To: Mitch Long, Executive Director

From: Natural Systems Design

Date: July 20th, 2017

Re: Gold Creek Instream Restoration Project - Risk Assessment 60% Preliminary Designs

BACKGROUND

The Kittitas Conservation Trust (KCT) has identified the lower 3 miles of Gold Creek above Keechelus Lake near Snoqualmie Pass, as a candidate location for habitat restoration. The primary objectives of the Gold Creek Instream Restoration Project are to improve instream habitat for threatened Gold Creek Bull Trout (*Salvelinus confluentus*). The hydrologic, hydraulic, habitat, and geomorphic conditions within the project reach have been assessed to better understand the mechanisms contributing to degraded habitat within the creek, and the associated impacts to Gold Creek Bull Trout (NSD 2013a, NSD 2013b, NSD 2014a, NSD 2014b). These findings were used to develop preliminary designs that met the primary objectives of the Project by restoring natural geomorphic and hydrologic processes.

Preliminary (60% design level) restoration designs were developed to meet the restoration objectives to improve instream habitat for threatened Gold Creek Bull Trout (Appendix A) (NSD 2017). The proposed restoration elements include the addition of instream structures, channel excavations, new vegetated inset floodplains, and planting of existing floodplains and gravel bars. These elements are anticipated to encourage natural geomorphic processes, and create and sustain habitat over the long term. Overall, the proposed restoration is intended to enhance channel and habitat stability through the creation of stable hard points that mimic the large trees historically present in the system, while allowing the channel to develop and sustain complex habitat (NSD 2017). The introduction of logjams also results in local increases to water surface elevations that meet the goal of increasing floodplain and side channel connectivity, but these increases must be balanced so as not to put adjacent floodplain development at additional risk. Thus, it is critical to evaluate the hydraulic effect of the large number of instream structures combined with other restoration elements to ensure they meet the project goals with no undesired impacts.

Risks considered for this assessment include those related to Gold Creek, and not those associated with other channels draining to Gold Creek (tributaries). Primary natural hazards for the project area included in this assessment are from flooding and erosion from Gold Creek, including lateral bank erosion, inundation, sediment deposition, the influence of natural large woody material (LWM), and channel avulsion. Natural variability in weather will impact magnitude of each hazard assessed, thus the anticipated effects of climate change will impact future risk. Non-natural hazards included in this assessment are the failure of instream structures, increases in water surface elevation (WSE) or instream velocities as a result of the project, and temporary construction activities.

Risk is a function of the probability of a hazard occurring (such as structure failure/washout, flood inundation, etc.) and the consequences of that event (eg. habitat loss, property damage, or injury). If an event has little or no consequence then the associated risk would be relatively low. For instance, if a piece of LWM is mobilized during a flood but there are no adverse consequences, then risk is negligible. However; if the LWM is a critical habitat element or poses risk to property if mobilized, then risk would be considered high. Generally, a high negative consequence coupled with a high probability of occurrence results in a high risk factor. Alternatively, a low negative consequence combined with a low probability of occurrence results in a low risk factor. A medium risk factor results when one component is high while the other is low. This risk assessment establishes due diligence in evaluating the preliminary design and consists of the following elements:

- Assessment of short-term risk associated with construction activities
- Assessment of potential impacts to property and habitat
- Assessment of structure stability for restoration elements
- An assessment of potential impacts of restoration elements on existing processes

Construction Activity Risks

Several hazards have been identified related to construction activities during implementation that pose potential risk to water and habitat quality. Construction activities considered in this risk assessment include:

- Earthmoving (excavation and placement)
- Planting
- Water Management
- Structure Construction

Earthmoving

Primary earthmoving activities included in the design are clearing, grubbing, and excavation of proposed channels and instream structures. Grading associated with staging and stockpile areas, and establishment of proposed access routes, is anticipated to be minimal. Any areas that are excavated or filled during construction will lose vegetated cover and remain exposed until either planted or is naturally re-vegetated (Appendix A). The grading associated with the proposed structures includes excavation of the channel bed for the installation of large wood to the design depth. Once the structure is completed the excavated material is then used to backfill the structure. Material generated from channel excavations will be transported to new inset floodplain areas along the project reach (Appendix A). Any excess material will be transported from the creek via new or existing temporary access routes, to be determined during final design.

The risk associated with flooding and erosion is very low for the project area during construction given the hydrologic regime during the likely construction time frame (summer months). Construction areas that are within the wetted channel during construction will be isolated where applicable to minimize risk to fish during construction, and limit inundation and erosion risk in the work area. All staged material and equipment not in use will be above ordinary high water (ohw), and all equipment will have biodegradable vegetable-based hydraulic fluids. Management of water isolated during construction is discussed later in this report. The transport of excavated material will be on temporary access routes, within the active channel to the extent possible. Existing gravel roads will be used to transport material if needed as shown in the design drawings (Appendix A).

Planting

Following completion, backfilled structures, new floodplains and any disturbed areas above the ordinary high water line (access routes, staging areas where applicable), will be planted and/or seeded to initiate establishment of native vegetation. Habitats to be formed include coniferous forest and riparian deciduous forest. The primary risk to establishment of the plantings is from drying during the summer months, and from flood erosion during the growth (rooting) period following construction. Selection of appropriate native vegetation and installation to sufficient depths will be used to mitigate risk to the success of re-vegetation efforts to the extent possible. This includes using the proposed hydraulic model results to strategically plant communities that will have the greatest likelihood of long-term success (Appendix A and B).

Water Management

Isolation and de-watering of the channel will likely be required to install proposed structures at multiple locations along the channel. Best management practices will be employed to minimize the risk to bull trout and other species that may be present during construction. Where work area isolation is required, a fish removal plan including a redd survey of the area to be isolated will be implemented to prevent fish stranding and/or the disturbance of active redds. Locations where the channel is dry will encounter groundwater at depth during structure installation at some locations. Any water removed from work areas will be treated to meet all permit requirements. The location of discharge and treatment of this water will likely be on the western floodplain, the details of which will be developed during final design.

Structure Construction

The project design includes in-stream structures, new floodplain areas, channel grading, clearing and grubbing, and planting. Construction of these design elements will be performed when the channel is slowly drying up in the early summer months, and continue through the dewatered period throughout the end of summer. The primary risk to project elements during construction is from flooding and erosion of the work area from short-duration, high-intensity thunderstorms that can re-wet the channel. Because the channel is typically dry or nearly so, even large storms do not typically result in flows exceeding ordinary high water. The risk to locations under active construction could be minimized by installing additional BMPs proceeding or during the event. The low likelihood of a flood with sufficient magnitude to result in damage results in a low risk for constructing instream structures. All work involving excavation in the active channel will include a water management plan.

Property and Habitat Risks

Potential impacts to property and habitat resulting from the proposed restoration project (Appendix A) were assessed using results from the existing and proposed hydraulic modeling (Appendix B). Primary concerns within the project reach include the potential harm to bull trout during construction, and damage (flooding and erosion) to private property and development on the eastern floodplain as a result of the project. Each of these concerns as well as the risk to existing habitat is discussed below.

Private Property and Infrastructure

There are several private properties along the left bank of the channel on the east side of valley. These properties vary in the types of landowner, existing development, and risk profile under the current condition. Most of the landowners are private individuals or groups (SkiTur), with the remaining land held by the non-profit Forterra. Development on the floodplain includes the construction of roads, buried utilities, cabins, flood control measures, gravel pits, and unimproved trails.

Erosion Risk

Within the creek, rock barbs have been installed and repaired several times, and logs of varying sizes and arrangements have been cabled together all in an effort to reduce bank erosion at key locations on the left bank. Erosion of property has occurred over the years on both banks of the channel, and has only been halted where homes are at immediate risk from further erosion. In addition to channel migration, side channels in the few locations where the floodplain is currently engaged have responded over time to increased flow. The relative magnitude of flow in these side channels is largely a function of the alignment of the main channel upstream. When the main channel is directing more flow into these side channels, they will erode banks and recruit adjacent trees as the channel expands. Locations of high channel velocity adjacent to channel banks, more where flow is directed toward the bank, are a proxy for locations where bank erosion is anticipated (Appendix B).

The proposed conditions hydraulic model results were used to assess the relative risk to property and development from channel erosion (Appendix B). The map depicting the change in velocity during the 100-yr flood shows there is an average overall decrease in main stem channel velocities of 2-ft/s (25% reduction relative to the existing condition), with local decreases more than 5-ft/s along banks of concern posing immediate risk. The few locations where bank erosion is predicted to increase relative to the current condition pose a very low risk to landowners on the eastern floodplain (Appendix B). Channel banks of concern include the left bank at RM 1.1, between 1.3 – 1.5, and RM 1.7. At all of these locations channel velocities along the banks are half that under the current condition, decreasing 3 – 5-ft/s (Appendix B).

The overall reduction in main stem channel velocity will reduce bank erosion rates over the long term along the entire project reach. Few bank locations are predicted to experience increases in velocity, including those currently at risk. Some immediate bank erosion is anticipated following the first several significant flow events, as the channel adjusted to the project. This is more likely to occur adjacent to instream structures as flow is deflected away and potentially toward the opposite bank. After the initial response is complete and the channel has adjusted to its new equilibrium, future channel erosion rates will be diminished along the main stem channel relative to the current condition. The overall reduced bank erosion hazard as a result of the project, coupled with dramatic local reductions in bank erosion where risk is greatest (adjacent to development), demonstrate that the proposed design will not increase risk associated with bank erosion in the project reach.

Flooding Risk

In addition to bank erosion, flooding from the channel can impact property and infrastructure. Cabins and roads are the primary development impacted by flooding. Due to historic disturbances in the valley, much of the current floodplain is disconnected from the channel (NSD 2014b). Between RM X 1.35 – 1.75 there are 5 cabins, and 200-ft of road/driveway, impacted by flooding during the 100-yr (3,000-cfs) flood. Inundation depths adjacent to the cabins ranges from 0.1 – 2-ft, with those most impacted located at the downstream end. The potential damage associated with this level of flooding is to ground-level portions of the cabins in contact with the flood waters. Our understanding and observations of cabins in the valley is that most if not all of those impacted by flood waters under the existing condition have cement basements exposed to a height exceeding the predicted depth of flow during the 100-yr flood. Some cabins with basement entryways are at greater risk of interior exposure.

The proposed conditions hydraulic model results were used to assess the relative risk to property and development from flooding (Appendix B). The map depicting the change in flow depth during the 100-yr flood shows the effect of the project varies by location. Of particular note is the abundant increases in flow depths on the western floodplain as a result of the project, providing valuable habitat with little to no risk. Within the main stem channel, local increases in flow depth as a result of instream structures and new floodplains are sporadically present upstream of RM 1.7 (Appendix B). Downstream of RM 1.7 flow depths are the same as or less than the current condition through the remainder of the project reach. The loss of flood flows to the western floodplain are the primary mechanism contributing to lower flow depths in the main stem channel downstream of RM 1.7. Flow depths in the main stem channel downstream of RM 1.7 are the same as or up to

4-ft lower than the current condition. Flow depths during the 100-yr flood are predicted to be the same under the proposed condition relative to existing (Appendix B).

Existing Habitat

Habitat conditions within Gold Creek are degraded relative to the historic condition due to disturbances that began in the 1940's (NSD 2014b). The nature of the disturbances and the resultant degradation of habitat have resulted in poor habitat conditions in the creek. The over-widened channel lacks large wood capable of forming and maintaining logjams that provide valuable habitat (pools, cover) and are key to the long-term recovery of the system. Existing pools and large wood distribution have been documented, as well as the current and historic channel widths (NSD 2014b). The results of these surveys concluded that habitat conditions along the creek are best where the channel has recently recruited trees into the channel, forming a logjam that provides cover and pool habitats. These locations however typically recruit trees that are smaller than those needed to persist long-term, and the logjams and the associated habitat are lost during subsequent floods.

The over-widening of the channel has also increased the capacity of the channel to convey flood flows, reducing the amount of water engaged with the floodplain. Disconnection with the floodplain results in a loss of important side channel and floodplain habitats, as well as focuses all of the stream energy on the main stem channel. Currently, floodplain engagement is lacking everywhere except on the left bank between RM 1.5 – 1.7, adjacent to the SkiTur community (Appendix B). This small portion of floodplain is likely a small fraction of the historic floodplain once available during floods.

The current channel has an average of 53-pools/RM, representing approximately 59 pools within the project reach (1.1-RM long) (NSD 2014b). Including the additional pools anticipated resulting from the proposed project (73) increases the total number of pools to 132, increasing the average pool spacing to 120-pools/RM (NSD 2017). This more than doubling of pool frequency will reduce the average distance between pools from 100-ft to 44-ft, dramatically increasing the likelihood fish will find refuge during annual dewatering. All of the new pools associated with logjams will have cover for rearing juveniles, and holding areas for migrating adults. This will dramatically improve instream habitat over the range of life stages of bull trout, and will mitigate for any loss of existing habitat that may be currently available.

Structure Stability

A stability analysis was performed to ensure the structures proposed are designed and constructed to withstand the hydraulic forces that occur during severe flood events. The structures expected to experience the most severe hydraulic conditions (highest velocity, flow depth, and shear stress), for each structure type, was evaluated for structural stability for that type. The stability analysis was performed using force balance equations developed to predict buoyant and lateral forces acting upon the structure utilizing hydraulic parameters generated from the 100-year proposed condition hydraulic model and material properties for the specific structure components (Appendix C). The stability analysis followed procedures outlined in the Bureau of Reclamation's technical release: "Large Woody Material-Risk Based Design Guidelines" (2014). Stability estimates were performed under hydraulic conditions of the 100-year recurrence discharge and considered destabilizing forces related to the buoyancy of large wood, hydrodynamic and hydrostatic forces, as well as by potential impact forces from natural debris transport. The results of the stability analysis in terms of the factor of safety (FOS) (resisting forces/destabilizing forces) for the analyzed structure are shown in Table 1, below. Each proposed structure type is designed to counteract vertical forces such as buoyancy and fluid uplift and lateral forces such as fluid drag, hydrostatic, and impact forces using excavated timber posts, alluvium backfill, and/or adequately sized and species of key-members. For this preliminary design, stability analysis was only performed for the Type-1 and Type-2 ELJs, as they are subject to the greatest forces. The Type-3 and Type-4 ELJs are modeled after designs currently installed on much larger rivers and are presumed to be stable in this less-extreme setting in Gold Creek; they will be analyzed to ensure stability during final design.

Table 1 Summary of Stability Analysis for Type 1 and Type 2 ELJs

STRUCTURE TYPE	DESIGN FLOW RETURN INTERVAL	SLIDING FOS*	BUOYANCY FOS*	PILE BREAKAGE FOS*
Minimum FOS	100-year	1.75	2	1.5
Type-1 ELJ	100-year	6.7	4.6	2.6
Type-2 ELJ	100-year	6.4	4.9	3.3

- FOS (Factor of Safety) presented are for the worst case for each structure type

Influence of Proposed Restoration on Natural Processes

An assessment of existing natural processes was conducted to determine the potential impacts of restoration actions and resultant increase in hazard and/or risk. Risks associated with flooding and erosion from Gold Creek are discussed in detail previously in this report. The remaining processes evaluated that pose potential risk include long-term channel aggradation (sediment deposition), altering the accumulation and transport of LWM, and channel avulsion. The existing hazards and risks associated with each of these processes, and how they may change under the proposed condition were evaluated.

Aggradation Risk

The risk associated with long-term channel aggradation is a loss of flow conveyance over time that will result in increased inundation of the floodplain where there is development impacted. Channel aggradation typically occurs where the transport capacity of flow is diminished, and/or the supply of sediment is increased. Aggradation will continue to occur until the channel has reached a new equilibrium slope where the average incoming sediment load equals the outgoing load. Local, short-term aggradation is anticipated within the project reach in the lee of proposed instream structures, floodplains activated by the project, and some gravel bars. The channel will likely adjust to the proposed project following construction over several flood events of sufficient magnitude to mobilize the channel bed. The aggradation associated with these events will be local and short-term.

Long-term aggradation in the channel is a risk to existing infrastructure on the floodplains, and inundation frequency and magnitude is increased. Changes to the hydraulics within the project reach could influence sediment transport capacity within the creek, thus the hydraulic model results were used to access this potential. The long-term average transport of sediment through a reach typically occurs during the bankfull flow, approximate by the 1,100-cfs flow results in Appendix B. The change in flow velocity during this event is an indication of how sediment transport could be altered as a result of the project (Appendix B). Velocities in the main stem channel are typically reduced 3-ft/s during the 1,100-cfs flow, however there is an increase in flow velocities on the western floodplain channels averaging 4-ft/s. It is anticipated that most sediment in transport during formative flood events will be effectively moved through the project reach via the current main stem channel, and in the proposed new channel through the western floodplain. The predicted velocities in these channels averages 5-ft/s, exceeding the threshold needed to entrain and transport most sediment in the channel (Appendix B). The addition of the western floodplain side channel in transporting sediment through the project reach may increase the total transport capacity of the system, as there will now be 2 channel conveying water and sediment downstream (Appendix A and B).

The risk associated with long-term aggradation in Gold Creek as a result of the project is the same or less than the current risk. Sediment transport capacity from the main stem channel is reduced, and is increased in the proposed western floodplain side channels, as a result of the project. The predicted velocities indicate most sediment will be transported in both channels during formative flood events (Appendix B). The reduction of transport capacity in the main stem channel will result in local deposition where proposed velocities are lowest, commonly in the lee of instream structures and in backwater areas (Appendix B).

Influence of LWM on Risk

Large wood is present in Gold Creek, recruited into the channel via bank erosion and typically transported downstream. Few trees are of sufficient size to remain immobile following recruitment, however some do exist in the creek. More commonly trees remain at the toe of the bank where recruited, collecting debris during small floods and the annual freshet. During larger flood events these trees are mobilized and transported downstream, forming a new logjam over time. The transport rate of wood through the project reach is largely a function of the timing of large flood events, as this is when wood is in transport. The risk associated with LWM in Gold Creek is the hazard from flow deflection into areas where is puts existing development at risk (from either flooding and/or erosion).

Currently LWM is deposited naturally across the active channel, collecting on channel banks, logjams, and on gravel bars during flood events. The proposed project will alter the locations naturally occurring LWM will deposit, however it will occur in more predictable locations. Currently LWM deposition can occur nearly anywhere within the active channel, the exact location of which is difficult to predict. Under the proposed condition, with the addition of 71 stable hard points (ELJs) in the main stem channel for mobile wood to collect on, predicting where wood will accumulate is much easier to predict. Wood entering the channel from upstream will encounter the flow split at the upstream end of the project, with some LWM entering the new side channel and the remaining wood flowing down the main stem channel (Appendix A). The ELJs at the upstream end of the project are more likely to accumulate mobile LWM than those further downstream due to their relative position. Accumulation of wood on these ELJs will further constrict the channel, enhancing the hydraulic effect of the structure. Backwatering of flow upstream of the structure will be greater (increased flooding), and the velocity of flow deflected from the ELJ will be greater. The location of these structures where most of the natural wood accumulation will occur, is far from the existing development in the project reach where there is risk. Potential additional flooding due to accumulated LWM in this reach would likely remain in the current main stem channel, or re-enter the main channel prior to impacting any existing development. The greatest risk of potentially impacting downstream development is from the formation of a channel-spanning logjam on the main stem channel. This risk has been mitigated in the current design by spacing ELJs sufficiently apart to provide space for large trees to pass by, and by limiting the height of structure to allow wood to pass over structures during larger floods.

The proposed design will reduce to risks associated with LWM moving through the project, by strategically locating structures and designing them to shed wood during large floods (Appendix A). Risk is diminished relative to the current risk by improving the predictability of locations where wood will accumulate, and locating structures upstream of where there is current risk to collect incoming LWM.

Channel Avulsion Risk

Channel avulsions are the complete or partial capture of a channel, and the development of a new channel parallel to the existing channel. This process occurs when hydraulic gradients change, and the location where the steepest hydraulic grade (where water will primarily flow) changes on the landscape. Channel avulsions occur due to natural processes, and have occurred at Gold Creek within the project reach through what is now Helis Pond (NSD 2014b).

The proposed design will dramatically alter the hydraulic gradients and flow character of the creek, and natural process may further change flow following implementation. Thus, the risk of channel avulsion was assessed to determine hazards and risk to habitat and development resulting from avulsions. The proposed design includes new channels traversing the western floodplain, re-emerging back into the main stem channel (Appendix A). The risk of avulsion as a result of the project is expansion of these channels sufficient to capture more than half of the main stem channel. Capture of more than half of the main stem channel would negatively impact habitat in the main stem channel (dramatically enhanced by the project), and concern landowners. Hydraulic gradients and water surface elevations (WSE) were evaluated from the proposed and existing conditions hydraulic models to assess the potential for channel avulsions within the project reach.

Channel avulsions typically evolve by enlarging the new channel until the hydraulic gradient is reduced sufficiently to equilibrate with the original channel. This enlargement of the channel occurs through bank erosion and the propagation of headcuts upstream lowering the channel bed. As the channel enlarges more water is conveyed down the avulsion pathway, continuing to drive further adjustment of the channel. This process proceeds until the hydraulic gradient down the avulsion channel is the same as that down the original channel. Proposed channels were evaluated at the upstream end to assess the risk of flow capture due to a steeper hydraulic gradient and the potential for either channel (current main stem or new floodplain channel) to capture flow over time. The course of the channels and downstream confluence with the main stem were assessed to determine the risk from headcut formation and propagation.

The hydraulic gradients at the proposed channel inlets are similar down the main stem and proposed channels, indicating a small potential for either channel to capture more flow (Figures 1 and 2). Discontinuities in the flow velocity in the proposed side channels can contribute to the potential for a headcut to initiate. Examination of the proposed conditions hydraulic model results show there are not locations along the proposed channel where the velocity abruptly changes significantly (Appendix B). The downstream confluence with the main stem channel is the other location where there is a risk of a headcut forming as flow re-enters the channel. Steep hydraulic gradients at the confluence up the potential avulsion channel indicates a high risk of headcut initiation and potential propagation upstream. Figures 1 and 2 show there are not significant steep hydraulic gradients at the downstream confluence of the proposed channels and the main stem channel.

Under the current condition the risk of avulsion is associated with the transient accumulation of LWM during flood events, re-directing flow into a depression on the floodplain (relic channel) that is lower in elevation relative to the main channel. While these locations exist, the potential is greatest where there is currently activated floodplain flow (between RM 1.5 – 1.7) (Appendix B). During the 2-yr flood there are 3 channels flowing to the left (east) of the main stem channel between RM 1.5 – 1.7 (Appendix B). Each of these existing channel pose a potential risk from avulsion due to the adjacent development. The likelihood of a channel avulsion developing in any of these flow paths diminished from west to east, however an accumulation of LWM at the inlet could change the potential locally. The risk of this occurring is moderate as it has occurred in the past, but typically takes several events to develop and the logjam formed has been removed either naturally or otherwise. The risk associated with avulsion initiation in these side channels on existing development has been mitigated in the proposed design by incorporating structures at strategic locations to limit the potential for additional flow and headcut formation from occurring.

The primary drivers contributing to the potential for a channel avulsion were evaluated for the new channels included in the proposed design, and existing side channels potentially impacting existing development, and were determined to be low based on the assessment completed. The near equal hydraulic gradient at the channel inlets, and smooth gradients along the channels and at the downstream confluence, demonstrate a low risk of avulsion initiation.

Appendices

Appendix A – Preliminary Design Drawings
Appendix B – Hydraulic Model Results

References

Natural Systems Design, 2013a. Gold Creek Habitat Assessment & Conceptual Design Task 1: Data Inventory & Data Gap Analysis. Unpublished report prepared for Kittitas Conservation Trust.

Natural Systems Design, 2013b. Gold Creek Hydrologic Assessment Memo. Unpublished report prepared for Kittitas Conservation Trust.

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