION

BALL CREEK STREAM RESTORATION CONSTRUCTION BID DOCUMENTS

SHEET	SHEET TITLE
1	COVER SHEET
2	GENERAL NOTES & LEGEND
3.1	HISTORIC CONDITIONS 1934 AERIAL PHOTO
3.2	DIGITAL ELEVATION MODEL (EXISTING CONDITIONS, 2005)
3.3	EXISTING SITE CONDITIONS
3.4	PROPOSED SITE CONDITIONS
4.1	EXISTING FLOODPLAIN MAP

SHEET	SHEET TITLE
4.2	PROPOSED BALL CREEK FLOODPLAIN MAP
5	SHEET INDEX
6.1 - 6.12	PROPOSED PLAN AND PROFILE
7.1 - 7.12	VEGETATION AND STRUCTURES
8.1 - 8.6	TYPICAL CROSS SECTIONS
9.1 - 9.9	TYPICAL HABITAT STRUCTURE DETAILS
10.1 - 10.4	MISCELLANEOUS DETAILS

SHEET	SHEET TITLE
11.1 - 11.2	TYPICAL PLANTING DETAILS AND CONFIGURATIONS
12.1	CONSTRUCTION SEQUENCING
12.2	CONSTRUCTION SEQUENCING NOTES
12.3	CONSTRUCTION QUANTITIES

Reference: Data for base drawing obtained from ESRI.

Revision No:	Date:	Description:	Initials:	Designed: JJF
		BID DOCUMENTS. NOT		Drawn: MGF/BMK
		FOR CONSTRUCTION		Checked: MKH
				Date: 07/08/09
				Project No: 9229-002-04

Kootenai River
Floodplain Reconnection
Boundary County, Idaho

Kootenai Tribe of Idaho

GEOENGINEERS
523 East Second Avenue
Spokane, WA 99202

Cover Sheet

Ball Creek Stream Restoration
Construction Bid Documents

Sheet
1

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GENERAL NOTES

- These designs and drawings have been prepared for the exclusive use of the Kootenai Tribe of Idaho, and their authorized agents. No other party may rely on the product of our services unless GeoEngineers Inc. (GeoEngineers) agrees in writing in advance of such use.
- These Ball Creek restoration plans represent an engineer-led (design/build) contract and are intended for construction bidding purposes. These plans are not intended for construction.
 - The drawings contained within should not be applied for any purpose or project except the one specified; specifically the habitat enhancements on Ball Creek within the Kootenai River floodplain.
 - These designs and drawings are copyrighted by GeoEngineers, Inc. Any use, alteration, deletion, or editing of this document without explicit written permission from GeoEngineers, Inc. is strictly prohibited. Any other unauthorized use of this document is prohibited.
 - The contractor shall construct the stream enhancement in accordance with the plans stamped "Approved for Construction." These plans will be provided to the contractor by the engineer or project inspector prior to construction. Work shall not be done without the current set of approved construction plans.
 - These plans are for construction bidding purposes only.
 - The enhancement designs depicted herein are approximate and are intended to express the overall design intent of the project. These designs will need to be adjusted in the field during construction in order to meet the specific site conditions and intended function. These stream improvements have been developed with the understanding that a qualified GeoEngineers engineer and/or scientist be on-site to provide construction guidance while the stream enhancements are constructed to ensure the overall intent of the design is met.
 - Geomorphic conditions can change and these designs are based on conditions that existed at the time the design was performed. The results of these designs may be affected by the passage of time, by manmade events such as construction on or adjacent to the site, or by natural events such as floods, earthquakes, slope instability or groundwater fluctuations. Always contact GeoEngineers before applying these designs to determine if they remain applicable.
 - All streams, rocks and woody habitat structures are potentially dangerous. This proposed stream enhancement design is intended to address a wide variety of constraints which target more naturally functioning stream systems and habitat; they are inherently dangerous. It is therefore strongly recommended that the Kootenai Tribe address the necessary safety concerns appropriately. Signs placed along the enhanced stream reaches in prominent locations to warn of the potential hazards should be considered a minimum.
 - The project is located in approximate Flood Zones A and B as identified on the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM) 1602070375B for Boundary County, Idaho (Community Number 160207), dated August 2, 1982. Changes to flood elevations and flood extents potentially resulting from the proposed enhancements have not been addressed by GeoEngineers as part of this project.
 - In general, the proposed enhancements are intended to result in more stable streambeds, banks and floodplains. However, channel erosion, channel migration and/or avulsions can be expected to occur over time. These channel processes are natural and appropriate for these stream systems.
 - Anchors, chains, cables, reinforcing bars, bolts and similar fasteners have purposely been excluded from the proposed woody habitat structures with the intent of mimicking naturally-occurring in-stream wood structures. While they are designed to be relatively stable during flood events, movement of these structures can be expected. It is recommended that the Kootenai Tribe implement appropriate monitoring and maintenance procedures to minimize potential adverse impacts at or near areas of concern, such as at low channel crossing. (Note, the lack of fasteners reduces the risk of large-scale rafts of trees floating downstream together and therefore minimizes potential blockages.)
 - These figures were originally produced in color.
 - Contour interval is 1-foot.
 - Refer to GeoEngineers accompanying stream enhancement design report for applicable design and construction limitations.
 - All elevations are based on NAVD88 datum.

LEGEND

	Proposed Minor Contour		Existing Ditch @ Elevation 1765 to Remain
	Proposed Major Contour		Fill Area
	Proposed Ball Creek Alignment		Proposed Streambed (Profile)
	Proposed Stream		Proposed Water Surface (Profile)
	Proposed Reach Limits		Proposed Bank (Profile)
	Bankfull Floodplain @ Kootenai River Elevation 1745		Ex. Ground Surface (Profile)
	100 Year Floodplain @ Kootenai River Elevation 1763		Upland/Transitional Vegetation
	Proposed Wetland		Riparian Floodplain Vegetation
	Roughened Channel and Floodplain		Wet Meadow Vegetation
	Fill Areas		Stream Bank Vegetation
	Kootenai River @ Elevation 1763		Existing Flood Zone A
	Existing Ditch to Remain		Existing Flood Zone B

REFERENCES

GENERAL CONSTRUCTION NOTES

- All contractors working within the project boundaries are responsible for compliance with all applicable safety laws. The contractor shall be responsible for all barricades, safety devices and control of traffic within and around the construction area.
- All material and workmanship furnished on or for the project must meet the minimum requirements of project permits, approving agencies, specifications as set forth herein, or whichever is more restrictive.
 - Contractor shall not work within any wetland area until the owner has obtained a 404 permit from the United States Army Corps of Engineers. All work within or adjacent to any wetland area shall comply with the conditions of the 404 permit.
 - Contractor shall obtain a short-term activity exemption from the Idaho Department of Environmental Quality prior to any dewatering activities.
 - The contractor shall install and maintain appropriate sediment control devices throughout the whole project site, including the construction staging area and stockpile area throughout the project's construction. Temporary construction and permanent erosion control measures shall be designed, constructed and maintained in accordance with all applicable local, state and federal regulations.
 - Record information shall be accurately recorded by the contractor and supplied to the owner for future use, reference and monitoring. Submittal of record information is a condition of final acceptance.

Revision No:	Date:	Description:	Initials:	Designed: JJF	Kootenai River Floodplain Reconnection Boundary County, Idaho Kootenai Tribe of Idaho	523 East Second Avenue Spokane, WA 99202	General Notes & Legend	Sheet 2
		BID DOCUMENTS. NOT		Drawn: MGF/BMK			Ball Creek Stream Restoration Construction Bid Documents	
		FOR CONSTRUCTION		Checked: MKH				
				Date: 07/08/09				
				Project No: 9229-002-04

Reference: 1934 aerial photo obtained from USFS.

Revision No:	Date:	Description:	Initials:	Designed: JJF	Kootenai River Floodplain Reconnection Boundary County, Idaho Kootenai Tribe of Idaho	523 East Second Avenue Spokane, WA 99202	Historic Conditions 1934 Aerial Photo	Sheet 3.1
		BID DOCUMENTS. NOT		Drawn: MGF/BMK				
		FOR CONSTRUCTION		Checked: MKH				
				Date: 07/08/09				
				Project No: 9229-002-04

Revision No:	Date:	Description:	Initials:	Designed: JJF	Kootenai River Floodplain Reconnection Boundary County, Idaho Kootenai Tribe of Idaho	GEOENGINEERS 523 East Second Avenue Spokane, WA 99202	Digital Elevation Model (Existing Condition, 2005) Ball Creek Stream Restoration Construction Bid Documents	Sheet 3.2
		BID DOCUMENTS. NOT		Drawn: MGF/BMK				
		FOR CONSTRUCTION		Checked: MKH				
				Date: 07/08/09				
				Project No: 9229-002-04				

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Revision No:	Date:	Description:	Initials:	Designed: JJF	Kootenai River Floodplain Reconnection Boundary County, Idaho Kootenai Tribe of Idaho	<div><div><div>GEOENGINEERS</div><div>523 East Second Avenue Spokane, WA 99202</div></div></div>	Existing Site Conditions	Sheet 3.3
		BID DOCUMENTS. NOT		Drawn: MGF/BMK			Ball Creek Stream Restoration Construction Bid Documents	
		FOR CONSTRUCTION		Checked: MKH				
				Date: 07/08/09				

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Revision No:	Date:	Description:	Initials:	Designed: JJF
		BID DOCUMENTS. NOT		Drawn: MGF/BMK
		FOR CONSTRUCTION		Checked: MKH
				Date: 07/08/09
				Project No: 9229-002-04

Kootenai River
Floodplain Reconnection
Boundary County, Idaho

Kootenai Tribe of Idaho

GEOENGINEERS
523 East Second Avenue
Spokane, WA 99202

Proposed Site Conditions

Ball Creek Stream Restoration
Construction Bid Documents

Sheet
3.4

NOTE:
FEMA DEFINES THE ASSOCIATED FLOODING ZONES ON THE PROPERTY BASED ON FIRM 1602070375B DATED AUGUST 2, 1982 FOR BOUNDARY COUNTY, IDAHO, COMMUNITY #160207 ARE AS FOLLOWS:
ZONE A – AREAS OF 100-YEAR FLOOD; BASE FLOOD ELEVATIONS AND FLOOD HAZARD FACTORS NOT DETERMINED.
ZONE B – AREAS BETWEEN LIMITS OF THE 100-YEAR FLOOD AND 500-YEAR FLOOD; OR CERTAIN AREAS SUBJECT TO 100-YEAR FLOODING WITH AVERAGE DEPTHS LESS THAN ONE (1) FOOT OR WHERE THE CONTRIBUTING DRAINAGE AREA IS LESS THAN ONE SQUARE MILE; OR AREAS PROTECTED BY LEVEES FROM THE BASE FLOOD.

Reference: 2005 Aerial photo obtained from Terra Remote Sensing, Inc.

Revision No:	Date:	Description:	Initials:	Designed: JJF	Kootenai River Floodplain Reconnection Boundary County, Idaho Kootenai Tribe of Idaho	<div>GEOENGINEERS</div> <div>523 East Second Avenue Spokane, WA 99202</div>	Existing Floodplain Map	Sheet 4.1
		BID DOCUMENTS. NOT		Drawn: MGF/BMK				
		FOR CONSTRUCTION		Checked: MKH				
				Date: 07/08/09			Ball Creek Stream Restoration Construction Bid Documents	
				Project No: 9229-002-04

NOTE:
FEMA DEFINES THE ASSOCIATED FLOODING ZONES ON THE PROPERTY BASED ON FIRM 1602070375B DATED AUGUST 2, 1982 FOR BOUNDARY COUNTY, IDAHO, COMMUNITY #160207 ARE AS FOLLOWS:
ZONE A – AREAS OF 100-YEAR FLOOD; BASE FLOOD ELEVATIONS AND FLOOD HAZARD FACTORS NOT DETERMINED.
ZONE B – AREAS BETWEEN LIMITS OF THE 100-YEAR FLOOD AND 500-YEAR FLOOD; OR CERTAIN AREAS SUBJECT TO 100-YEAR FLOODING WITH AVERAGE DEPTHS LESS THAN ONE (1) FOOT OR WHERE THE CONTRIBUTING DRAINAGE AREA IS LESS THAN ONE SQUARE MILE; OR AREAS PROTECTED BY LEVEES FROM THE BASE FLOOD.
Reference: 2005 Aerial photo obtained from Terra Remote Sensing, Inc.

Revision No:	Date:	Description:	Initials:	Designed: JJF	Kootenai River Floodplain Reconnection Boundary County, Idaho Kootenai Tribe of Idaho	GEOENGINEERS <i>523 East Second Avenue Spokane, WA 99202</i>	Proposed Ball Creek Floodplain Map Ball Creek Stream Restoration Construction Bid Documents	Sheet 4.2
		BID DOCUMENTS. NOT		Drawn: MGF/BMK				
		FOR CONSTRUCTION		Checked: MKH				
				Date: 07/08/09				
				Project No: 9229-002-04

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Reference: 2005 Aerial photo obtained from Terra Remote Sensing, Inc.

Revision No:	Date:	Description:	Initials:	Designed: JJF	Kootenai River Floodplain Reconnection Boundary County, Idaho Kootenai Tribe of Idaho	<div>GEOENGINEERS</div> <div>523 East Second Avenue Spokane, WA 99202</div>	Plan View Sheet and Reach Index	Sheet 5
		BID DOCUMENTS. NOT		Drawn: MGF/BMK				
		FOR CONSTRUCTION		Checked: MKH				
				Date: 07/08/09				
				Project No: 9229-002-04			Ball Creek Stream Restoration Construction Bid Documents

Revision No:				Date:	Description:	Initials:	Designed: JJF	Kootenai River Floodplain Reconnection Boundary County, Idaho Kootenai Tribe of Idaho	GEOENGINEERS 523 East Second Avenue Spokane, WA 99202	Proposed Plan and Profile Sta. 25+00 to 40+00 Ball Creek Stream Restoration Construction Bid Documents	Sheet 6.2
					BID DOCUMENTS. NOT		Drawn: MGF/BMK				
					FOR CONSTRUCTION		Checked: MKH				
							Date: 07/08/09				
							Project No: 9229-002-04

Reference: 2005 Aerial photo obtained from Terra Remote Sensing, Inc.

Revision No:				Date:	Description:	Initials:	Designed: JJF	Kootenai River Floodplain Reconnection Boundary County, Idaho Kootenai Tribe of Idaho	GEOENGINEERS 523 East Second Avenue Spokane, WA 99202	Proposed Plan and Profile Sta. 40+00 to 55+00 Ball Creek Stream Restoration Construction Bid Documents	Sheet 6.3
					BID DOCUMENTS. NOT		Drawn: MGF/BMK				
					FOR CONSTRUCTION		Checked: MKH				
							Date: 07/08/09				
							Project No: 9229-002-04				

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PROFESSIONAL ENGINEER
REGISTERED
8238
07/08/09
STATE OF IDAHO
MICHAEL K. HOMZA

Revision No:	Date:	Description:	Initials:	Designed: JJF	Kootenai River Floodplain Reconnection Boundary County, Idaho Kootenai Tribe of Idaho	GEOENGINEERS 523 East Second Avenue Spokane, WA 99202	Proposed Plan and Profile Sta. 55+00 to 70+00 Ball Creek Stream Restoration Construction Bid Documents	Sheet 6.4
		BID DOCUMENTS. NOT		Drawn: MGF/BMK				
		FOR CONSTRUCTION		Checked: MKH				
				Date: 07/08/09				
				Project No: 9229-002-04

Revision No:	Date:	Description:	Initials:	Designed: JJF	Kootenai River Floodplain Reconnection Boundary County, Idaho	523 East Second Avenue Spokane, WA 99202	Proposed Plan and Profile Sta. 70+00 to 85+00	Sheet 6.5	
		BID DOCUMENTS. NOT		Drawn: MGF/BMK			Kootenai Tribe of Idaho		Ball Creek Stream Restoration Construction Bid Documents
		FOR CONSTRUCTION		Checked: MKH					
				Date: 07/08/09					
				Project No: 9229-002-04

Revision No:				Date:	Description:	Initials:	Designed: JJF	Kootenai River Floodplain Reconnection Boundary County, Idaho Kootenai Tribe of Idaho	GEOENGINEERS 523 East Second Avenue Spokane, WA 99202	Proposed Plan and Profile Sta. 85+00 to 100+00 Ball Creek Stream Restoration Construction Bid Documents	Sheet 6.6
					BID DOCUMENTS. NOT		Drawn: MGF/BMK				
					FOR CONSTRUCTION		Checked: MKH				
							Date: 07/08/09				
							Project No: 9229-002-04				

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Revision No:	Date:	Description:	Initials:	Designed: JJF	Kootenai River Floodplain Reconnection Boundary County, Idaho Kootenai Tribe of Idaho	GEOENGINEERS 523 East Second Avenue Spokane, WA 99202	Proposed Plan and Profile Sta. 100+00 to 115+00 Ball Creek Stream Restoration Construction Bid Documents	Sheet 6.7
		BID DOCUMENTS. NOT		Drawn: MGF/BMK				
		FOR CONSTRUCTION		Checked: MKH				
				Date: 07/08/09				
				Project No: 9229-002-04				

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Revision No:	Date:	Description:	Initials:	Designed: JJF	Kootenai River Floodplain Reconnection Boundary County, Idaho Kootenai Tribe of Idaho	GEOENGINEERS 523 East Second Avenue Spokane, WA 99202	Proposed Plan and Profile Sta. 115+00 to 130+00 Ball Creek Stream Restoration Construction Bid Documents	Sheet 6.8
		BID DOCUMENTS. NOT		Drawn: MGF/BMK				
		FOR CONSTRUCTION		Checked: MKH				
				Date: 07/08/09				
				Project No: 9229-002-04				

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Revision No:	Date:	Description:	Initials:	Designed: JJF	Kootenai River Floodplain Reconnection Boundary County, Idaho Kootenai Tribe of Idaho	GEOENGINEERS 523 East Second Avenue Spokane, WA 99202	Proposed Plan and Profile Sta. 130+00 to 145+00 Ball Creek Stream Restoration Construction Bid Documents	Sheet 6.9
		BID DOCUMENTS. NOT		Drawn: MGF/BMK				
		FOR CONSTRUCTION		Checked: MKH				
				Date: 07/08/09				
				Project No: 9229-002-04				

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Revision No:	Date:	Description:	Initials:	Designed: JJF	Kootenai River Floodplain Reconnection Boundary County, Idaho Kootenai Tribe of Idaho	GEOENGINEERS 523 East Second Avenue Spokane, WA 99202	Proposed Plan and Profile Sta. 145+00 to 160+00 Ball Creek Stream Restoration Construction Bid Documents	Sheet 6.10
		BID DOCUMENTS. NOT		Drawn: MGF/BMK				
		FOR CONSTRUCTION		Checked: MKH				
				Date: 07/08/09				
				Project No: 9229-002-04

Reference: 2005 Aerial photo obtained from Terra Remote Sensing, Inc.

PROFESSIONAL ENGINEER
REGISTERED
8238
07/08/09
STATE OF IDAHO
MICHAEL K. HOMZA

Revision No:	Date:	Description:	Initials:	Designed: JJF	Kootenai River Floodplain Reconnection Boundary County, Idaho Kootenai Tribe of Idaho	GEOENGINEERS 523 East Second Avenue Spokane, WA 99202	Proposed Plan and Profile Sta. 160+00 to 175+00 Ball Creek Stream Restoration Construction Bid Documents	Sheet 6.11
		BID DOCUMENTS. NOT		Drawn: MGF/BMK				
		FOR CONSTRUCTION		Checked: MKH				
				Date: 07/08/09				
				Project No: 9229-002-04

Revision No:	Date:	Description:	Initials:	Designed: JJF
		BID DOCUMENTS. NOT		Drawn: MGF/BMK
		FOR CONSTRUCTION		Checked: MKH
				Date: 07/08/09
				Project No: 9229-002-04

Kootenai River
Floodplain Reconnection
Boundary County, Idaho

Kootenai Tribe of Idaho

GEOENGINEERS
523 East Second Avenue
Spokane, WA 99202

**Proposed Plan and Profile
Sta. 175+00 to 190+00**
Ball Creek Stream Restoration
Construction Bid Documents

Sheet
6.12

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HABITAT STRUCTURES LEGEND:

RW

- ROOT WAD

SW

- SWEEPER

MJ

- MEANDER JAM

TW

- TURNING WAD

FB

- FASCINE BUNDLE

JM

- JUTE MAT

AJ

- APEX JAM

ST

- STEP TURN

BS

- BURIED SNAG

WD

- WOODY DEBRIS

BC

- BOULDER CLUSTER

RC

- ROUGHENED CHANNEL

BW

- BURRITO WRAP

AS

- ANGLED LOG SILL

AB

- ANGLED BARB

NOTE:
1. IDENTIFY AREAS WHERE GRAVEL IS EXPOSED IN NEW CHANNEL AND ENCOURAGE EROSION THERE FOR GRAVEL RECRUITMENT. (LESS OR NO BANK ARMORING)
2. BANK VEGETATION ZONE IS NOT SHOWN, BUT IS 10 FEET ON EITHER SIDE OF THE BANK.

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HABITAT STRUCTURES LEGEND:

(RW)		- ROOT WAD	(ST)		- STEP TURN
(SW)		- SWEEPER	(BS)		- BURIED SNAG
(MJ)		- MEANDER JAM	(WD)		- WOODY DEBRIS
(TW)		- TURNING WAD	(BC)		- BOULDER CLUSTER
(FB)		- FASCINE BUNDLE	(RC)		- ROUGHENED CHANNEL
(JM)		- JUTE MAT	(BW)		- BURRITO WRAP
(AJ)		- APEX JAM	(AS)		- ANGLED LOG SILL
			(AB)		- ANGLED BARB

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Revision No:	Date:	Description:	Initials:	Designed: JJF
		BID DOCUMENTS. NOT		Drawn: MGF/BMK
		FOR CONSTRUCTION		Checked: MKH
				Date: 07/08/09
				Project No: 9229-002-04

Kootenai River
Floodplain Reconnection
Boundary County, Idaho

Kootenai Tribe of Idaho

GEOENGINEERS
523 East Second Avenue
Spokane, WA 99202

Vegetation and Structures
Sta 25+00 to 40+00
Ball Creek Stream Restoration
Construction Bid Documents

Sheet
7.2

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Revision No:	Date:	Description:	Initials:	Designed: JJF
		BID DOCUMENTS. NOT		Drawn: MGF/BMK
		FOR CONSTRUCTION		Checked: MKH
				Date: 07/08/09
				Project No: 9229-002-04

Kootenai River
Floodplain Reconnection
Boundary County, Idaho

Kootenai Tribe of Idaho

GEOENGINEERS
523 East Second Avenue
Spokane, WA 99202

Vegetation and Structures
Sta 40+00 to 55+00
Ball Creek Stream Restoration
Construction Bid Documents

Sheet
7.3

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HABITAT STRUCTURES LEGEND:

RW

- ROOT WAD

SW

- SWEEPER

MJ

- MEANDER JAM

TW

- TURNING WAD

FB

- FASCINE BUNDLE

JM

- JUTE MAT

AJ

- APEX JAM

ST

- STEP TURN

BS

- BURIED SNAG

WD

- WOODY DEBRIS

BC

- BOULDER CLUSTER

RC

- ROUGHENED CHANNEL

BW

- BURRITO WRAP

AS

- ANGLED LOG SILL

AB

- ANGLED BARB

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Reference: 2005 Aerial photo obtained from Terra Remote Sensing, Inc.

AB

ANGLED BARB

LETTER SIDE TO THE BANK.

Revision No:	Date:	Description:	Initials:	Designed: JJF
		BID DOCUMENTS. NOT		Drawn: MGF/BMK
		FOR CONSTRUCTION		Checked: MKH
				Date: 07/08/09
				Project No: 9229-002-04

Kootenai River Floodplain Reconnection Boundary County, Idaho
Kootenai Tribe of Idaho

GEOENGINEERS 523 East Second Avenue Spokane, WA 99202
--

Vegetation and Structures Sta 55+00 to 70+00
Ball Creek Stream Restoration Construction Bid Documents

Sheet 7.4

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HABITAT STRUCTURES LEGEND:

(RW)		- ROOT WAD	(ST)		- STEP TURN
(SW)		- SWEEPER	(BS)		- BURIED SNAG
(MJ)		- MEANDER JAM	(WD)		- WOODY DEBRIS
(TW)		- TURNING WAD	(BC)		- BOULDER CLUSTER
(FB)		- FASCINE BUNDLE	(RC)		- ROUGHENED CHANNEL
(JM)		- JUTE MAT	(BW)		- BURRITO WRAP
(AJ)		- APEX JAM	(AS)		- ANGLED LOG SILL
			(AB)		- ANGLED BARB

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PROFESSIONAL ENGINEER
REGISTERED
8238
07/08/09
STATE OF IDAHO
MICHAEL K. HOMZA

Revision No:	Date:	Description:	Initials:	Designed: JJF
		BID DOCUMENTS. NOT		Drawn: MGF/BMK
		FOR CONSTRUCTION		Checked: MKH
				Date: 07/08/09
				Project No: 9229-002-04

Kootenai River Floodplain Reconnection Boundary County, Idaho Kootenai Tribe of Idaho	GEOENGINEERS 523 East Second Avenue Spokane, WA 99202	Vegetation and Structures Sta 70+00 to 85+00	Sheet 7.5
		Ball Creek Stream Restoration Construction Bid Documents	

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HABITAT STRUCTURES LEGEND:

(RW)		- ROOT WAD	(ST)		- STEP TURN
(SW)		- SWEEPER	(BS)		- BURIED SNAG
(JM)		- MEANDER JAM	(WD)		- WOODY DEBRIS
(TW)		- TURNING WAD	(BC)		- BOULDER CLUSTER
(FB)		- FASCINE BUNDLE	(RC)		- ROUGHENED CHANNEL
(JM)		- JUTE MAT	(BW)		- BURRITO WRAP
(AJ)		- APEX JAM	(AS)		- ANGLED LOG SILL
			(AB)		- ANGLED BARB

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		FOR CONSTRUCTION		Checked: MKH
				Date: 07/08/09
				Project No: 9229-002-04

Kootenai River
Floodplain Reconnection
Boundary County, Idaho

Kootenai Tribe of Idaho

GEOENGINEERS
523 East Second Avenue
Spokane, WA 99202

Vegetation and Structures
Sta 85+00 to 100+00
Ball Creek Stream Restoration
Construction Bid Documents

Sheet
7.6

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HABITAT STRUCTURES LEGEND:

RW

- ROOT WAD

SW

- SWEEPER

MJ

- MEANDER JAM

TW

- TURNING WAD

FB

- FASCINE BUNDLE

JM

- JUTE MAT

AJ

- APEX JAM

ST

- STEP TURN

BS

- BURIED SNAG

WD

- WOODY DEBRIS

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RC

- ROUGHENED CHANNEL

BW

- BURRITO WRAP

AS

- ANGLED LOG SILL

AB

- ANGLED BARB

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		BID DOCUMENTS. NOT		Drawn: MGF/BMK
		FOR CONSTRUCTION		Checked: MKH
				Date: 07/08/09
				Project No: 9229-002-04

Kootenai River
Floodplain Reconnection
Boundary County, Idaho

Kootenai Tribe of Idaho

GEOENGINEERS

523 East Second Avenue

Spokane, WA 99202

Vegetation and Structures
Sta 100+00 to 115+00
Ball Creek Stream Restoration
Construction Bid Documents

Sheet
7.7

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HABITAT STRUCTURES LEGEND:

(RW)		- ROOT WAD	(ST)		- STEP TURN
(SW)		- SWEEPER	(BS)		- BURIED SNAG
(MJ)		- MEANDER JAM	(WD)		- WOODY DEBRIS
(TW)		- TURNING WAD	(BC)		- BOULDER CLUSTER
(FB)		- FASCINE BUNDLE	(RC)		- ROUGHENED CHANNEL
(JM)		- JUTE MAT	(BW)		- BURRITO WRAP
(AJ)		- APEX JAM	(AS)		- ANGLED LOG SILL
			(AB)		- ANGLED BARB

Reference: 2005 Aerial photo obtained from Terra Remote Sensing, Inc.

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		FOR CONSTRUCTION		Checked: MKH
				Date: 07/08/09
				Project No: 9229-002-04

Kootenai River
Floodplain Reconnection
Boundary County, Idaho

Kootenai Tribe of Idaho

GEOENGINEERS
523 East Second Avenue
Spokane, WA 99202

Vegetation and Structures
Sta 115+00 to 130+00
Ball Creek Stream Restoration
Construction Bid Documents

Sheet
7.8

HABITAT STRUCTURES LEGEND:					
(RW)		- ROOT WAD	(ST)		- STEP TURN
(SW)		- SWEEPER	(BS)		- BURIED SNAG
(MJ)		- MEANDER JAM	(WD)		- WOODY DEBRIS
(TW)		- TURNING WAD	(BC)		- BOULDER CLUSTER
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(JM)		- JUTE MAT	(BW)		- BURRITO WRAP
(AJ)		- APEX JAM	(AS)		- ANGLED LOG SILL
			(AB)		- ANGLED BARB

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PROFESSIONAL ENGINEER
REGISTERED
8238
07/08/09
STATE OF IDAHO
MICHAEL K. HOMZA

HABITAT STRUCTURES LEGEND:

(RW)		- ROOT WAD	(ST)		- STEP TURN
(SW)		- SWEEPER	(BS)		- BURIED SNAG
(MJ)		- MEANDER JAM	(WD)		- WOODY DEBRIS
(TW)		- TURNING WAD	(BC)		- BOULDER CLUSTER
(FB)		- FASCINE BUNDLE	(RC)		- ROUGHENED CHANNEL
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		BID DOCUMENTS. NOT		Drawn: MGF/BMK
		FOR CONSTRUCTION		Checked: MKH
				Date: 07/08/09
				Project No: 9229-002-04

Kootenai River
Floodplain Reconnection
Boundary County, Idaho

Kootenai Tribe of Idaho

GEOENGINEERS
523 East Second Avenue
Spokane, WA 99202

Vegetation and Structures
Sta 145+00 to 160+00
Ball Creek Stream Restoration
Construction Bid Documents

Sheet
7.10

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HABITAT STRUCTURES LEGEND:

(RW)		- ROOT WAD	(ST)		- STEP TURN
(SW)		- SWEEPER	(BS)		- BURIED SNAG
(MJ)		- MEANDER JAM	(WD)		- WOODY DEBRIS
(TW)		- TURNING WAD	(BC)		- BOULDER CLUSTER
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		BID DOCUMENTS. NOT		Drawn: MGF/BMK
		FOR CONSTRUCTION		Checked: MKH
				Date: 07/08/09
				Project No: 9229-002-04

Kootenai River
Floodplain Reconnection
Boundary County, Idaho

Kootenai Tribe of Idaho

GEOENGINEERS
523 East Second Avenue
Spokane, WA 99202

Vegetation and Structures
Sta 160+00 to 175+00
Ball Creek Stream Restoration
Construction Bid Documents

Sheet
7.11

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HABITAT STRUCTURES LEGEND:					
(RW)		- ROOT WAD	(ST)		- STEP TURN
(SW)		- SWEEPER	(BS)		- BURIED SNAG
(MJ)		- MEANDER JAM	(WD)		- WOODY DEBRIS
(TW)		- TURNING WAD	(BC)		- BOULDER CLUSTER
(FB)		- FASCINE BUNDLE	(RC)		- ROUGHENED CHANNEL
(JM)		- JUTE MAT	(BW)		- BURRITO WRAP
(AJ)		- APEX JAM	(AS)		- ANGLED LOG SILL
			(AB)		- ANGLED BARB

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Revision No:	Date:	Description:	Initials:	Designed: JJF	Kootenai River Floodplain Reconnection Boundary County, Idaho Kootenai Tribe of Idaho	GEOENGINEERS 523 East Second Avenue Spokane, WA 99202	Vegetation and Structures Sta 175+00 to 181+50 Ball Creek Stream Restoration Construction Bid Documents	Sheet 7.12	
		BID DOCUMENTS. NOT		Drawn: MGF/BMK					
		FOR CONSTRUCTION		Checked: MKH					
				Date: 07/08/09					
				Project No: 9229-002-04					

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Stream Geometry Summary Table																			
Reach 1	Reach 2		Reach 3		Reach 4		Reach 5		Reach 6		Reach 7		Reach 8 (Main)		Reach 8 (Side)		Reach 9		Stream Geometry/Parameters
Grade to Drain Toward Kootenai River	C4		E5		E5		C5c		E5		C4		D4		D4		C3		= Rosgen Stream Type
	1.01		1.62		1.85		1.23		1.72		1.22		1.03		1.03		1.01		= Sinuosity
	20		9		8		10		8		10		15		15		20		= Width / Depth Ratio
	2.3		18		12		6		23		5		17		28		3.3		= Minimum Entrenchment Ratio
	0.0101		0.0006		0.0006		0.0006		0.00030		0.0037		0.0052		0.0052		0.0152		= Average Valley Gradient (ft/ft)
	0.0100		0.0004		0.0003		0.0005		0.00017		0.0030		0.0050		0.0050		0.0150		= Average Creek Gradient (ft/ft)
	691		1,733		1,890		1,622		2,067		981		1,893		1,893		383		= Valley Length (ft)
	700		2,800		3,500		2,000		3,550		1,200		1,950		1,950		387		= Creek Length (ft)
	323		323		126		323		30		323		206		59		323		= Bankfull Discharge (cfs)
	2,364		2,364		2,364		2,364		2,364		2,364		2,364		2,364		2,364		= 100-Year Flood Discharge (cfs)
	5.7		2.1		1.7		2.4		0.4		4.4		4.5		3.3		6.4		= Average Bankfull Velocity (fps)
	35.50		40.40		26.40		39.80		26.20		30.20		28.00		17.40		33.60		= W_{BF} = Bankfull Width (ft)
	1.80		4.50		3.30		4.00		3.30		3.00		1.90		1.20		1.70		= D_{BF} = Bankfull Depth (At Riffle) (ft)
	4.40		9.00		8.20		9.90		8.20		7.50		4.70		3.00		4.20		= D_p = Pool Depth at Bankfull Flow (ft) (Ranges from $2.0D_{BF}$ to $3.5D_{BF}$)
	2		1.5		1.25		1.5		1.25		2		2		2		2		= Z_1 = Channel Sideslope (Horizontal Ratio)
	3		2.5		2.5		2.5		2.5		3		3		3		3		= Z_2 = Channel Sideslope on Inside of Bend, Approximate (Horizontal Ratio)
	8.7		0.20		0.70		0.70		0.08		0.09		2.4		2.4		17.7		= D_{10} = Riffle Substrate Size (in) (16% of material this size or smaller)
	17.3		0.40		1.30		1.50		0.16		0.19		4.7		4.7		35.4		= D_{50} = Riffle Substrate Size (in) (50% of material this size or smaller)
	22.5		0.60		1.70		1.90		0.21		0.25		6.1		6.1		46.1		= D_{84} = Riffle Substrate Size (in) (84% of material this size or smaller)
	27.7		0.70		2.10		2.40		0.26		0.30		7.6		7.6		56.7		= D_{100} = Riffle Substrate Size (in) (100% of material this size or smaller)
	27.7		3.0		3.0		3.0		3.0		3.0		7.6		7.6		56.7		= T = Minimum Substrate Layer thickness (in)
	289	354	409	1262	252	791	402	1052	252	784	295	691	253	332	137	162	270	333	= WL = Range of Acceptable Meander Wavelengths (ft)
	205	239	277	841	171	527	272	702	171	523	200	461	181	222	98	108	189	225	= BL = Range of Bend Length (ft)
	191	201	233	783	144	490	229	653	144	486	168	428	154	206	91	101	176	189	= FP = Range of Acceptable Minimum Floodplain Widths (ft)
	55	71	82	225	51	141	80	188	50	140	59	123	49	59	27	32	51	67	= R = Range of Acceptable Radii of Curvature (ft)
	106	177	121	631	79	395	119	526	79	392	90	345	84	166	52	87	101	168	= P/P = Range of Acceptable Pool To Pool Spacing (ft)

- NOTES:
1. STREAM AND FLOODPLAIN SHALL BE CONSTRUCTED TO MEET THESE GEOMETRIES.
 2. CONSTRUCT FLOODPLAIN FIRST. MAKE FLOODPLAIN LEVEL FROM SIDE TO SIDE. EXCAVATE BANKFULL CHANNEL SECOND. PLACE SOIL FROM CHANNEL ON FLOODPLAIN. GRADE FLOODPLAIN TO CREEK AT 20H:1V SLOPE. GRADE TO APPEAR NATURAL. GRADE FLOODPLAIN WITH GENTLE HIGH AND LOW SPOTS.
 3. PLANT STREAMBANKS AND FLOODPLAINS AS SPECIFIED IN PLANTING PLAN (BY OTHERS).
 4. ADD TREES, WOOD HABITAT STRUCTURES TO CREEK TO INCREASE CHANNEL ROUGHNESS.

Revision No:	Date:	Description:	Initials:	Designed: JJF
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		FOR CONSTRUCTION		Checked: MKH
				Date: 07/08/09
				Project No: 9229-002-04

Kootenai River
Floodplain Reconnection
Boundary County, Idaho

Kootenai Tribe of Idaho

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Stream and Floodplain Geometry

Ball Creek Stream Restoration
Construction Bid Documents

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Kootenai River
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Typical Cross Sections
Ball Creek Stream Restoration
Construction Bid Documents

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		BID DOCUMENTS. NOT		Drawn: MGF/BMK			Ball Creek Stream Restoration Construction Bid Documents	
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Kootenai River
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Typical Cross Sections
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Kootenai River
Floodplain Reconnection
Boundary County, Idaho

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Proposed Cross Sections

Ball Creek Stream Restoration
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				Drawn: MWJ				
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(MJ) TYPICAL MEANDER JAM DETAIL PLAN
NOT TO SCALE

(A-A') TYPICAL MEANDER JAM DETAIL SECTION A-A'
NOT TO SCALE

NOTES:

Purpose:

- Limit channel migration, protect banks, restore aquatic and riparian habitat.
- Enhances fish habitat: creates large bankside pools for fish holding and sediment sorting.

Design Specifics:

- Top of rootwad (roots) should not extend more than ½-ft above top of bank.
- Place along outsides of channel bends.
- Relatively large "Key Members" secured into banks with backfill (and/or anchors).
- Smaller "Racked Members" wedged between Key Members.
- Jam designed to collect more debris over time.
- Backfill with Stream Substrate & plant dense vegetation on top to bank.
- Install vegetation among armoring and root wads while installing root wads.
- Irrigate vegetation as required.

(RW) TYPICAL ROOT WAD DETAIL PLAN
NOT TO SCALE

(B-B') TYPICAL ROOT WAD DETAIL SECTION B-B'
NOT TO SCALE

NOTES:

Purpose:

- Increases pool depth.
- Inhibits lateral migration.
- Prevents bank erosion.

Design Specifics:

- Orient root wads so the creek's flow attacks them "head on" as much as possible. Anchors should be oriented towards flow.
- Top of rootwad (roots) should not extend more than ½-ft above top of bank.
- Place root wads along outside of bends.
- Install vegetation among armoring and root wads while installing root wads.
- Irrigate vegetation as required.
- Rootwad diameter = Pool Depth. If greater than depth, bury deeper.

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Kootenai River
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Typical Habitat Structure Details

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SW TYPICAL SWEEPER DETAIL PLAN
NOT TO SCALE

A-A' TYPICAL SWEEPER DETAIL SECTION A-A'
NOT TO SCALE

NOTES:

Purpose:

- Redirects flow.
- Creates scour holes.
- Encourages gravel deposition.

Design Specifics:

- Bury at least 2/3 of the tree length and root wad or secure "dry" end of log with anchors.
- Place sweeper at upstream end of bend.
- Trees with branches or multiple trunks preferred.

TW TYPICAL TURNING WAD DETAIL PLAN
NOT TO SCALE

B-B' TYPICAL TURNING WAD DETAIL SECTION A-A'
NOT TO SCALE

NOTES:

Purpose:

- Redirects flow.
- Creates scour holes.
- Creates diverse fish habitat.

Design Specifics:

- Place turning wad at upstream end of bend.
- Place root wad on/in bank.
- Tree should not block more than 50% of channel cross sectional area (at base flow).
- Tree may be installed at, near or below low pool elevation.
- Slope tree into creek.
- Tree may also be placed in channel bed to create a plunge pool downstream.
- Place trees, branches, gravel and cobbles on upstream of tree to prevent water from flowing beneath log.
- Use only on smaller streams or side channels.

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BS TYPICAL BURIED SNAG DETAIL PLAN
NOT TO SCALE

A-A' TYPICAL BURIED SNAG DETAIL SECTION A-A'
NOT TO SCALE

NOTES:

Purpose:

- Slows creek velocity.
- Creates diverse fish habitat.
- Encourages sediment sorting.

Design Specifics:

- Tree length (L) and diameter at breast height (DBH) may vary (smaller snags are acceptable).
- Place/locate snag as shown on plans and/or as directed in field.
- Snags may be parallel or angled to flow.
- Trees with branches and/or multiple trunks preferred.
- Root wads may be placed on top of channel bed if anchored.

ST TYPICAL STEP TURN DETAIL PLAN
NOT TO SCALE

NOTES:

Purpose:

- Redirects flow.
- Creates scour holes.
- Appropriate in steeper reaches.

Design Specifics:

- Step 1 is a plunge pool.
- Step 1 is lower than step 2 (6" max).
- Step 2 is lower than step 3 (6" max).
- Notch intersection of trees and secure with chain (if necessary).
- Exposed portion of tree = $\frac{1}{4} L$ (L = tree length).
- Secure trees with anchors, (3 min).
- $L = 3 \times WBF$ (min).
- Backfill upstream portions of structure (steps 2 and 3) with larger rock, small trees and branches to prevent flow under trees.
- Maximum total step height = 12"
- Bury upstream portion of trees deeper into channel bed (downward sloping in upstream direction).
- Place turning step at upstream end of pool/bend.
- Use only in small streams or side channels.

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BC **TYPICAL BOULDER CLUSTER DETAIL PLAN**
NOT TO SCALE

- NOTES:**
- Purpose:**
- Enhances fish habitat: creates large mid-stream pools, fish holding in eddies and sorts sediment.
 - Directs flow for full range of flow.
- Design Specifics:**
- Generally large, stream-wide structure with center coincident with channel centerline or thalweg.
 - Place largest boulders closest to banks. Boulders decrease in size towards channel center. Or use same size boulders & bury center boulders deeper.
 - Decreasing boulder size causes structures to slope downwards towards center.
 - “Upstream Vee” configuration directs water to center of channel.
- Key largest Boulders into bank so they do not overtop or become “out-flanked” during flood flows.
 - Plant dense vegetation along banks.
 - Reinforce channel bed with footer boulders and cobbles to prevent scour at/below boulders.
 - Place structure upstream of bends or upstream of desired stream-wide pools locations.
- Variations:**
- Large woody debris may be wedged between boulders. (Jam rootwads between boulders with tree bole hanging downstream as a sweeper for added fish habitat.)
 - “Single Vane” structures may be used to direct water away from bank.
 - Relatively large but stable cobbles may be used in lieu of boulders in smaller, cobble dominated streams.

JH **TYPICAL J-HOOK DETAIL PLAN**
NOT TO SCALE

- NOTES:**
- Purpose:**
- Enhances fish habitat: creates localized pools, fish holding in eddies and sorts sediment.
 - Protects outsides of banks by directing flow away from bank.
- Design Specifics:**
- Placed on banks and in channel along “outside” of bends. Apex Boulder extends into thalweg.
 - All boulders may be same size. Place largest boulders towards bank if size varies.
 - Slope J-Hook downwards towards Apex Boulder.
 - “Upstream Vee” configuration directs water towards Apex Boulder and into center channel.
 - Apex Boulder overtops during low flows. Bank boulders do not overtop significantly during floods.
 - Plant dense vegetation along banks.
- Variations:**
- Reinforce channel bed with Footer Boulders and cobbles to prevent scour at/below boulders.
 - May be used for flow redirection and/or bank protection without “Hook Boulders” if thalweg is too far from bank to be practical.
 - Large woody debris may be wedged between Top Boulders along bank. (Jam rootwads between boulders with tree bole hanging downstream as a sweeper for added fish habitat.)
 - Relatively large but stable cobbles may be used in lieu of boulders in smaller, cobble dominated streams.

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BUNDLE
NOT TO SCALE

FB TYPICAL FASCINE BUNDLE DETAIL
NOT TO SCALE

NOTES:

Purpose:

- Bank stabilization.
- Provides habitat and cover.

Design Specifics:

- Harvest live willow or dogwood cuttings during the dormant season, late fall to early spring. Install fascines immediately after preparation and coir fabric installation.
- Excavate trenches for fascines beginning with the base of the slope.
- Install coir fabric uniformly from the base of the lowest trench to the base of the uppermost trench. Overlap coir mats by at least 5 feet, with the upstream mat laying over the downstream mat.
- Anchor fascines and coir fabric in place by driving dead stakes at the base of the fascines and live stakes through the center of the fascines. Live stakes are also to be driven through the coir fabric in between fascine bundle rows.
- Refill the fascine trenches with moist soil, leaving 1/4 of the fascine bundle exposed. Compact the soil slightly, filling in the voids in the fascines.

JM TYPICAL JUTE MAT DETAIL
NOT TO SCALE

A-A' TYPICAL JUTE MAT DETAIL SECTION A-A'
NOT TO SCALE

NOTES:

Purpose:

- Bank stabilization.
- Encourages vegetation growth.
- Decreases bank erosion.
- Provides fish habitat and cover.

Design Specifics:

- Install jute matting beginning with the downstream mat and working upstream.
- Overlap upstream mat over downstream mat by a minimum of 5 feet.
- Secure matting with 10" u-nails every 1 square yard. Install live willow and/or dogwood stakes between nails as specified. Install live stakes on the floodplain and down the bank to the low pool elevation.
- Secure ends of jute mat in trenches backfilled and compacted with local material.
- When jute mat is installed at large wood structures, cut mat to accommodate structure. Extend mat at least 5 feet downstream of structure, and overlap downstream mat by at least 5 feet.

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Kootenai River
Floodplain Reconnection
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NOTES:

Purpose:

- Bank stabilization.
- Encourages vegetation growth.
- Decreases bank erosion.
- Provides fish habitat and cover.

Design Specifics:

Live cuttings:

- Minimum length 3' with $\frac{1}{2}$ " minimum diameter.
- Cuttings should be placed 2'-6" apart.
- Place several inches of soil around rooting zones of cuttings.
- Water thoroughly and lightly compact to ensure good soil contact with cuttings.

Inner fabric:

- Non-woven coir fabrics, straw, or burlap blanket to contain soil.

Outer fabric:

- Woven coir or synthetic fabric for structural integrity.
- See erosion control fabric installation detail.

BW

TYPICAL BURRITO WRAP BANK ARMORING DETAIL

NOT TO SCALE

WD

TYPICAL WOODY DEBRIS DETAIL PLAN

NOT TO SCALE

A-A'

TYPICAL WOODY DEBRIS DETAIL SECTION A-A'

NOT TO SCALE

NOTES:

Purpose:

- Increases stream diversity.
- Provides fish habitat and cover.
- Decreases bank erosion.
- Mimics natural stream structures.

Design Specifics:

- Use medium to small logs.
- Bury at least $\frac{2}{3}$ the length of the key members in the bank.
- Place similarly sized logs randomly on and between key members. Members may be tied together with rope or wire.
- Scatter brush, slash, branches, and other woody debris among the larger members.
- Reinforce area with dense vegetation between woody debris.
- Minimum length of key members is $3 \times W_{BF}$.

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Floodplain Reconnection
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A-A' **PROFILE**
NOT TO SCALE

NOTES:

Purpose:

- Creates or enlarges mid-stream gravel bars, diverts flow and creates multiple channels and/or side channels.
- Place jam below the low water elevation to create a pool on upstream side of jam.
- Upstream bar grows as a result of slower "backwatered" flow upstream.
- Principal mechanism for formation of anastomosing channel systems.
- Enhances fish habitat by creating multiple channels and pools. Sorts gravel.

Design Specifics:

- Placed on constructed mid-stream gravel bars.
- Narrow end of large Key Members, and Secondary Members, are buried into the bar in a downward sloping manner to reinforce structure. Smaller Racked Members placed among Key Members.
- Fill and dense vegetation placed and planted on top of structure.
- Flow through new side channel may be encouraged by excavation.
- Minimum length of key members is $3xW_{BF}$.

A-A' **PROFILE**
NOT TO SCALE

NOTES:

Purpose:

- Provides fish habitat and cover.
- Creates diversity in stream geometry.
- Mimics natural stream features.
- Reduces scour on the right bank when sill is pointed downstream.

Design Specifics:

- Place on straight reaches.
- Bury both ends of the log in stream banks.
- Place the base of the log at the upstream thalweg elevation.
- Plant vegetation on both banks for bank stabilization.
- Minimum log sill length is $4W_{BF}$.

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W_{BF} = BANKFULL WIDTH
 $L = 2.5 W_{BF}$ (Min.)

NOTES:

Purpose:

- Provides fish habitat and cover.
- Reduces bank scour.
- Redirects flow.
- Creates scour pools.

Design Specifics:

- Bury $\frac{2}{3}$ of the log length.
- Plant dense vegetation on bank above buried structure for stabilization.
- Slope tree toward stream.
- Tree should not block more than 50% of channel cross sectional area at base flow.
- Minimum length of barb shall be $1.5 W_{BF}$.

W_{BF} = BANKFULL WIDTH
 $L \geq 2.5 W_{BF}$
 $PL \geq 3 D_{BF}$

NOTES:

Purpose:

- Increases stream diversity.
- Provides fish habitat and cover.
- Decreases bank erosion.

Design Specifics:

- Log length = $2 \times W_{BF}$ min.
- Buried fill log is optional.
- Anchor logs into both banks as specified.
- Drive pile logs vertically into banks at a depth of two times the bankfull depth.
- Plant dense vegetation on both banks to secure logs and supplement habitat structure.

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Kootenai River
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RC **TYPICAL ROUGHENED CHANNEL PLAN**
NOT TO SCALE

SECTION B-B'
NOT TO SCALE

SECTION A-A'
NOT TO SCALE

NOTES:

Purpose:

- Enhances fish habitat: creates large mid-stream pools, fish holding in eddies and sorts sediment.
- Protects channel against headcutting.

Design Specifics:

- Generally large, stream-wide structure with center coincident with channel centerline or thalweg.
- Structures to slope downwards towards center.
- "Upstream Vee" configuration directs water to center of channel.
- Plant dense vegetation along banks.
- Reinforce channel bed with mixture of boulders, cobbles and gravel to prevent scour and roughen channel.
- Place structure upstream of desired stream-wide pool locations and downstream of sensitive areas that are prone to head cutting.
- Grade to appear natural.

Variations:

- Woody habitat structures may be installed with bed material.
- Use of uniform cobbles throughout structure.

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- NOTES:**
- WRAP CONCRETE ECOLOGY BLOCKS WITH IMPERVIOUS PLASTIC LINER TO PREVENT SEEPAGE.
 - BURY BOTTOM ECOLOGY BLOCK TO PREVENT SEEPAGE AND ADD STABILITY.
 - USE ECOLOGY BLOCKS AS BUTTRESSES AS REQUIRED.
 - INSTALL 2"x6" FLASHBOARDS, 7' LONG, IN FLASHBOARD GUIDE.
 - FABRICATE FLASHBOARD GUIDE BY BOLTING 2"x8" AND 2"x4" LUMBER (WITH A 1/8" SPACER).
 - STEEL CHANNELS OR "W" SECTIONS MAY BE USED IN LIEU OF WOODEN FLASHBOARD GUIDE.
 - SECURE FLASHBOARD GUIDE INTO CHANNEL BED AND TO ECOLOGY BLOCK WITH BOLTS.
 - BOTTOM OF GUIDES SHALL EXTEND BELOW BOTTOM OF ECOLOGY BLOCKS.
 - CONSTRUCT 3 FLASHBOARD OPENINGS, MINIMUM OF 5' LONG AND 2.5' HIGH.

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TENDON AND ATRA ANCHOR DETAIL

GEOCELL AND ATRA ANCHOR DETAIL

TYPICAL STAKE DETAILS

Design Specifics

- Dewater groundwater as necessary.
- Geocell shall be Presto Geosystem's Geoweb or equivalent.
- Excavate and shape 14" to 26" depth by 16' wide swath as specified. Dig toe-in trenches at each end and upstream and downstream of the geocell crossing.
- Install non-woven geotextile fabric 16' wide along the entire geocell crossing. Overlap adjacent sections in a downstream direction. Place geotextile in toe-in trenches along all 4 perimeters.
- Place ATRA anchors at 11.2-inch centers along the upper edge of the slope. Place each end cell over one stake and secure.
- Expand geocells in place across the specified sections. Hold the geocells open with ATRA anchors, and infill outer cells with gravel. Staple geocell sections together per manufacturers instructions to form one continuous cell structure. Ensure that the upper edge of adjoining geocell sections are flush.
- Anchor geocells to the ground with ATRA anchors.
- For section B, install tendons through specified tendon slots prior to expanding the geocell section. Tie a double loop knot at the ends of each tendon to secure in place. Drive ATRA stakes at 3-foot intervals, ensuring that the tendon is under the arm of the ATRA clip. Do not add tension to the tendon.
- Backfill geocells with gravel by dumping gravels directly into the expanded cells. All gravels referred to in this design shall be 2" to 4" minus clean gravel, washed of fines. Limit drop height to 20 inches above geocells.
- Cover filled geocells with 8" of clean gravel.
- Note: the top of the finished geocell crossing, including top course, shall be level with the upstream and downstream channel elevation.

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GEOCELL LOW-WATER CROSSING A-A'

HORIZONTAL SCALE: 1"=20'
VERTICAL SCALE: 1"=10'

Revision No:	Date:	Description:	Initials:	Designed: JJF	Kootenai River Floodplain Reconnection Boundary County, Idaho Kootenai Tribe of Idaho	<div>GEOENGINEERS</div> <div>523 East Second Avenue Spokane, WA 99202</div>	Miscellaneous Details	Sheet 10.3
		BID DOCUMENTS. NOT		Drawn: MGF/BMK			Ball Creek Stream Restoration Construction Bid Documents	
		FOR CONSTRUCTION		Checked: MKH				
				Date: 07/08/09				
				Project No: 9229-002-04

PLAN VIEW

ROUGHENED CHANNEL SUBSTRATE

$D_{100} = 27.7"$
 $D_{84} = 22.5"$
 $D_{50} = 17.3"$
 $D_{16} = 8.6"$

TYPICAL ROCK WEIR SECTION A-A'

POOL SUBSTRATE

$D_{100} = 10.3"$
 $D_{84} = 4.1"$
 $D_{50} = 1.7"$
 $D_{16} = 0.5"$

TYPICAL POOL SECTION B-B'

PROFILE

OUTLET CONTROL NOTES

1. INSTALL FOUR (4) PLUNGE POOLS BACK TO BACK THROUGH THE 700 FOOT SECTION OF REACH 2 FROM STATION 20+00 UPSTREAM TO 27+00.
2. LARGE BOULDERS SHALL BE PLACED WITH NO LESS THAN 1/3 OF THEIR HEIGHT BELOW THE SURROUNDING SUBSTRATE.
3. BOULDERS SHALL BE PLACED IN A "KEYED IN" CONFIGURATION SO THAT MOVEMENT OF ANY GIVEN BOULDER WOULD REQUIRE ROLLING UP AND OVER ADJACENT BOULDERS.
4. REINFORCE CHANNEL AND POOL BED WITH SMALL BOULDERS, COBBLES, GRAVEL, AND SAND TO PREVENT SCOUR AT/BELOW BOULDERS TO MATCH GRADATIONS SHOWN.
5. INSTALL ROUGHENED CHANNEL STRUCTURES FOR THE ENTIRE WIDTH OF THE FLOODPLAIN (ROUGHLY 110 FEET).
6. TO AID FISH PASSAGE, LARGE BOULDERS SHALL BE PLACED IN LOCATIONS AND ORIENTATIONS THAT PROMOTE POCKET WATER CONDITIONS AND WATER VELOCITY VARIATION.
7. PROPOSED BOULDER PLACEMENT SHOWN AS APPROXIMATE.
8. INSTALL BURIED AND PARTIALLY BURIED (AT LEAST 1/2 DIAMETER BURIED) LARGE WOODY DEBRIS THROUGHOUT THE FLOODPLAIN TO ROUGHEN OVERBANK FLOOD CONDITIONS AND AID IN SLOWING WATER VELOCITIES. (MINIMUM OF 8 PIECES PER INDIVIDUAL PLUNGE POOL.)
9. DENSELY VEGETATE THE FLOODPLAIN AND CHANNEL BANKS TO AID IN REACH STABILITY.
10. BOULDERS SHALL BE KEYED INTO BANK UPTO AN ELEVATION OF 1763.

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Kootenai River
Floodplain Reconnection
Boundary County, Idaho
Kootenai Tribe of Idaho

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Outlet Control Detail
Ball Creek Stream Restoration
Construction Bid Documents

Sheet
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KOOTENAI RIVER

EXISTING BALL CREEK ALIGNMENT

ZONE		ACREAGE
	UPLAND/TRANSITIONAL	63.76
	RIPARIAN FLOODPLAIN	122.07
	WET MEADOW	51.30
	STREAM BANK	9.63
TOTAL		246.77

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Kootenai River
Floodplain Reconnection
Boundary County, Idaho

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Typical Planting Zone

Ball Creek Stream Restoration
Construction Bid Documents

Sheet
11.1

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Notes:
TOB = Top of Bank, OHW = Ordinary High Water

TYPICAL PLANTING CONFIGURATIONS

REFER TO TABLE BELOW TO DETERMINE PLANTING APPLICATIONS.

TYPICAL PLANTING ZONES
Not To Scale

Planting Specifications Table			
Planting Area	Vegetation	Instructions	Densities rates
Bank Zone	Black cottonwood, western red cedar, red osier dogwood, Drummonds willow and coyote willow	1. Add topsoil mix and/or organic mulch at base of plants, if necessary. 2. Plant in proper hydrologic regime (see sheet 11.3).	12 ft on-center (o.c.) for trees and 6 ft o.c. for shrubs
Wet Meadow Zone	Red osier dogwood, Drummonds willow, coyote willow, hardhack, beaked sedge, creeping spikerush, tufted hairgrass and red fescue	1. Add topsoil mix and/or organic mulch at base of plants and throughout seeding area, if necessary. 2. Plant in proper hydrologic regime (see sheet 11.3).	6 ft o.c. for shrubs and 5.6 lbs/ac for seed mix
Riparian Zone	Black cottonwood, western red cedar Engelmann spruce, quaking aspen, cascara, red osier dogwood, Drummonds willow, coyote willow, hardhack, mountain alder, thimbleberry, snowberry and Wood's rose	1. Add topsoil mix and/or organic mulch at base of plants if necessary. 2. Plant in proper hydrologic regime (see sheet 11.3).	12 ft on-center (o.c.) for trees and 6 ft o.c. for shrubs
Upland Transitional Zone	Black cottonwood, western red cedar, quaking aspen, snowberry, blue elderberry, Serviceberry, thimbleberry, oceanspray, golden currant, Wood's rose, Sandbergs bluegrass, bluebunch wheatgrass, slender wheatgrass and Idaho fescue	1. Add topsoil mix and/or organic mulch at base of plants and throughout seeding area, if necessary. 2. Plant in proper hydrologic regime (see sheet 11.3).	12 ft o.c. for trees, 6 ft o.c. for shrubs and 6 lbs/ac for seed mix

TYPICAL PLANTING DETAILS

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Kootenai River
Floodplain Reconnection
Boundary County, Idaho

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**Typical Planting Details
and Configurations**

Ball Creek Stream Restoration
Construction Bid Documents

Sheet
11.2

PROFESSIONAL ENGINEER
REGISTERED
8238
07/08/09
STATE OF IDAHO
MICHAEL K. HOMZA

Revision No:	Date:	Description:	Initials:	Designed: JJF	Kootenai River Floodplain Reconnection Boundary County, Idaho Kootenai Tribe of Idaho	GEOENGINEERS 523 East Second Avenue Spokane, WA 99202	Construction Sequencing Ball Creek Stream Restoration Construction Bid Documents	Sheet 12.1
		BID DOCUMENTS. NOT		Drawn: MGF/BMK				
		FOR CONSTRUCTION		Checked: MKH				
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General Notes:

- 1. Stream and floodplain construction shall occur during low seasonal streamflow conditions on the Kootenai River between late spring and early autumn.
- 2. Stream and floodplain construction shall only occur in dry conditions and off-line from active stream flow to the greatest extent possible.
- 3. Work shall be managed to minimize sediment entering active (flowing) streams when work is necessary in active stream channels.
- 4. Surface and groundwater shall be drained away from active construction and into sediment ponds to eliminate sediment from flowing into active stream channels.
- 5. Appropriate Best Management Practices shall be employed to minimize construction related sediment from running offsite and to prevent onsite erosion.
- 6. Permanent erosion and sedimentation control will be achieved by: a) constructing the proposed stream as designed, b) stabilizing the streams and floodplains with vegetation and c) irrigating the proposed riparian vegetation until vegetation is stable, established and irrigation is no longer necessary.
- 7. Discharges entering active streams both onsite and offsite shall satisfy all state and Federal standards for contaminants and turbidity.
- 8. Diverted and controlled streamflow can be used to test and adjust newly constructed stream reaches prior to permanently activating new stream channel.
- 9. Construction shall commence at downstream end of project and shall progress upstream.
- 10. Only appropriate approved native riparian vegetation shall be used for cuttings and transplanting. Vegetation cutting, transplanting, planting and irrigation shall be managed by appropriate professional.
- 11. Cuttings and transplants shall be installed immediately or stockpiled appropriately to ensure viability. All acceptable existing vegetation to be disturbed shall be transplanted.
- 12. Soil shall be stockpiled and/or managed for use elsewhere onsite.

Stream Construction Phasing:

It is proposed to construct the stream enhancements in the following steps. The phasing below assumes a three year construction schedule, based on funding. This phasing plan is suggested and should be modified to accommodate construction of the overall restoration project.

Year 1

- 1.1 Install a drainage culvert through the existing downstream levee to facilitate draining from the proposed channel construction. We expect to encounter shallow groundwater in certain portions of the proposed channel. The upstream invert of the proposed drainage culvert will coincide with the proposed stream elevation. The culvert will be gated with a flap gate to prevent Kootenai flood water from backwatering the proposed channel during high river levels. Ideally the culvert will be installed in the fall of the year prior to the next year's channel construction.
- 1.2 Starting at the drainage culvert and proceeding upstream, excavate and grade the proposed floodplain offline.
- 1.3 Starting at the drainage culvert and proceeding upstream excavate, grade and shape stream channel. Install substrate and structures, including backfill for limiting wetland extents.
- 1.4 Excavated material will be used to create the compacted armored berms adjacent to reach 8. Excess material will be used to elevate the surrounding fields to decrease the likelihood of flooding. The excavated soil will be stockpiled along the outer edges of the field until it can be placed prior to turning the soil.
- 1.5 Construct the geocell stream crossing and any associated access roads.
- 1.6 Plant riparian vegetation along the constructed stream moving from upstream to downstream after channel construction and shaping is complete. During planting install temporary check dams in the channel to backwater proposed alignment to a bankfull elevation to provide irrigation water for plantings. Check dams shall be installed at a distance that maintains water within 1/2 a foot of bankfull elevation.
- 1.7 During construction, irrigation of the completed reaches will need to be completed using a temporary irrigation system. When the proposed channel extends to the existing alignment, construct the temporary irrigation diversion structure as defined and detailed on sheet 10.1. This diversion will allow regulated flows to enter the proposed alignment for irrigation purposes.
- 1.8 Regulate the check boards at the diversion structure to allow a small flow of water through the proposed alignment to irrigate the newly planted vegetation.

Year 2

- 2.1 Allow the planted vegetation along the proposed alignment to become established. The irrigation flows through the channel should be varied to ensure proper irrigation of the proposed channel vegetation. This could include maintaining check dams to ensure water maintains bankfull depth throughout the channel.
- 2.2 In the late summer or fall, complete construction of Reaches 1 and 2 by removing the downstream levee. Install grade control structures as shown on sheet 10.4 for Reach 2. Plant riparian vegetation along channel and floodplain. Install check dams along Reach 2 and continue to irrigate to establish vegetation.

Year 3

- 3.1 Remove all temporary check dams in the new channel after high spring runoff flows have subsided.
- 3.2 Use the upstream diversion structure to supply the new channel with incremental flows from low to bankfull conditions. This will allow monitoring of the functionality of the proposed channel and allow for design adjustments, if needed, prior to full diversion.
- 3.3 Complete construction of the proposed channel by compacting and backfilling the existing Ball Creek alignment and diverting Ball Creek into the proposed channel. Backfill shall be as per the grading plan and shall be compacted to a minimum of 85% as per the modified proctor density.
- 3.4 Close monitoring during this phase will be required.

Year 4

- 4.0 Monitor functionality of the stream during spring runoff conditions. Monitoring during this phase will be crucial to determining design adjustments that will aid the long term stability of the proposed alignment.
- 4.1 After the spring runoff is completed, make design adjustments as needed to the new channel.

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Kootenai River
Floodplain Reconnection
Boundary County, Idaho

Kootenai Tribe of Idaho

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Construction Sequencing Notes

Ball Creek Stream Restoration
Construction Bid Documents

Sheet
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Item #	Item Description	Units	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Total	Units	Item Description	Item #
1	Groundwater Dewatering	LS	10000	10000	10000	10000	10000	10000	0	0	0	60000	LS	Groundwater Dewatering	1
2	Floodplain Excavation (short and long haul)	CY	19425	166384	238894	606990	340261	120778	12975	120891	5697	1632293	CY	Floodplain Excavation (short and long haul)	2
3	Floodplain Grading	Acre	6977	9884	57898	76429	22562	29278	9086	65138	1740	278992	Acre	Floodplain Grading	3
4	Stream Excavation	CY	5833	7701	82091	45522	52329	56005	16982	31039	4242	301744	CY	Stream Excavation	4
5	Stream Grading	Acre	5216	4308	21009	15295	13811	17629	6281	21267	2505	107322	Acre	Stream Grading	5
6	Boulders, cobbles, gravel placed in stream	CY	5000	266250	0	0	8000	150	0	300	300	280000	CY	Boulders, cobbles, gravel placed in stream	6
7	Large Woody Debris (acquisition, haul & installation)	Per Piece	0	4800	33000	34200	33000	103800	33000	84000	13800	339600	Per Piece	Large Woody Debris (acquisition, haul & installation)	7
8	Riprap	CY	0	0	0	0	0	0	0	0	0	0	CY	Riprap	8
9	Local Grading of Excavated Material	Acre	6212	0	274207	174374	0	0	0	95085	28841	578718	Acre	Local Grading of Excavated Material	9
10	Tidegate	Each	500	0	0	500	0	0	0	0	0	1000	Each	Tidegate	10
11	24" HDPE Corrugated Pipe (acquired, installed, drilled)	LF	22032	0	0	0	0	0	0	0	0	22032	LF	24" HDPE Corrugated Pipe (acquired, installed, drilled)	11
12	Geogrid Crossing	LS	0	0	0	0	18386	0	0	0	0	18386	LS	Geogrid Crossing	12
13	BMP's (Jute mat, silt fence, staked hay bales)	LS	1250	1250	1250	1250	1250	1250	1250	1250	1250	11250	LS	BMP's (Jute mat, silt fence, staked hay bales)	13
14	Wetland and Riparian Planting	LS	4067	3238	86380	89634	26873	222210	76414	106345	18489	633650	LS	Wetland and Riparian Planting	14
15	Irrigation/Backwater Berms	EA	263	263	788	788	1050	788	525	1050	263	5775	EA	Irrigation/Backwater Berms	15
16	Diversion Structure	LS	0	0	0	0	0	0	0	0	41930	41930	LS	Diversion Structure	16
17	Fascine Bundle	LS	6936	31890	10052	3304	0	0	2115	0	0	54297	LS	Fascine Bundle	17
18	Burrito Wrap	LS	0	0	3962	3023	15840	8641	0	0	0	31466	LS	Burrito Wrap	18
19	Jute Mat Bank	LS	0	17270	711	2240	0	1635	0	0	0	21856	LS	Jute Mat Bank	19

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Kootenai River
Floodplain Reconnection
Boundary County, Idaho

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Construction Quantities
Ball Creek Stream Restoration Construction Bid Documents

Sheet
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APPENDIX D
REPORT LIMITATIONS AND GUIDELINES FOR USE

APPENDIX D REPORT LIMITATIONS AND GUIDELINES FOR USE¹

This appendix provides information to help you manage your risks with respect to the use of this report.

STREAM AND RIVER DESIGN ENGINEERING SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES, PERSONS AND PROJECTS

This report has been prepared for Kootenai Tribe of Idaho and their authorized agents for the Ball Creek Ranch site. The information contained herein is not applicable to other sites. GeoEngineers structures our services to meet the specific needs of our clients. No party other than Kootenai Tribe of Idaho may rely on the product of our services unless we agree to such reliance in advance and in writing. This is to provide our firm with reasonable protection against open-ended liability claims by third parties with whom there would otherwise be no contractual limits to their actions. Within the limitations of scope, schedule and budget, our services have been executed in accordance with our Agreement with the Kootenai Tribe of Idaho as executed on August 21, 2007, and generally accepted practices in this area at the time this report was prepared. Use of this report is not recommended for any purpose or project except the one originally contemplated.

A STREAM OR RIVER DESIGN ENGINEERING REPORT IS BASED ON A UNIQUE SET OF PROJECT-SPECIFIC FACTORS

This report has been prepared for the Kootenai Tribe of Idaho for the Ball Creek Ranch site. GeoEngineers considered a number of unique, project-specific factors when establishing the scope of services for this project and report. Unless GeoEngineers specifically indicates otherwise, it is important not to rely on this report if it was:

- not prepared for you,
- not prepared for your project,
- not prepared for the specific site, or
- completed before important project changes were made.

For example, changes that can affect the applicability of this report include those that affect:

- the function of the proposed design and/or structure;
- elevation, configuration, location, orientation or weight of the proposed structures;
- composition of the design team;
- environmental regulations; or
- project ownership.

If important changes are made after the date of this report, we recommend that GeoEngineers be given the opportunity to review our interpretations and recommendations. Based on that review, we can provide written modifications or confirmation, as appropriate.

CONDITIONS CAN CHANGE

This report is based on conditions that existed at the time the study/design was performed. The findings and conclusions of this report may be affected by the passage of time, by man-made events such as

¹ Developed based on material provided by ASFE, Professional Firms Practicing in the Geosciences; www.asfe.org.

construction on or adjacent to the site, or by natural events such as floods, earthquakes, slope instability, stream flow fluctuations, reservoir regulation or stream channel fluctuations. If more than a few months have passed since issuance of our report or work product, or if any of the described events may have occurred, please contact GeoEngineers before applying this report for its intended purpose so that we may evaluate whether changed conditions affect the continued reliability or applicability of our conclusions and recommendations.

REPORT RECOMMENDATIONS AND DESIGNS ARE NOT FINAL

Do not over-rely on the preliminary construction recommendations included in this report. These recommendations are not final, because they were developed principally from GeoEngineers' professional judgment and opinion. GeoEngineers' recommendations can be finalized only by observing actual site-specific conditions revealed during construction.

We recommend that you allow sufficient monitoring and consultation by GeoEngineers during construction to provide recommendations for design changes if the conditions revealed during the work differ from those anticipated and to evaluate whether construction activities are completed in accordance with our recommendations. GeoEngineers is unable to assume responsibility for the recommendations in this report without performing construction observation.

The designs depicted herein are approximate and are intended to express the overall design intent of the project. These designs will need to be adjusted in the field during construction in order to meet the specific-site conditions and intended function.

REPORT COULD BE SUBJECT TO MISINTERPRETATION

Misinterpretation of this report by members of the design team or by contractors can result in costly problems. GeoEngineers can help reduce the risks of misinterpretation by conferring with appropriate members of the design team after submitting the report, reviewing pertinent elements of the design team's plans and specifications, participating in pre-bid and preconstruction conferences, and providing construction observation.

To help prevent costly problems, we recommend giving contractors the complete report, but preface it with a clearly written letter of transmittal. In that letter, advise contractors that the report's accuracy is limited. In addition, encourage them to confer with GeoEngineers and/or to conduct additional study to obtain the specific types of information they need or prefer.

INSTREAM HABITAT STRUCTURES

Instream habitat, stabilization, enhancement and/or restoration structures and artificial (Structures) involve the placement of large logs, logs with root wads, large rocks and other natural and artificial materials and/or features in and adjacent to creeks, streams and rivers (streams). They are designed for various purposes including but not limited to: improvement of aquatic and riparian habitat; stabilization of eroding stream banks and channels; restoration of stream channels; creation or improvement of recreational uses; irrigation; and flood management.

HAZARDS OF INSTREAM HABITAT STRUCTURES

Instream habitat structures create potential hazards, including, but not limited to: humans falling from the Structures and associated injury or death; collisions of recreational users' watercraft with the Structures and associated risk of injury or death, with partial or total damage of the watercraft; mobilization of a

portion or all of the Structures during high water flow conditions and related damage to downstream properties, utilities, roads, bridges and other infrastructure, and injury or death to humans; flooding; erosion; and channel avulsion. In some cases, instream habitat structures are only intended to be temporary, providing temporary stabilization while riparian vegetation becomes established while or stream/river processes stabilize. This gradual deterioration with age and vulnerability to major flood events make temporary Structures inherently dangerous with increasing age.

It is strongly recommended that the Kootenai Tribe of Idaho address the necessary safety concerns appropriately. This would include warning construction workers of hazards associated with working in or near deep and fast moving water and on steep, slippery and unstable slopes. In addition, signs should be placed along the enhanced stream reaches in prominent locations to warn recreational users of the potential hazards noted above and pamphlets should be distributed to nearby residents warning of the potential hazards to children and adults posed by these Structures.

INCREASED FLOOD ELEVATIONS AND WETLAND EXPANSION ARE POSSIBLE

The proposed stream enhancements may result in increased flood elevations and expansion of wetlands. The analysis of these impacts, which are generally considered advantageous for aquatic and riparian habitat in the project locations of these stream systems, may need to be considered and quantified if they were beyond the context of GeoEngineers' scope of services.

CHANNEL EROSION AND MIGRATION ARE POSSIBLE

In general, river and stream enhancements are intended to result in more stable streambeds, banks and floodplains. In some cases, stream enhancement and channel stability means reestablishing the natural balance of sediment erosion, distribution and deposition, which induces channel meandering and migration. Therefore, channel erosion, channel migration and/or avulsions can be expected to occur over time.

IMPORTANCE OF MONITORING AND MAINTENANCE

Piles, anchors, chains, cables, reinforcing bars, bolts and similar fasteners may have purposely been excluded from woody habitat structures with the intent of mimicking naturally-occurring instream wood structures. Conversely, such fasteners may have purposely been included in woody habitat Structures if considered appropriate. While the Structures are designed to be relatively stable during flood events, movement of these Structures should be expected. As noted in the text of this report, we recommend that the Kootenai Tribe of Idaho implement appropriate monitoring and maintenance procedures to minimize potential adverse impacts at or near areas of concern, such as at downstream road, bridge and/or culvert crossings. This would include replacing, adjusting and removing damaged, malfunctioning or deteriorated components of Structures, particularly following a major storm event.

CONTRACTORS ARE RESPONSIBLE FOR SITE SAFETY ON THEIR OWN CONSTRUCTION PROJECTS

Our recommendations are not intended to direct the contractor's procedures, methods, schedule or management of the work site. The contractor is solely responsible for job site safety and for managing construction operations to minimize risks to on-site personnel and adjacent properties.