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Kittitas Conservation Trust
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Attention: Mitch Long, Project Manager
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Subject: DRAFT Gold Creek 2014 Hydrologic Assessment Memo

PROJECT BACKGROUND

The Kittitas Conservation Trust (KCT) has identified the lower 3 miles (mi) of Gold Creek above Keechelus Lake near Snoqualmie Pass as a candidate location for habitat restoration (Figure 1). The primary objectives of the Gold Creek Restoration Project (Project) are to restore perennial flow and improve instream habitat for threatened Gold Creek Bull Trout (*Salvelinus confluentus*). The hydrologic, hydraulic, and geomorphic conditions within the project reach will be assessed to better understand the causal mechanisms contributing to seasonal dewatering, and the associated impacts to Gold Creek Bull Trout. These findings will be used to develop conceptual designs that meet the primary objectives of the Project by restoring natural geomorphic processes.

This assessment includes hydrologic monitoring conducted during the 2014 season, and builds upon similar monitoring that was completed in 2013 (NSD 2013). The intent of continuing monitoring of hydrologic data into 2014 was to better understand the variability of groundwater and surface water conditions year-to-year within the project reach to inform the development of restoration concepts that will maintain perennial flow in Gold Creek.

PROJECT REACH

Gold Creek drains a 14.3 mi² (9,122 acre) watershed in the Cascade Mountain range, flowing for approximately 8 miles before entering Keechelus Lake near Interstate 90 (Figure 1) (Craig 1997, Wissmar & Craig 2004, USFS 1998). The drainage basin ranges from 2,507 to 6,933 feet (ft) above sea level with a total relief of 4,426 ft. Average annual precipitation is 87.6 inches (in) and mean temperature ranges between 33 – 52 degrees Fahrenheit (Western Regional Climate Center 2013). The lower reach of Gold Creek (river mile (RM) 0 – 1.85) is a low-gradient (1%), braided pool riffle channel flowing through a broad, alluvial valley of highly permeable sand and gravel (USFS 1998, Collins 1997). The average bankfull width in this reach is 160 ft and valley width is 2000 ft. The middle reach (RM 2.33 – 2.9) is more confined, with average bankfull and valley widths of 50 and 800 ft, respectively (Collins 1997). This reach averages a 3% gradient, and is composed of pool-riffle segments dominated by cobble and boulders (USFS 1998, Collins 1997). The upper reach (RM 2.9 – 7.1) is a high-gradient (5%) channel of step-pool segments underlain by boulders and bedrock (Collins 1997). The upper reach is moderately confined, with an average bankfull width of 40 ft and a mean valley width of 250 ft. Fish passage is impeded by a bedrock cascade segment and a waterfall at RM 5.3 and 7.1, respectively (Craig 1997, Collins 1997). Stream discharge measurements in lower Gold Creek range from 12.3 cfs in mid-August to 19.9 cfs in late September and a peak flow of 331 cfs was measured in mid-June (Thomas 2001). In recent years, channel dewatering in the lower and middle reaches has been observed between mid-July and late September (Craig

1997, Mayo 2003). The dewatered segment has appeared to expand over time and directly impacts Bull Trout migration.

2014 HYDROLOGIC ASSESSMENT METHODOLOGY

The 2014 hydrologic monitoring used the same methodology as the 2013 study (NSD 2013) to describe the spatial and temporal character of ground and surface water gradients, and the timing and extents of dewatering in Gold Creek from July to October 2014. The network of monitoring locations was the same or similar to that used in the 2013 study, and collected water surface elevations (wse) for groundwater and surface water prior to, during, and following dewatering of the channel (Figure 2). These wse are used to establish flow gradients depicting direction and magnitude of water movement throughout the monitoring period. In addition to wse monitoring, the up and downstream extents of connected surface water were recorded to portray the spatial and temporal extent of channel dewatering.

MONITORING NETWORK

The layout of the monitoring network was setup in 2013 to optimize data locations for determining hydraulic gradients across and down Gold Creek valley. The locations of groundwater and surface water monitoring were limited by access, and total number of locations limited by available budget. Groundwater wells were limited to the eastern floodplain of Gold Creek, as there is no road access to the western floodplain for drilling equipment. Surface water stations were limited by landowner permission to below RM 0.52, and above RM 0.9.

The surface water stations were chosen to have one station upstream and one downstream of the dewatered reach extents, including one in Gold Creek Pond and Heli's Pond. The remaining surface water stations were located within the dewatered reach in deep pools, to maximize the period of record during the dewatering season. The groundwater wells were located to establish cross-valley gradients with the surface water stations, with a higher density of wells installed north of Gold Creek Pond.

Groundwater Wells

A total of 6 groundwater wells were included in the 2014 monitoring network (Figure 2), each at locations utilized in the 2013 assessment. An existing well installed by the U.S. Bureau of Reclamation west of the Gold Creek Pond parking lot (GW 1) was utilized again for this 2014 assessment. The remaining groundwater wells installed as part of the 2013 study were re-occupied for the 2014 monitoring season. One groundwater well location (GW 5) was re-drilled to a deeper depth (hit refusal at 25-ft) to provide minimum groundwater depths at this key location where groundwater was shown to be significantly lower than other locations in the 2013 study (NSD 2013). This well remained dry for much of the 2013 monitoring season, and the adjacent surface water station (SG 7) was the initiation point of dewatering in the channel. Increasing the depth of this well (GW 5) allowed measurement of the maximum depth of groundwater within the project reach to inform the development of restoration concepts.

Surface Water Stations

The 10 surface water stations used in the 2013 study were re-occupied for the 2014 assessment. These included 8 stations in the creek, and 1 each in Gold Creek and Heli's Ponds. The 8 stations in the creek include the downstream (SG 11) and upstream (SG 10) controls that are beyond the limit of seasonal dewatering, and 6 stations within the reach of the creek that dewater seasonally (Figure 2). Three of the 10 surface water stations (SG 7, 8, 9) moved sometime during the Winter of 2013-2014, and were re-established as part of the 2014 assessment at the nearest deep pool.

Gold Creek (SG 2) and Heli's Ponds (SG 8) were used as a proxy for groundwater elevations where they occupy the valley bottom. A new pressure transducer was installed at Gold Creek Pond to provide more data than the manual staff plate readings made during the 2013 study.

FIELD OBSERVATIONS

Several field surveys were conducted by NSD and KCT staff during the monitoring period to record the up and downstream extents of watered channel in Gold Creek, locations of pools holding water in dewatered sections of the creek, and to collect measurements at the surface water stations for calibrating the pressure transducer data. These locations were collected with GPS and accompanying photos taken periodically. The up and downstream extents of watered channel are used to depict the spatial and temporal character of dewatering in Gold Creek.

2014 HYDROLOGIC ASSESSMENT RESULTS

The initiation of dewatering for the 2014 season was recorded on the SG 7 pressure transducer on August 3rd, 10 days later than the 2013 season. Dewatering propagated up and downstream of SG 7, however several mid-summer rainfall events re-wetted portions of the channel temporarily. The channel completely re-wet (continuous surface flow through the project reach) 5 times over the course of the 2014 monitoring season in response to rainfall, defining 5 distinct dewatering events of varying duration and magnitude (spatial extent). Pools within the dewatered sections of the creek remained wet longer than other sections of the channel during dewatering, however most of the pools ultimately dried by late summer. The channel remained continuously flowing on October 17th, when all data was retrieved from the monitoring wells and surface water stations.

Daily rainfall recorded at Olallie Meadows, WA (NOAA SNOTEL station OMWW1) was used as a proxy for rainfall within the project reach for the duration of monitoring (Figure 3). The station is located on the southwestern side of Mount Catherine (on the southern side of Snoqualmie Pass across from Gold Creek valley) in the Cold Creek watershed at 3,700 ft elevation. The timing and magnitude of rainfall, and the resultant response in wet and watered channel extent are examined for the duration of monitoring. The 2014 monitoring season was significantly wetter than 2013, with at or above average precipitation during the summer months (Table 1). During the 2013 monitoring season early summer (June and July) precipitation was lower than average, with on 9% of normal in July 2013 (Table 1). The above average rainfall during the 2014 season had a dramatic influence on flows in Gold Creek, maintaining flow longer into the summer, reducing the duration of dewatering in the creek, as well as recharging groundwater.

TABLE 1 – 2014 SUMMER PRECIPITATION AT OLALLIE MEADOWS, WA

	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER
Average Precipitation (in) (1980-2014)	4.7	2.2	2.3	5.4	11.1
2013 Precipitation Total (in)	2.9	0.2	2.6	14.5	4.4
2013 % Average	61%	9%	112%	271%	40%
2014 Precipitation Total (in)	4.7	2.6	4.1	6.1	13.5
2014 % Average	99%	120%	177%	114%	121%

MONITORING NETWORK

The monitoring network consisting of 6 groundwater wells and 10 surface water stations collected data from July 18th to October 17th 2014. Wse were recorded at all monitoring locations, however gaps in the data exist where wse dropped below the pressure transducer. 3 of the 10 surface water stations (SG 6, 7, 9), and 2 of the 6 groundwater wells (GW 4 and 8) wet dry for a portion of the monitoring period. Dewatering was first recorded at SG 7 on August 3rd, 2014. During the 2013 monitoring season 5 surface water stations and 4 groundwater wells went dry during monitoring, a 20-25% increase compared to 2014. SG 2 and 8 (Gold Creek Pond and Heli's Pond, respectively) are assumed to represent groundwater wse.

Figure 4 shows recorded wse at all of the monitoring locations over the course of the study. Some surface water stations and groundwater wells have missing data, representing time when the wse fell below the transducer at the location. The paired surface water and groundwater locations are shown in more detail in Figures 5-9. To better compare the temporal changes in wse between all of the surface water stations and groundwater wells, wse was scaled to start at 0-ft at the start of the monitoring period (Figure 10 and 11). Once scaled, the surface water stations (Figure 10) and groundwater wells (Figure 11) show that wse responds differently depending on the location along the creek. The relative change in wse demonstrates that some the stations respond similarly, with similar rates and magnitudes of change over the course of the monitoring season.

Upstream & Downstream Control Water Surface Stations

SG 10 was setup to capture the surface flow in Gold Creek upstream of the dewatered reach. This station is characterized by punctuated rapid increases in wse in response to rainfall events (Figure 3) that occurred during the 2014 monitoring season (Figure 10). The wse leveled off around September 16th and remained relatively constant at baseflow until the rainfall event on September 26th. The relatively constant summer base flow at SG 10 suggests adjacent groundwater elevations are sufficient to maintain the creek wse during the dry summer months at this reference location.

SG 11 is located downstream of the dewatered channel extent, and is below the confluence of the perennial Gold Creek outlet channel. Outflow from Gold Creek Pond maintains perennial flow in the outlet channel, and is sufficient to keep Gold Creek flowing year-round downstream of the outlet confluence (Figure 10). This highlights the importance of where the pond's outlet channel enters the creek. WSE at this station varied the least of all the surface water monitoring locations, and increased in response to the mid-summer rainfall events. This in contrast to 2013, where the mid-summer rainfall events did not increase wse at SG 11. The relatively higher wse at SG 11 compared to SG 10 (Figure 10) is attributed to the additional flow from the outlet channel.

Instream Surface Water Locations

Due to multiple rainfall events sufficient to re-wet the entire channel, multiple dewatering events occurred during the 2014 monitoring season. Five separate dewatering events occurred where some part of the channel dewatered, all of which completely dewatered the channel at SG 7. WSE at SG 7 declines the most rapidly compared to the other surface water stations, followed by SG 6, SG 9, SG 3, SG 5, SG 10, SG 4, and SG 11, respectively (Figure 10). SG 7 was dry for most of the monitoring period, only briefly rewatering for 2-4 days (Figure 10) following the mid-summer rainfall events (Figure 3). SG 9 dewatered 2 times (minus a brief rewatering during one event) during the monitoring period, and remained wetted following these dewatering events for 2 weeks before remained watered. SG 6 was the only other surface water station to record dewatering in the channel, occurring for a 10 day period from September 15th to the 25th.

Groundwater Locations

The multiple rainfall events during the 2014 monitoring season recharged groundwater throughout the basin sufficiently that only 2 of the 6 groundwater wells went dry for a portion of the time (Figure 11). The 2 surface water stations representative of groundwater elevations (SG 2 (Gold Creek Pond) and SG 8 (Heli's Pond)) both remained wetted during the 2014 season. SG 2 varied the least of all the stations monitoring groundwater use, followed by GW 1 which is located just down valley of Gold Creek Pond, and GW 7 located just up valley of Gold Creek Pond (Figure 2). The near constant use of Gold Creek Pond (SG 2) during the monitoring period limits the range of use in the adjacent groundwater locations. GW 5 had the fastest rate of declining use, followed by SG 8, GW8, GW 4, GW 3, GW 7, GW 1, and SG 2, respectively (Figure 11). The timing of surface water stations drying directly correlates to the rate of use decline in the groundwater wells. For example, SG 7 was the first station to go dry in the creek, and the closest groundwater well is GW 5 (well that dropped the fastest). The second station to go dry (SG 9) is closest to Heli's Pond (SG 8), which was the second fastest declining groundwater station. Similar to 2013, GW 8 was the third fastest declining groundwater well, indicating groundwater elevations on the eastern side of the valley drop faster than on the western side.

Paired Surface Water/Groundwater Locations

The use at the groundwater stations is higher at each of the paired surface water/groundwater locations (Figures 5, 6, 8), except for at SG 6/GW 4 (Figure 7), and at SG 4/GW 7 (Figure 9) where the groundwater well is located down valley of the paired surface water station (Figure 2). This demonstrates that groundwater is supplying water to the creek throughout the summer, and the creek is not losing to groundwater but rather dropping with groundwater. Critical groundwater elevations that trigger dewatering in the adjacent creek can be determined by comparing the use of the groundwater well when the surface water station goes dry. At the SG 9/SG 8 (Heli's Pond) location, the creek dewateres when the use of Heli's Pond drops below approximately 2600-ft use (Figure 5). The use at SG 9 is approximately 1.6-ft below the use in Heli's Pond (SG 8), but increases to 2.4-ft lower as dewatering initiates in the creek (Figure 5). Using the 2.4-ft measurement, when Heli's Pond reaches its minimum use elevation of 2597.6-ft, the predicted use in the creek at SG 9 is 2596.3-ft, which is approximately 1-ft below the channel bed. At the initiation point of dewatering in the creek (SG 7), the creek dewateres when the use of GW 5 drops below approximately 2576.8-ft use (Figure 6). The use at SG 7 is approximately 1.5-ft below the use at GW 5. Using this measurement, when GW 5 reaches its minimum use elevation of 2572.5-ft, the use at SG 7 is predicted to be at 2571-ft, approximately 4-ft below the channel bed. Because GW 4 went dry before dewatering occurred at SG 6 (Figure 7), there is insufficient data to approximate the maximum depth of water below the channel at this location.

2014 FIELD OBSERVATIONS

The observed extents of wetted channel collected during several field surveys were used to map the spatial and temporal changes in the wetted channel (Figure 12 -14). The first field observation of dewatering was on August 7th (Figure 12), which extended from RM 1.47 to RM 1.54 (370-ft of dewatered channel) (Table 2). Dewatering was first recorded at SG 7 on August 3rd. The dewatered segment of the creek expanded upstream to RM 1.74 at an average rate of 211-ft/day, and only expanded downstream to RM 1.43 at an average rate of 42-ft/day by August 12th to 1637-ft of dewatered channel (Figure 12 Table 2). A significant rainfall on August 13th (1.7-in at Olallie Meadows, Figure 3) rewetted the entire channel, and remained so until August 16th (based on SG 7 going dry, Figure 10). By August 18th a dewatered segment of the creek was again observed near SG 7, extending from RM 1.5 to RM 1.52 (106-ft of dewatered channel) (Figure 12, Table 2). This dewatering expanded upstream to RM 1.66 at an average rate of 246-ft/day, and downstream to RM 1.48 at an average rate of 35.2-ft/day by August 21st ultimately to 950-ft of dewatered channel. By August 28th dewatering expanded to 3485-ft of channel, between RM 1.24 and RM 1.9,

expanding up and downstream 1267-ft at an average rate of 181-ft/day (Figure 13, Table 2). Significant rainfall on August 31st and September 3rd (1.2-in and 1.3-in respectively at Olallie Meadows, Figure 3) rewatered the entire channel, and remained so until September 5th (based on SG 7 going dry, Figure 10). By September 10th a dewatered segment of the creek was again observed near SG 7, extending from RM 1.42 to RM 1.77 (1848-ft of the channel) (Figure 13, Table 2). This dewatering expanded upstream to RM 1.94 at an average rate of 180-ft/day, and downstream to RM 1.1 at an average rate of 338-ft/day by September 15th to 4435-ft of dewatered channel (Table 2). By September 19th dewatering contracted 105-ft to 4330-ft of channel, between RM 1.06 and RM 1.88 (Figure 13, Table 2). Despite the contraction of the dewatered channel segment, its downstream extent expanded 2011-ft (further downstream), while the upstream extent moved downstream 316-ft (total contraction of 105-ft). A small rainfall event (0.2-in at Olallie Meadows, figure 3) may have been sufficient to rewater the upstream end of the dewatered channel, but was not sufficient to recharge groundwater sufficiently to limit downstream propagation of the dewatered segment of the channel. By September 22nd dewatering expanded to 4805-ft of channel, between RM 1.06 and RM 1.97, the maximum extent observed during the 2014 monitoring season (Figure 14, Table 2). The downstream limit of dewatered channel remained at RM 1.06, but the extent expanded upstream at an average rate of 158-ft/day between September 19th-22nd (Table 2). A significant rainfall event between September 24th and 30th totaling 3.5-in of precipitation at Olallie Meadows (Figure 3) was sufficient to rewet the entire channel, and remained so until October 2nd (based on SG 7 going dry, Figure 10). By October 8th a dewatered segment of the creek was again observed near SG 7, extending from RM 1.4 to RM 1.79 (2059-ft of dewatered channel) (Figure 14, Table 2). A significant rainfall event between October 11th and 17th totaling 3.5-in of precipitation at Olallie Meadows (Figure 3) was sufficient to rewet the entire channel, and was observed to be continuously flowing on October 18th at which time all dataloggers were retrieved from each of the monitoring locations marking the end of the 2014 monitoring season.

TABLE 2 – 2014 DEWATERED CHANNEL SUMMARY

DATE	MAX UPSTREAM EXTENT (RM)	MAX DOWNSTREAM EXTENT (RM)	MAX EXTENT MOVEMENT UPSTREAM (MI)	MAX EXTENT MOVEMENT DOWNSTREAM (MI)	RATE OF MOVEMENT UPSTREAM (FT/DAY)	RATE OF MOVEMENT DOWNSTREAM (FT/DAY)	TOTAL LENGTH OF DEWATER CHANNEL (MI)	TOTAL LENGTH OF DEWATERED CHANNEL (FT)
7/18/14	-	-	-	-	-	-	-	0
8/7/14	1.54	1.47	-	-	-	-	0.07	370
8/12/14	1.74	1.43	0.2	0.04	211.2	42.2	0.31	1637
8/13/14 *	-	-	-	-	-	-	-	0
8/18/14	1.52	1.5	-	-	-	-	0.02	106
8/21/14	1.66	1.48	0.14	0.02	246.4	35.2	0.18	950
8/28/14	1.9	1.24	0.24	0.24	181	181	0.66	3485
9/3/14 *	-	-	-	-	-	-	-	-
9/10/14	1.77	1.42	-	-	-	-	0.35	1848
9/15/14	1.94	1.1	0.17	0.32	179.5	337.9	0.84	4435
9/19/14	1.88	1.06	0.06	0.04	79.2	52.8	0.82	4330
9/22/14	1.97	1.06	0.09	0	158.4	0	0.91	4805

DATE	MAX UPSTREAM EXTENT (RM)	MAX DOWNSTREAM EXTENT (RM)	MAX EXTENT MOVEMENT UPSTREAM (MI)	MAX EXTENT MOVEMENT DOWNSTREAM (MI)	RATE OF MOVEMENT UPSTREAM (FT/DAY)	RATE OF MOVEMENT DOWNSTREAM (FT/DAY)	TOTAL LENGTH OF DEWATER CHANNEL (MI)	TOTAL LENGTH OF DEWATERED CHANNEL (FT)
9/24/14 - 9/30/14 *	-	-	-	-	-	-	-	-
10/8/14	1.79	1.4	-	-	-	-	0.39	2059
10/18/14	-	-	-	-	-	-	-	0

* indicates rainfall event sufficient to rewet the entire channel

COMPARISON TO 2013 MONITORING

The data collected during the 2014 monitoring season were compared to that collected in 2013 to evaluate the difference in wse at each of the monitoring locations (Figure s 15 - 17).

Baseflow conditions in the creek remained the same as last year. At SG 10 and 11 (up and downstream control stations) the minimum flow (baseflow) during the monitoring period remained the same as in 2013 (Figure 16). The mid-summer rainfall events produced brief increases above baseflow wse during 2014, and were of larger magnitude than those that occurred in 2013 (Figure 3). Thus the creek remained above baseflow longer following the rainfall events when compared to 2013. Similarly, at SG 3 the mid-summer rainfall events are shown superimposed upon baseflow wse, however the baseflow wse was the same as that which occurred in 2013 (Figure 15). SG 3, 4, and 5 also show that baseflow wse was similar in 2014 to that in 2013, with the brief increases in wse due to the mid-summer rainfall events. At SG 4 and 5, these rainfall events were sufficient to keep the creek watered at these locations, whereas both locations experienced drops below baseflow in 2013 and SG 5 completely dewatered (Figure 15). The surface water stations that dewatered during the 2014 and 2013 monitoring seasons (SG 6, 7, 9) all experienced dewatering for a shorter time in 2014, and at SG 6 and 9 there were fewer dewatering events (Figure 2 15, 16). At SG 7 there were more dewatering events in 2014 as the station rewet several times in response to the mid-summer rainfall events, whereas the station experienced a single prolonged dewatering event during the 2013 monitoring season. The fluctuation of Gold Creek Pond (SG 2) remained nearly identical to that recorded in 2013.

Similar trends are shown in the groundwater wells when comparing to the 2013 data. Overall, groundwater elevations were higher during the 2014 season, and wse did not drop as low as in 2013 (Figure 17). The groundwater wells recharged significantly during the mid-summer rainfall events, with wse rising back to near the wse at the start of the monitoring season (Figure 17). Monitoring well GW 1, located down valley of Gold Creek Pond did not drop more than 0.5-ft during the entire 2014 season, compared to 1.25-ft during the 2013 season (Figure 17).

CONCLUSIONS

Based on the findings from the 2014 monitoring data and field observations, coupled with the 2013 data and observations, a more detailed understanding of the spatial and temporal character of dewatering in the creek emerges, and how that character is influenced by historic disturbances.

During the 2014 monitoring season a single dewatering reach emerged, unlike in 2013 when two distinct reaches of dewatering formed. The shorter (length and duration) dewatered reach between RM 0.5 and

0.66, just upstream of the confluence with the outlet channel, did not appear in 2014. Dewatering in the upstream dewatered reach was first recorded at SG 7 on August 3rd, 2014, 10 days later than in 2013. The downstream extent of the dewatered reach was similar to that in 2013, and the upstream extent was 265-ft further downstream compared to 2013. The maximum observed extent of dewatering reached 0.91-miles, compared to 1.09-miles during the 2013 season. The later onset of dewatering, and the shorter spatial extent during the 2014 monitoring season is attributed to the above average rainfall (Table 1) during this time.

Both the field observations and monitoring data show dewatering initiates near RM 1.5 (Figure 12), and progresses up and downstream from this point in the channel. The rate of groundwater decline is also highest near RM 1.5 (at GW 5, Figure 11), and generally declines less rapidly closer to Gold Creek Pond. These observations are the same as in 2013. Figure 18 shows wse contours during dewatering (left), rewetting in response to rainfall (middle), and subsequent dewatering (right) of the channel during the 2014 monitoring season. The influence of Gold Creek Pond on groundwater gradients across the entire valley bottom is immediately apparent, as the northeastern corner of the pond extends up-valley relative to the northwestern corner (Figure 18). The orientation of the northern shoreline of Gold Creek Ponds is east west, which is 20-25° offset from the axis of the valley (roughly northeast-southwest trending). This orientation projects the Pond's influence about 460 ft further upstream than if it was oriented perpendicular to the valley and lowers groundwater elevations on the eastern side of the valley relative to the western side to water away from the channel. Prior to the excavation of Gold Creek Pond, groundwater gradients would be expected to have been generally perpendicular to the valley axis, with Keechelus Lake as the downstream baselevel control. Gold Creek Pond does not significantly change wse during the dewatering season (Figure 11), and currently acts as baselevel control for groundwater elevations up-valley of the pond. Figure 18 shows that groundwater elevations immediately up-valley of the pond remain relatively constant up to elevations of 2454-2550 ft over the dewatering period. However, further up-valley the groundwater elevations drop as much as 4.5 ft, with the greatest drop along the eastern side of the valley relative to the western side due to the orientation of Gold Creek Pond. Near RM 1.0 the creek intercepts groundwater flow from the western valley floodplain, which is coincident with the downstream limit of dewatering. This groundwater from the western valley floodplain was sufficient to keep SG 4 and 5 wetted throughout the 2014 monitoring season, but was not during the 2013 season.

Figure 19 demonstrates the effect of Gold Creek Pond on groundwater elevations in the valley. As stated earlier, Gold Creek Pond provides near constant baselevel control on groundwater elevations, however this elevation is approximately 5-ft below the pre-pond (natural) groundwater elevation at the northern center end of the pond (Figure 19). On the eastern side Gold Creek Pond groundwater elevations are close to 10-ft below the pre-pond elevation (Figure 18). Suppression of groundwater elevations due to Gold Creek Pond is shown to extent up to RM 1.75 (Figure 19), and likely extends up-valley to about RM 2.0 on the eastern side of the valley, just upstream of Heli's Pond (RM 1.9) (Figure 18).

The presence of perched wetlands on the western valley floodplain supply subsurface flows to the creek during the summer months. Similar wetland features are currently absent on the eastern valley bottom, but once were present where Gold Creek Pond was excavated (Figure 20). This historic wetland complex would have had a similar contribution to groundwater elevations on the eastern valley floodplain during the summer months, resulting in much higher groundwater elevations than currently exist. These higher groundwater elevations would have sustained more surficial flow to Gold Creek and limited the duration and magnitude of dewatering during normal summers.

RECOMMENDATIONS

Historic disturbances within Gold Creek valley have altered natural geomorphic processes and hydrologic conditions, resulting in degraded habitat conditions. The cumulative impact of these disturbances has resulted in an over-widened channel lacking instream complexity and cover, that dewateres annually for a significant reach during the summer months.

Based on this second year of surface and groundwater monitoring, it is clear that Gold Creek Pond is the major contributor to seasonal dewatering of Gold Creek. The primary influence of the pond is to lower groundwater elevations on the eastern side of the valley relative to the western side, modifying the natural gradient of flow toward the eastern floodplain and away from Gold Creek. In addition to modifying flow direction, the pond decreases groundwater elevations up to 10-ft from what would be their natural elevation. Both of these influences of the pond are a result of the orientation and size of the pond relative to the valley.

Restoring Gold Creek Pond back to the historic wetland complex (Figure 20) would provide the greatest benefit to maintaining perennial flow in Gold Creek. This approach would include the following elements:

1. Fill of the pond back to the historic floodplain elevation (using fill material of similar grain size and hydraulic conductivity, K, to that removed) and restore historic wetland mosaic
2. Lower berms surrounding the pond (material will partially contribute to pond fill)
3. Remove riprap or other artificial barriers to channel migration
4. Fill the outlet channel (using fill material of similar size to that used to fill the pond)
5. Establishment of new tributary alignment from hillslope drainage East of pond
6. Plant of native vegetation appropriate for ecotone to be established (wetlands, streamside, uplands)
7. Establishment of new ADA compliant trail around/through new wetland mosaic
8. Establishment of new picnic area

Several alternatives to completely filling Gold Creek Pond exist that would reduce the spatial extent and duration of dewatering in Gold Creek. These alternatives would improve maintaining flow in Gold Creek, however they would likely not be as effective as complete filling of the pond and restoration back to the historic wetland complex that existed prior to excavation of the pond. Some of the alternatives considered include:

- Partial fill of Gold Creek Pond
 - Focus fill on the northeastern corner to realign the northern shoreline more perpendicular to the valley axis
 - Restore northeastern corner of the pond back to the historic floodplain elevation creating wetland mosaic
 - Relocate the outlet channel to discharge into Gold Creek near the northwestern corner of the pond (near SG 2, Figure 2), raise the new inlet invert elevation of the outlet channel (relative to current invert elevation) to permanently raise the pond five to six feet
 - Lower berm surrounding pond and using material to fill pond and current outlet channel
 - Re-establish ADA trail where is removed in regarding the berm
- Permanently raising the use of Gold Creek Pond using any of the following approaches

- Relocate the outlet channel to discharge into Gold Creek near the northwestern corner of the pond, raise the new inlet invert elevation of the new outlet channel (5-6 ft relative to current invert elevation)
- Relocate the outlet channel to discharge into Gold Creek near the southwestern corner of the pond, raise the new inlet invert elevation of the new outlet channel (5-6 ft relative to current invert elevation)
- Either raise the invert elevation of the current outlet channel inlet, or build structure in outlet channel to raise wse in the pond. This would require raising SW berm where picnic area is currently located and re-constructing new picnic area.
- Divide Gold Creek Pond into multiple three smaller terraced pools that would each raise WSE about two feet, so that furthest upstream pool at NE corner of pond would have WSE six feet higher than existing pond elevation. Berms across the current pond to create the pools will require an impermeable core and engineered spillways. The berms would build upon the existing high ground within the pond.

Any restoration modifications to Gold Creek Pond will include reestablishing and improving existing recreational infrastructure. To preserve the recreational access and use at Gold Creek, modifications to the ADA trail and picnic area would be required for each of these alternatives. Modifications would include changing the location and elevation of these features to accommodate the higher wse of the pond. Currently the ADA trail takes visitors through a completely artificial landscape that is responsible for the ecological degradation of Gold Creek. Site restoration will provide visitors a much more natural experience and valuable historic lesson on landscape disturbance and rehabilitation, substantially increasing the interpretative value of the ADA trail and picnic facilities.

In addition to Gold Creek Pond, we recommend restoration of Heli's Pond to provide a similar benefit to that described for Gold Creek Pond (locally raise groundwater elevations). Heli's Pond was excavated in a relic channel flow path, however restoration of the site could include several options, including:

- Complete fill of pond and outlet channel, planting to restore the area to forested floodplain
- Partial filling of the pond to establish isolated wetland mosaic, filling outlet channel

Restoration at Heli's Pond would also include relocation of the existing trail around the pond to preserve that recreational benefit. While the magnitude of anticipated response in Gold Creek is less than that for filling Gold Creek Pond, filling Heli's Pond could reduce the upstream limit of dewatering in the creek, and/or reduce the duration of dewatering in the adjacent creek. Restoration of Heli's Pond could serve as a pilot project for restoration of Gold Creek Pond, due to the smaller scale but similar approach to that proposed for Gold Creek Pond.

The finding of the geomorphic assessment (NSD 2014) highlights the role of channel destabilization from historic logging of the riparian corridor contributing to habitat degradation in Gold Creek. The over-widened channel has resulted from a loss of large riparian trees that once were recruited into the channel as the channel banks eroded. These large trees formed large logjams, that over time helped to stabilize the channel by partitioning shear stress and reducing further bank erosion. This dynamic equilibrium allowed for wood and sediment recruitment into the channel while providing a much more narrow and multi-thread channel with habitat and hydraulic complexity from instream wood. Key to restoring habitat quantity and quality in Gold Creek is to narrow the active channel, increase the number to channel flowpaths where possible, and increase wood loading and frequency of large logjams.

Restoration of the historic channel width and number of flowpaths would have the greatest benefit in reducing infiltration area and the resultant loss of surface flow to groundwater during the summer months. Given the length of channel impacted, targeted restoration of the most significantly over-widened reaches

should be prioritized. Key to restoring a narrower channel is the creation of a hardened floodplain along the margins of the current channel to mimic the historic role large logjams once provided. The hardened floodplain would be composed of a matrix of large timber of varying width constructed on gravel bars and partially to completely backfilled and planted with trees. The hardened floodplain will function by :

- Limiting bank erosion and further widening of the active channel
 - o Hardened floodplain to be constructed along current channel banks without large riparian trees along margin to limit erosion into these areas.
 - o Moving banks inward from both sides to reduce channel width
- Roughen exposed gravel bars to promote formation of new floodplain
 - o Extend structure from current bank onto adjacent gravel bars
 - o Partitioning of shear stress due to roughened floodplain will reduce sediment transport capacity, and will fill-in and further bury wood over time creating new floodplain
- Formation of new channel flowpaths where gaps in structure allow flow
 - o Gaps in structures will allow new channel formation at designed locations to provide flow conveyance during formative flow events lost from narrowing channel width

The proposed architecture, locations, and dimensions will be determined in the conceptual design phase of the project, however the overarching goal of narrowing the channel to reduce infiltration, and formation of multiple channel flowpaths to provide conveyance lost by narrowing the channel and to improve instream habitat conditions will remain. Installation of large logjams in the narrowed channel are proposed that will provide instream habitat complexity and cover, form and maintain pools, and if buried into the channel bed would help force hyporheic flow upward to help maintain perennial flow. Buried log sills spanning the creek channel could be installed to further force hyporheic upwelling in the creek to further help maintain perennial flow during the summer months. The locations, architecture, and dimensions of instream wood placements will be further evaluated during concept design development.

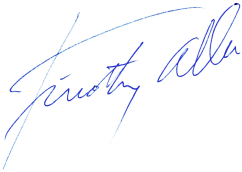
These recommendations are consistent with those proposed in 2013 (NSD 2013), and build upon the concepts based on observation and assessments completed as part of this study.

LIMITATIONS

We have prepared this report for Kittitas Conservation Trust, their authorized agents and regulatory agencies responsible for the Gold Creek restoration project. Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices for geomorphology and hydraulics 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, expressed or implied, should be understood.

We appreciate this opportunity to be of service to Kittitas Conservation Trust for this project and look forward to continuing to work with you. Please call if you have any questions regarding this report, or if you need additional information.

Sincerely,
Natural Systems Design, Inc.



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Attachments:

- Figure 1 – Project reach map
- Figure 2 – Monitoring network locations
- Figure 3 – Rainfall during the 2013 and 2014 monitoring periods
- Figure 4 – Water surface elevations at all monitoring locations for the entire monitoring period
- Figure 5 – Water surface elevations at SG 8 and 9 for the entire monitoring period
- Figure 6 – Water surface elevations at SG 8 and GW 5 for the entire monitoring period
- Figure 7 – Water surface elevations at SG 6 and GW 4 for the entire monitoring period
- Figure 8 – Water surface elevations at SG 5, GW 3 and GW 8 for the entire monitoring period
- Figure 9 – Water surface elevations at SG 2, 3, and 4, and GW 7 for the entire monitoring period
- Figure 10 – Relative wse at all surface water stations for the entire monitoring period
- Figure 11 – Relative wse at all groundwater wells for the entire monitoring period
- Figure 12 – Extent of dewatered channel between August 7th and August 21st
- Figure 13 – Extent of dewatered channel between August 28th and September 19th
- Figure 14 – Extent of dewatered channel between September 22nd and October 8th
- Figure 15 – WSE Comparison of 2013-2014 monitoring locations (SG 2, 3, 4, 5, 6, 7)
- Figure 16 – WSE Comparison of 2013-2014 monitoring locations (SG 8, 9, 10, 11)
- Figure 17 – WSE Comparison of 2013-2014 monitoring locations (GW 1, 3, 4, 5, 7, 8)
- Figure 18 – Water surface elevations during dewatering, following re-wetting, and subsequent dewatering
- Figure 19 – Groundwater and ground elevation profile through project reach down the center of the valley

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