

Prepared for:
Angus Mackay, Fund Coordinator,
Pacific Salmon Commission

Completion Report

Kleanza Creek Spawning Weirs Feasibility Project



Executive Summary

With the funding of the Pacific Salmon Commission and the generous contributions and in-kind donations from various federal and provincial agencies, we have been able to examine the feasibility of using rock weirs to restore spawning habitat to the lower reach of Kleanza Creek, which was heavily degraded in the 1960s as a result of stream training related to highway construction.

This report documents the study activities that have taken place during 2014, and discusses results of baseline work and consultation, leading to the recommendation that weirs be installed on Kleanza Creek.

Project activities, listed chronologically:

1. Weekly Fyke net trapping beneath Highway 16 bridge, March 21st through June 6th, 2014, capturing outmigrating pink, chinook, chum and coho salmon fry and documenting juvenile salmon and trout moving through the system during the spring season.
2. Engineering surveys, April 28th through August 25th, 2014.
3. Site visit by DFO Resource Restoration Unit June 5th, 2014 (followed up by a letter of support—attached).
4. Stream walk for spawning adult steelhead and steelhead redds, June 16th.
5. Site visit by FLNRO's senior research hydrologist, research geomorphologist, and the provincial ecosystem specialist for this area, July 16th (followed up by letters of support—attached).
6. Weekly stream walks documenting pink salmon spawning, August 6th through September 26th, 2014.
7. Substrate transects, Aug 19th.
8. Minnow trapping on Kleanza Creek within project site and at locations upstream of the falls-cascade barrier, August 28th to 29th.
9. Jeff Lough (provincial fisheries biologist) led electroshocking transects in and above the proposed weir area, September 8th.
10. Flow measurements, December 13th.
11. Consultation with regulatory agencies, February through December.
12. Field data organization and analysis, and reporting, November through December.

All findings point to the likelihood that weirs can be constructed without negative impacts to the stream channel or to downstream infrastructure. Fish and fish habitat sampling and observations indicate that there is minimal habitat complexity within the existing channel, and that both rearing and spawning habitat could be effectively restored and enhanced through the improvement of structural complexity, namely the installation of rock weirs.

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Introduction

Kleanza Creek (watershed code 400-231800-) is a 5th order tributary to the Skeena River, draining approximately 655 kilometers of stream in a 202 square kilometer watershed. Near its mouth, Kleanza Creek is crossed by a modern two-lane highway bridge. This bridge was constructed in 1966 when Highway 16 was realigned: The old highway bridge was located approximately 775 m upstream; the old bridge was removed, and the old road largely obliterated, with the exception of the north side, which currently provides access to Kleanza Creek Provincial Park Campground (Figure 1). Between the old and new highway bridges—a span of approximately 600 m—the creek was trained using high rip-rap berms. All off channel habitat was cut off at this time, including a major side channel to the south (left bank) of the current stream channel. Because the berming straightened this extensive segment of creek, most habitat complexity was entirely lost. Increased flows and a lack of structural habitat elements have resulted in a major loss of spawning gravels through this reach.



Kleanza Creek watershed is located within traditional Tsimshian Territory, with a long history of use by the Kitselas Band.

This project is a feasibility study into the possibility of installing rock weirs within the stream channel, in order to provide areas of gravel accumulation for spawning salmonids. A variety of biophysical background data have been collected to support analysis of this concept: Baseline fish sampling and spawner surveys were undertaken at key migration periods (e.g. smolt outmigration,

steelhead and pink salmon spawning) and for rearing fry and resident trout and char. Baseline substrate surveys and flow data were collected to allow pre-/post- monitoring and analysis should the weirs be constructed.

This project proposes to assess the feasibility of installing engineered rock weirs in the mainstem stretch that was trained. These weirs would capture smaller substrates, restoring viable spawning in the affected areas. Mainstem weirs would also inhibit the unnatural accelerated deposit of material into the fan, providing more stability to the side channel habitat downstream. Similar weirs were constructed in Anderson Creek (Kitimat Watershed) with immediate and continuing positive results in 2011, 2012, 2013 and 2014.

Existing Fisheries Information

A considerable amount of information about fish utilization of the Kleanza watershed is documented and available: A *Reconnaissance (1:20,000) Fish and Fish Habitat Inventory* report was prepared in 2000 (Applied Ecosystem Management Ltd.), documenting both fish species presence and barriers.

Although good habitat is known throughout the watershed, barriers at the upper end of reach 1 (i.e., from the cascade-falls located in Kleanza Creek Provincial Park, approximately 1400m upstream of the Highway 16 bridge) prevent most anadromous fish from accessing the remainder of the watershed.

Current knowledge is that pink (*Oncorhynchus gorbusha*), chinook (*O. tshawytscha*) and chum (*O. keta*) salmon are known to spawn in the upper section of reach 1 (that is, up to the first cascade/canyon). Coho spawning has been reported in reach 2, with an important holding area located in the pools immediately below the cascade and waterfall—notably, coho and steelhead are the only anadromous species documented above this barrier. Resident Dolly Varden char (*Salvelinus malma*), bull trout (*S. confluentus*), cutthroat trout (*O. clarki*), rainbow trout (*O. mykiss*), mountain whitefish (*Prosopium williamsoni*) and kokanee (*O. nerka*) have been identified throughout much of the watershed. Numerous species are also known to use the area near the confluence with the Skeena River, including sockeye salmon (*O. nerka*), longnose dace (*Rhinichthys cataractae*), peamouth chubb (*Mylocheilus caurinus*), burbot (*Lota lota*), and prickly sculpin (*Cottus asper*). (Applied Ecosystem Management Ltd. 2000; MoE 2014 and 2014a).

Partners and Stakeholders

Partners in this feasibility projects have made major contributions by providing funding, collaboration, and technical expertise.

The BC Ministry of Transportation and Infrastructure (MoTI), under the direction of Daryl Nolan (Environmental Manager, Prince George, BC), has provided funding for engineering services, and has made in-house resources available to facilitate the project and reduce hurdles.

Fisheries and Oceans Canada (DFO) have provided technical and specialist support, shared resources (e.g. Fyke net and box trap, Swoffer velocity meter, etc.), and contributed to data analysis.

BC Ministry of Forests, Lands and Natural Resource Operations (FLNRO) have provided time and support for the project. Matt Sakals (Research Geomorphologist, Smithers), Dave Wilford (Research Hydrologist/Team Leader, Smithers), Jeff Lough (Fisheries Biologist, Smithers) and Chris Broster (Ecosystems Officer, Terrace) contributed their time and expertise to the feasibility project.

The Kitselas Band (Tsimshian Nation) is a primary stakeholder for this project, as the project site is located within Tsimshian traditional territory. Kitselas Technicians participate in several of the biophysical aspects of the feasibility study. In particular, the assistance of Aaron McMillan was indispensable during substrate survey, fish sampling and salmon spawning assessments.

BC Ministry of Environment (MoE), Parks and Protected Areas (BC Parks), under the authority of Ben Sabal (Area Supervisor, Lakelse Douglas Channel), support the project, and has provided review of the project boundaries.

Regulatory Considerations

Both access and in-stream construction activities require consideration of a number of legislative and bureaucratic requirements, including land ownership.

Transport Canada was consulted early in the feasibility study to determine the need for review under the *Navigable Waters Protection Act*. A discussion with Brent McGee (pers. comm. 2014) indicated that the project, should it prove feasible, would fall under the new *Navigation Protection Act*, and as such, would not require review or authorization (under the new Act, Kleanza Creek is not on the *Schedule* of waterbodies that require review). Although he did not recommend it for our project, McGee noted that it is possible to opt-in for an official project review if certain criteria are met (for example, if there is documented historical navigational use with which the project may substantially interfere).

DFO was consulted regarding approval requirements should weir construction prove both feasible and advisable. The project type falls under *Projects that Do Not Require Review* (DFO 2014).

Unless MoTI becomes a partner in the construction of the weirs, an MoTI permit will be required for use and alteration of access areas along the trained stream banks and approaches.

Because, in the area of interest, ownership of the berms and right-of-ways lies with MoTI, it appears that Kleanza Creek Provincial Park boundary is outside of the project limits, and no use of the park has or will be required for feasibility or construction works (Appendix A, Legal Boundaries). However, Mr. Sabal would like to be informed and involved in determining any access routes that may affect the park or park users.

The need for a provincial Water Act approval has been discussed with Sean Staplin, FLNRO's Senior Water Stewardship Officer (pers. comm. 2014), who indicated that a Section 9 approval would likely be the required approval route for this project, should it be constructed.

Hydrotechnical Engineering Activities

McElhanney Consulting Services Ltd. undertook hydraulic modelling of Kleanza Creek to determine expected velocities at peak and fisheries design flow recommendations for sizing. Survey and Lidar imagery of the trained segment of Kleanza Creek contributed to a base plan of the site (Appendix B).

Design flows were based on a regional hydrology analysis and HEC-RAS water surface profile modelling were also prepared based on topographic and bathymetric survey combined with existing LiDAR data for portions of the overbank areas. High flow scenarios have satisfied concerns related to both diking and the existing bridge, with results indicating that, at the 200 year flow level, the proposed weirs will contribute no increase in danger to existing infrastructure.



Monthly flow averages were used to optimize design for four weir heights and locations, with consideration given to keep locations as close as possible to existing infrastructure to improve access and ease of build. Weir spacing is at approximately 40m, and has been optimized for the best gravel capture.

A major side channel whose flow was cut off through the 1966 dike construction was explored as part of this project, to determine any potential restoration effects that might be garnered through weir construction activities and resulting changes to water levels and potential flows. As such, McElhanney surveyed this dry channel, and a base plan for this area is also presented in Appendix

B. McEllhanney's complete letter report is provided as an attachment to this document. Shown below are DFO staff assessing relic channel.



Fish Sampling Activities

Fyke Net and Trap Box: Capturing Pink Fry Outmigration

Initial field work at the site was directed at capturing a subset of the pink salmon fry outmigration. A suitable, accessible site for fyke net and trap box placement was located on the right bank beneath the highway 16 bridge. Trapping was conducted weekly, from March 21st through June 6th, 2014, showing a peak in pink fry from April 19th through May 6th (Figure 1).

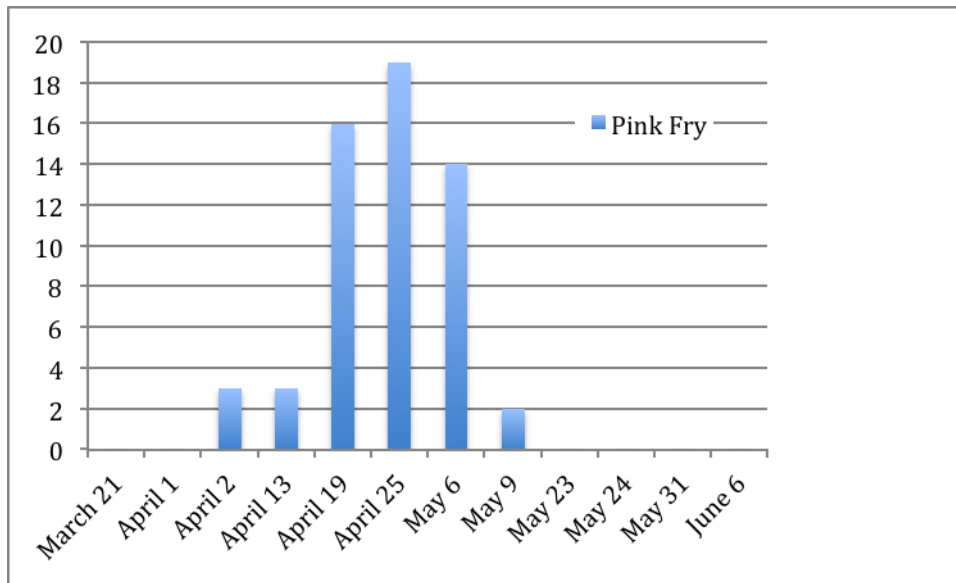


Figure 1. Fyke net-box trap results for pink fry.

Several coho and chinook fry, as well as sculpins and rainbow trout/steelhead were also captured during the trap sets. Complete fyke net-trap box data are provided in Appendix C.

Fyke net and trap box, on right bank of Kleanza Creek below the Highway 16 bridge.



Substrate Surveys

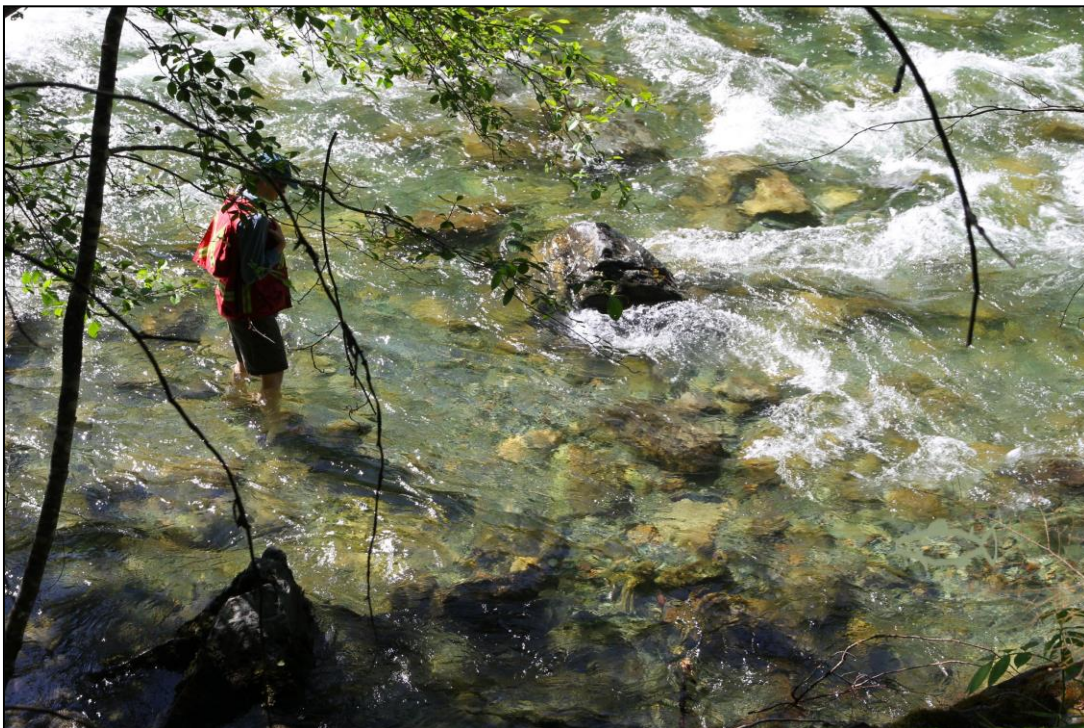
Ten transects were established on August 19th, 2014, to document baseline substrate conditions in Kleanza Creek study area. The transects were distributed at approximate 50m intervals, beginning immediately upstream from the top of the engineering survey (station 3241, 0+580), and substrate and depth were noted at 0.5 m intervals across the creek, for a total of 545 data points. Substrate at each point was classified as fines (<2mm), gravels (2mm-64mm), cobbles (64mm-256mm) and boulders (>256mm). Within the entire surveyed area, a total of 4.6% of substrate was found to be composed of fines, 26.1% was gravels, 39.6% was cobble, and 29.7% was boulder. Detailed survey results are presented in Table D-2, Appendix D.

The data indicate that the amount of gravel present within the stream is not insignificant; however, substrate surveys are not able to speak directly to the spawning suitability of the channel. During spawning surveys (see below), an estimate of total spawning area in the study area of the channel provides further insight into the habitat potential of this reach of Kleanza Creek.

Spawner Surveys

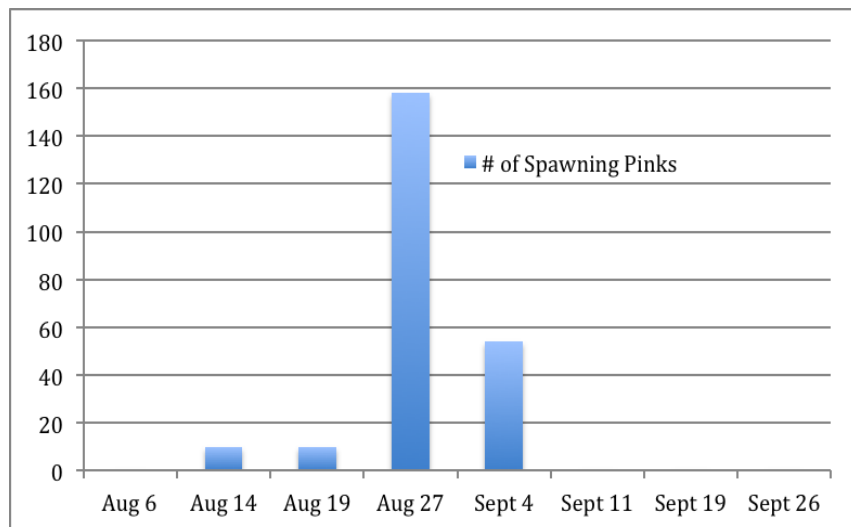
On June 16th, the study area of Kleanza Creek was walked by the project leaders, to locate any spawning steelhead or steelhead redds. Despite ideal observing conditions, only one potential redd was identified during this survey.

Possible steelhead redd on right bank of Kleanza Creek



Salmon spawning surveys—primarily targeting pink salmon—were conducted within the study area (i.e. from the upper survey marker located approximately 550m upstream of the highway bridge, downstream for a minimum of 350m) once per week from August 6th through to September 26th,

when the pink salmon run was complete. During these surveys, salmon were recorded as new spawning, holding/moving, old/guarding, or dead, such that new spawning individuals were differentiated from other salmon in the system and thus only new spawners were counted each week towards the total. In total, 232 spawning pink salmon were counted within the study area, with the definitive peak of spawning observed the week of August 27th, when 158 actively spawning individuals were counted in the study area. Below the study area, spawning was observed through September 19th.



At the end of the spawning period, spawning redd locations were recorded using a handheld GPS, and total spawning area was estimated for each. These results are summarized in the table below (and are provided in full in Appendix D, with spawning areas broken down into 50m segments beginning at the upstream survey marker 3421). The majority of existing spawning gravels and spawning activity were located at the downstream end of the study area, towards the Highway 16 bridge, where gradient slightly declines and velocity is reduced.

Table 1: Spawning Area within Study Area.

Study Area Segment	Total Area of Spawning Gravel (m ²)
1: 0-50m	5.4
2: 50-100m	29.7
3: 100-150m	3.4
4: 150-200m	5.6
5: 200-250m	21.8
6: 250-300m	36.4
7: 300-350m	34.2
Total gravels	136.5

Kitselas Technician recording pink salmon spawning areas



Minnow Trapping

Minnow trapping was conducted August 28-29th throughout the trained area of Kleanza Creek, as well as at two locations upstream of the cascade barrier, at 8 km and 26 km on the Kleanza Creek Forest Service Road. The Gee-style traps were baited with salmon roe, and were set for approximately 24 hours. Five traps were set in a variety of habitat at each of the two upstream sites; in the trained area of Reach 1, nineteen traps were also placed in a variety of habitat subtypes, and were spaced throughout the study area. Locations and detailed sampling results are presented in Appendix C. A total of 25 rainbow trout/steelhead parr were captured at the 26 km site—for an average catch of five trout per trap. At the 8 km site, 25 coho fry were captured in addition to 7 rainbow trout/steelhead parr—averaging 5 coho and 1.4 trout per trap. The 19 traps placed in the study area yielded 86 coho fry, 16 rainbow trout/steelhead fry and parr, 1 char (bull trout or Dolly Varden), and 8 coast range sculpin—averaging 4.5 coho, 0.84 rainbow trout/steelhead, 0.05 char and 0.42 sculpin per trap.

Minnow trapping (8 km bridge, upstream of study area)



Juvenile rainbow/steelhead captured during minnow trapping



Electrofishing

On September 8th, three areas that did not have pink salmon redds were selected for electrofishing. The areas were selected as a “control” immediately upstream of the study area, and two downstream sites within the study area that provided good, shockable habitat and could be effectively enclosed during sampling.

The control area (“Area 1”)—which is within the same general habitat type but is not expected to be affected by weir construction in the future—yielded a total of 4 coast range sculpin, 16 rainbow trout/steelhead, and 3 coho fry. “Area 2,” located within the study area, yielded 11 rainbow trout/steelhead, and 9 coho fry. “Area 3,” also within the project study area, yielded a total of 7 rainbow trout/steelhead, 5 coho fry, 1 coast range sculpin and 1 chinook fry. Details of habitat within the three enclosures, and electrofishing specifications are provided in Table C-3, and electrofishing results are presented in Table C-4, Appendix C. These data provide baseline that can be compared in future years, post-construction.

Provincial Fisheries Biologist and Kitselas Technician electroshocking



Flow Measurements

On December 13th, 2014, three transects were completed within the Kleanza Creek study area to augment the engineering data collected by McElhanney as part of their analysis, and which were collected by surveyors to support their design flow and infrastructure analyses. We anticipate that weir construction will alter the flow regimes, creating greater complexity and heterogeneity in flow patterns. The data presented in Appendix E thus provide baseline values at moderate water levels, which may be monitored and compared in a post-construction scenario.

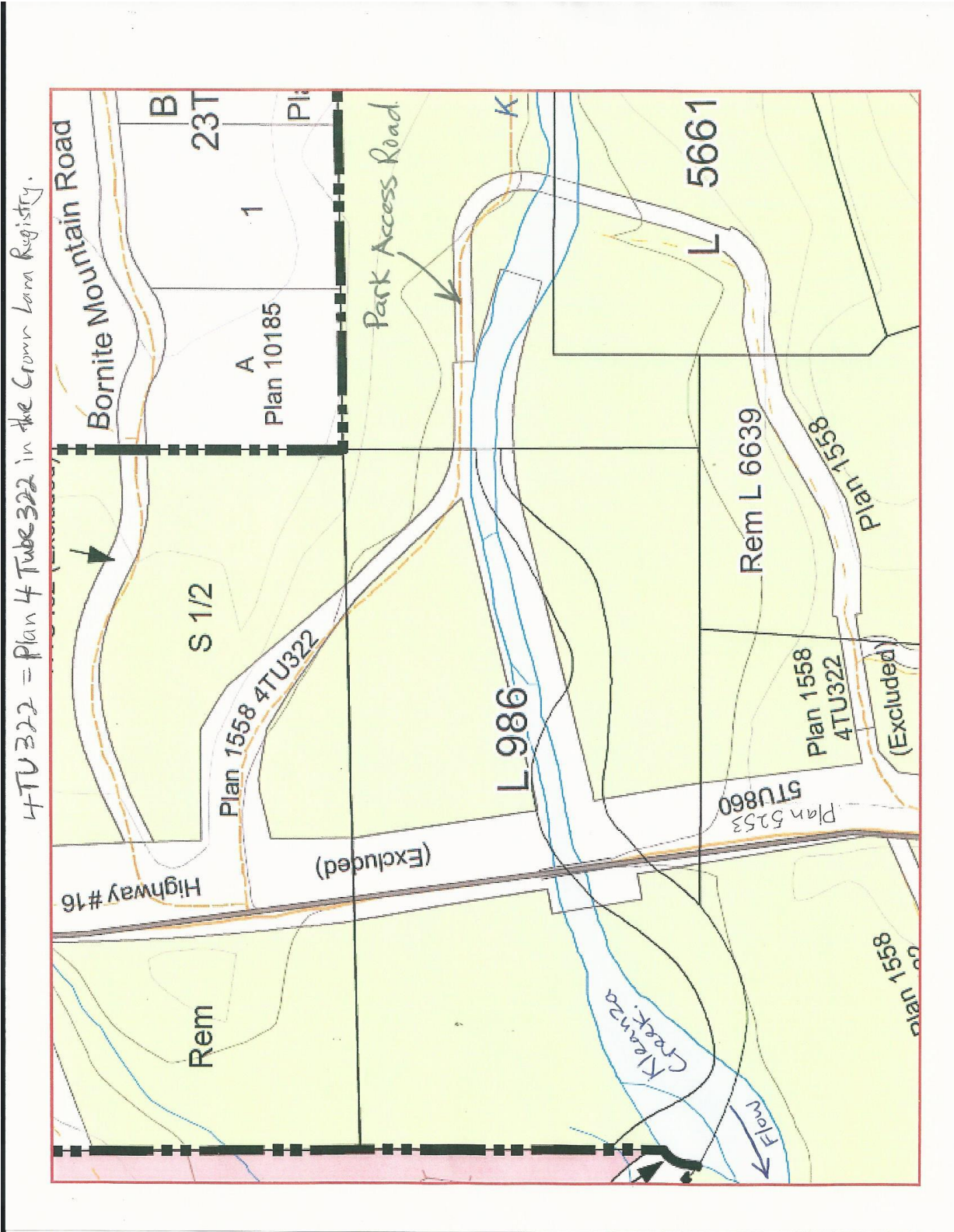
Conclusions and Recommendations

Through the course of 2014, many professionals and partners have participated in the collection and analysis of a variety of biophysical data examining the feasibility of habitat restoration in a large segment of trained channel in the lower reach of Kleanza Creek. Fish and fish habitat sampling and observations have confirmed a lack of habitat complexity within the study area: given the historical modifications to the channel, the area is not currently fulfilling its potential for both rearing and spawning salmonids. Improving habitat complexity, in the form of constructed rock weirs, appears to be a useful undertaking in terms of improving that complexity and salmonid habitat, showing potential to return this segment of stream to historical levels of habitat quality and productivity. This method has been piloted in Anderson Creek, near Kitimat, BC, with good success in terms of a marked, immediate and sustained improvement in terms of salmon spawning. In turn, engineering study undertaken as part of this project has indicated that weir construction is feasible, and that such construction is not expected to have an adverse effect on downstream infrastructure.

References and Personal Communications

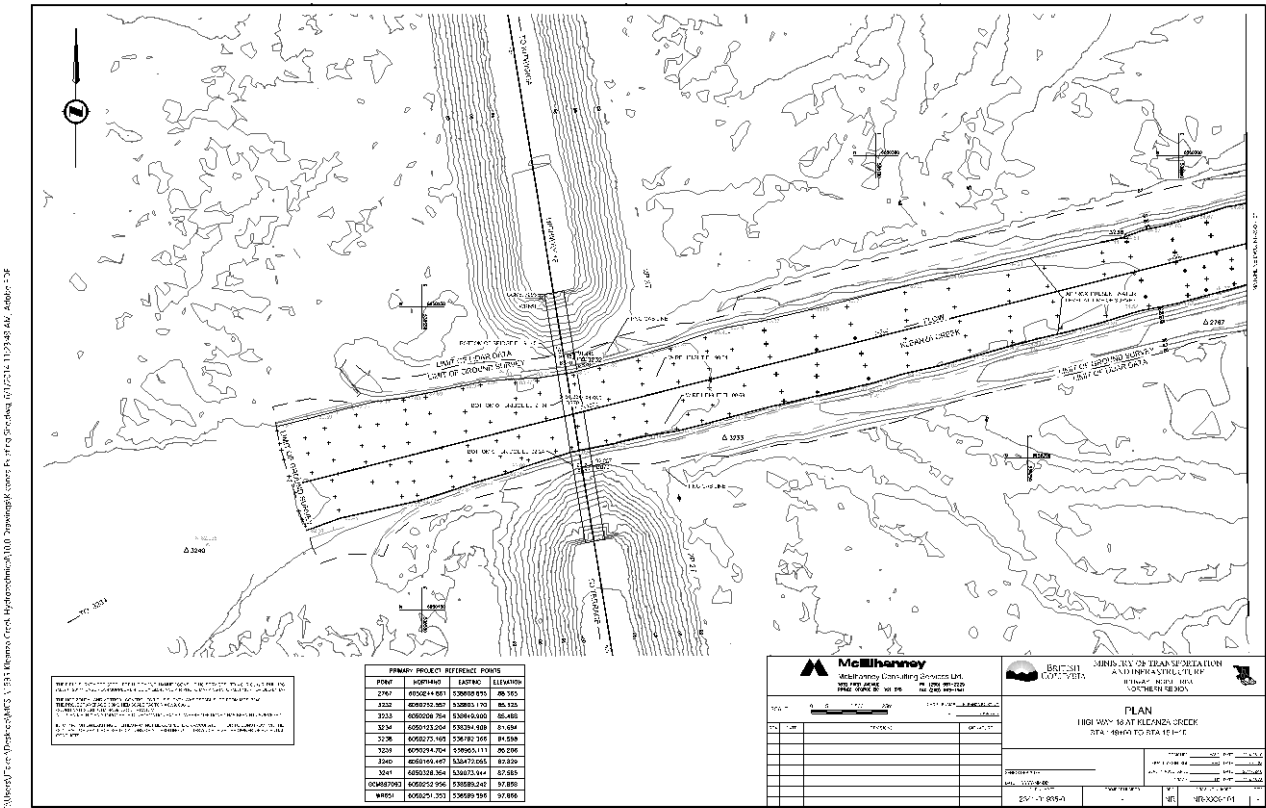
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- Staplin, S. 2014. Personal telephone communication between Mitch Drewes and Sean Staplin, Senior Water Stewardship Officer, FLNRO—Lands and Water Section (Smithers, BC); 12 December 2014.

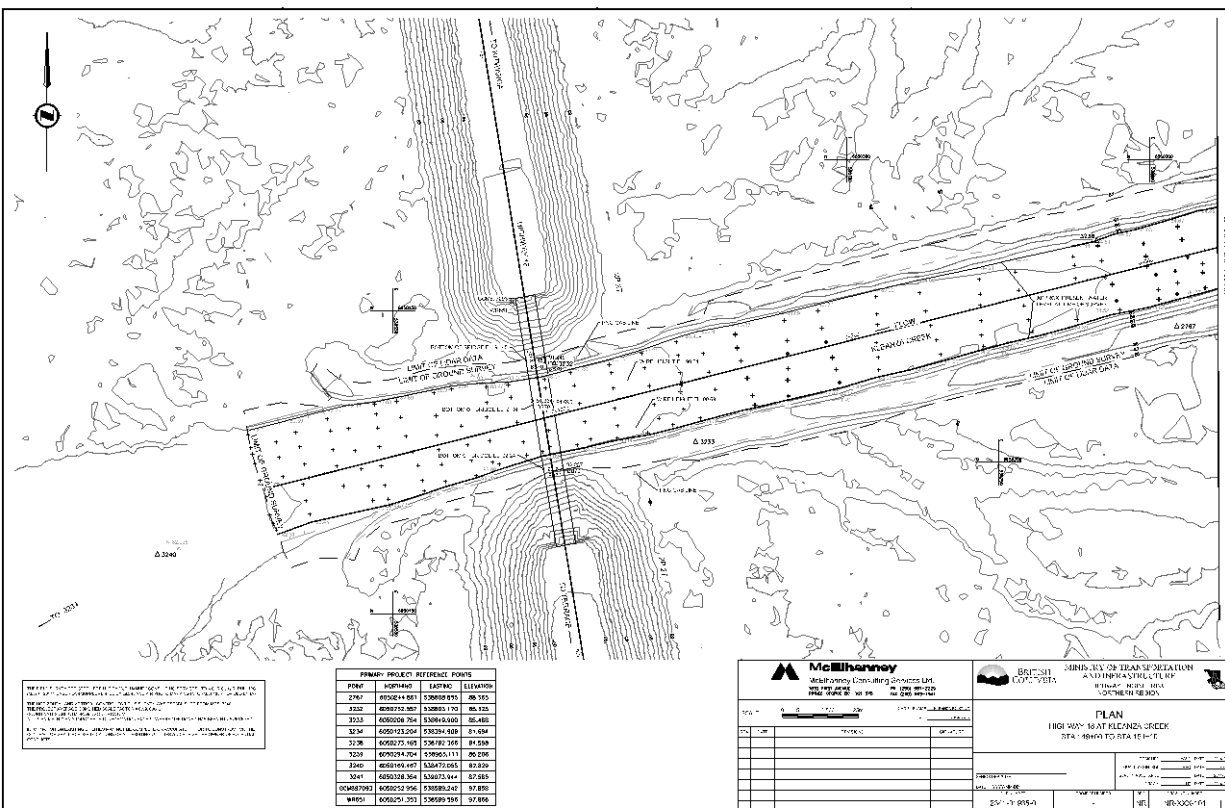
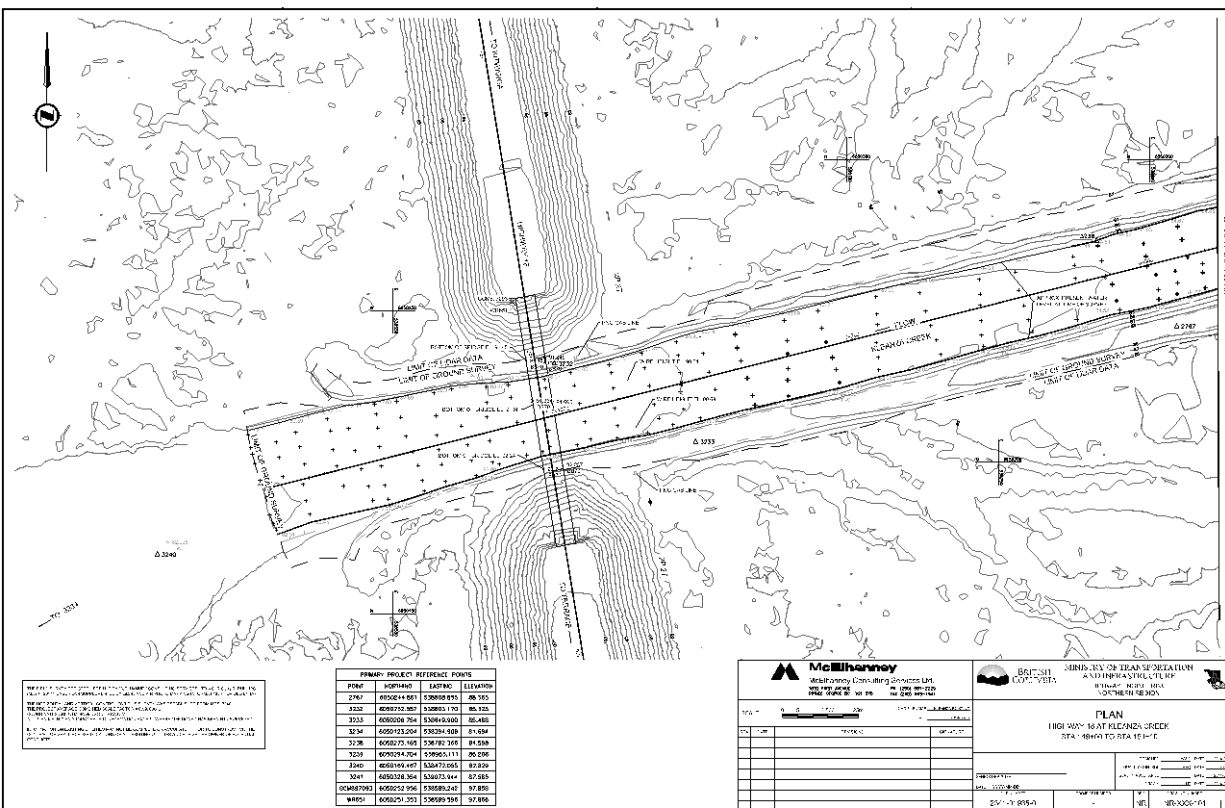
Appendix A: Legal Boundaries

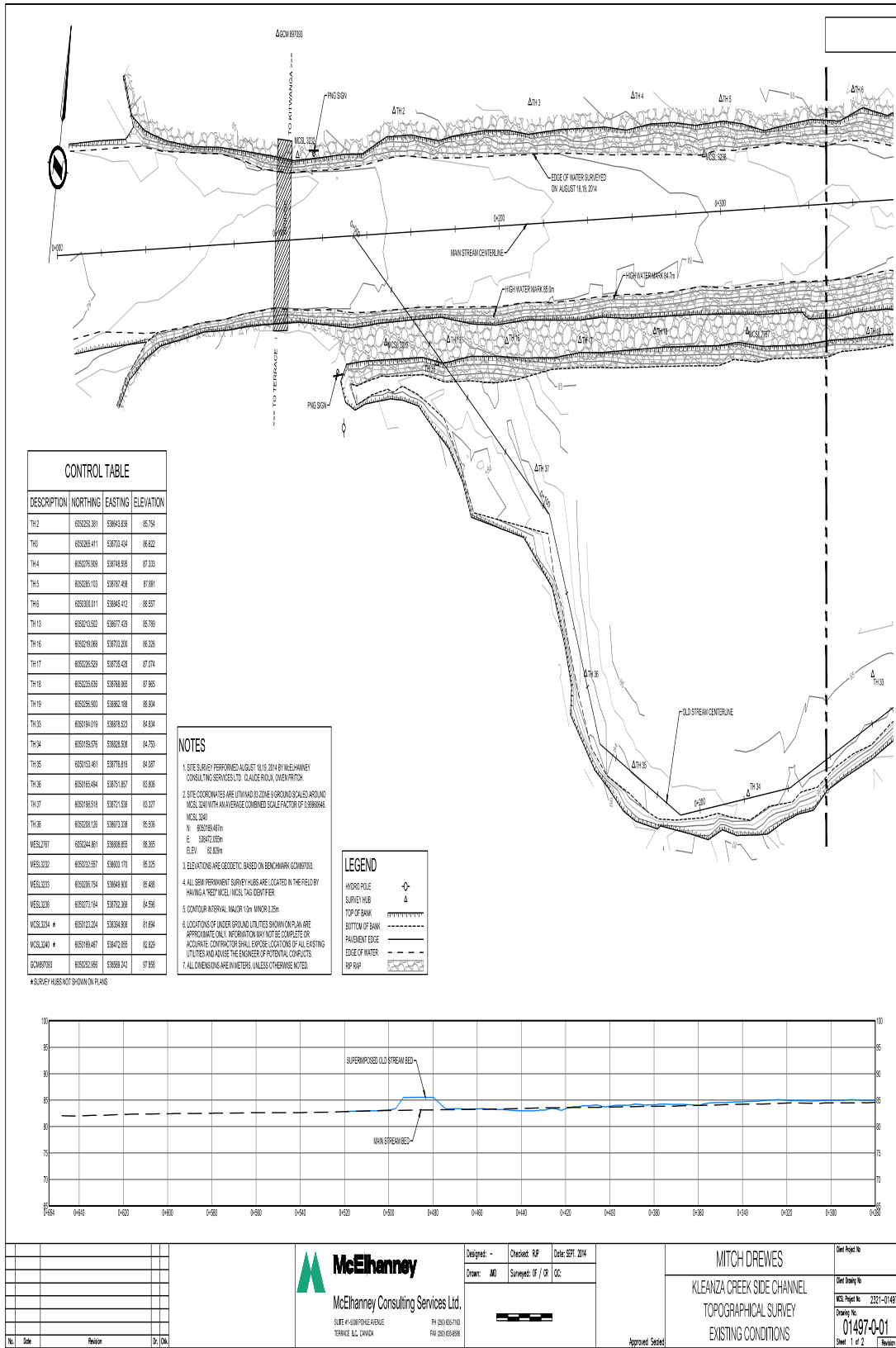


Appendix B: Site Base Plan

The following drawings were prepared and submitted by McElhanney:t5







CONTROL TABLE			
DESCRIPTION	NORTHING	EASTING	ELEVATION
TH 2	859262.381	536643.808	85.754
TH3	859265.411	536702.424	86.622
TH 4	859267.393	536744.565	87.333
TH 5	859268.133	536781.428	87.881
TH 6	859268.011	536845.412	88.557
TH 13	859270.552	536877.429	88.786
TH 16	859274.088	536702.208	88.328
TH 17	859268.529	536755.428	87.074
TH 18	859265.026	536788.865	87.985
TH 19	859259.800	536862.198	88.934
TH 33	859294.019	536878.523	84.834
TH 34	859295.576	536828.538	84.753
TH 35	859292.481	536781.818	84.887
TH 36	859293.484	536791.857	85.886
TH 37	859293.518	536791.538	83.327
TH 38	859288.135	536772.338	85.538
MESL2371	859244.861	536808.855	88.365
MESL3232	859232.557	536802.170	85.325
MESL3233	859238.734	536848.808	85.488
MESL3238	859237.194	536782.388	84.588
MESL3234 *	859232.254	536848.808	81.684
MESL3240 *	859248.487	536722.853	82.829
SCM69783	859252.991	536888.342	87.888

NOTES

1. SITE SURVEY PERFORMED AUGUST 18/19, 2014 BY MCH/WHANNEY CONSULTING SERVICES LTD. CLAUDE ROUX, OVEN PRITCH.

2. SITE COORDINATES ARE UTM NAD 83 ZONE 18 GROUND SCALING AROUND MCSL 3240 WITH AN AVERAGE CONVERSION SCALE FACTOR OF 0.999994.

3. ELEVATIONS ARE GEODETIC, BASED ON BENCHMARK GCM087803.

4. ALL SEMI-PERMANENT SURVEY HUBS ARE LOCATED IN THE FIELD BY HAVING A "RED" MCEL/MCSL TAG IDENTIFIER.

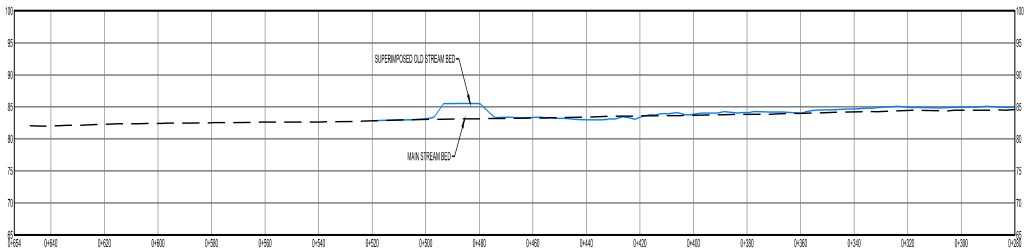
5. CONTOUR INTERVAL: MAJOR 1.0m MINOR 0.25m

6. LOCATIONS OF UNDERGROUND UTILITIES SHOWN ON PLAN ARE APPROXIMATE ONLY. INFORMATION MAY NOT BE COMPLETE OR ACCURATE. CONTRACTOR SHALL EXPOSE LOCATIONS OF ALL EXISTING UTILITIES AND ADVISE THE ENGINEER OF POTENTIAL CONFLICTS.

7. ALL DIMENSIONS ARE IN METERS, UNLESS OTHERWISE NOTED.

LEGEND	
HYDRO POLE	
SURVEY HUB	
TOP OF BANK	
BOTTOM OF BANK	
PAVEMENT EDGE	
EDGE OF WATER	
RIP RAP	

* SURVEY HUBS NOT SHOWN ON PLANS



 McElhanney Consulting Services Ltd. SUITE #1-200 FORBES AVENUE TORONTO, ONT. CANADA	Designed: - Checked: RP Date: SEPT. 2014 Drawn: AU Surveyed: UF / CR CC:	MITCH DREWES KLEANZA CREEK SIDE CHANNEL TOPOGRAPHICAL SURVEY EXISTING CONDITIONS	Client Report No. Client Drawing No. MCSL Project No. 2221-1-01497-01 Drawing No. 01497-0-01 Sheet 1 of 2 Revision A
Approved:	Safety is your safety priority. Please wear your seat belt.		

Appendix C: Fish and Fish Habitat Sampling Data

Table C-1. Kleanza Creek Fyke Net-Box Trapping 2014.

Date	H2O Temp.°C	Duration	Pink Fry	Coho Fry	Chinook Fry	Other	Mortality	Comments
March 21	1.5	1500-0900	0			1 sculpin		
April 1	1.5	1500-0900	0			2 sculpins		
April 2	1.8	1600-0930	3					
-	-	-	-	-	-	-	-	high water April 3-April 11: did not fish trap
April 13	2	1600-0930	3					
April 19	2.5	1600-1000	16	2			4 pink fry	
April 25	3.9	1600-1000	19		1		5 pink fry	
May 6	2.9	1600-1000	14		5	2 rb		
May 9	5.1	1600-1000	2		3			water levels up significantly
May 23	4.9	1600-1000	0		7			water up again - trap not fishing in am
May 24	4.6	1600-1000	0					
May 31	6	1600-1000	0	8				
June 6	5.7	1600-1000	0	12		1 rb		

rb = rainbow trout/steelhead

Table C-2: Pink Salmon Spawner Survey Results.

Date	Species	# of Holding/ Moving	# of Old/ Guarding	# of New Spawning	# of Dead	Visibility*	# in Survey Crew
Aug 6	-	0	0	0	0	5	4
Aug 14	Pink	24	0	10	0	5	4
Aug 19	Pink	28	11	10	0	5	2
	Chinook	1	0	0	0		
Aug 27	Pink	101	25	158	4	5	2
Sept 04	Pink	60	78	54	7	4	2
	Chum	0	0	0	1		
Sept 11	Pink	0	95	0	11	5	2
	Chum	0	0	0	1		
Sept 19	Pink	40	35	0	31	4	3
	Chum	0	0	0	4		
Sept 26	Pink	2	18	0	0	5	2
	Chum	0	0	0	2		
2014 Total Counted Pink Salmon Spawners				232			

*visibility: 1 = poor, 5 = excellent

Table C-3. Kleanza Creek Minnow Trapping, August 28-29th, 2014.

Location	UTM	Trap #	Species	# caught
Kleanza Creek 26 km	9U, 560775E, 6056864N	1-5	RB Parr	25
Kleanza Creek 8 km	9U, 546285E, 6047293N	1-5	CO Fry (1g-3g) RB/ST Parr	25 7
Kleanza Creek Study Area	9U, 539060E, 6050317N	1	CO Fry	3
	9U, 539060E, 6050320N	2	CO Fry RB/ST Parr CAL	2 1 3
	9U, 539029E, 6050309N	3	CO Fry RB/ST Fry CAL	8 2 1
	9U, 539013E, 6050311N	4	CO Fry RB/ST Parr RB/ST Fry CAL	1 3 1 1
	9U, 539001E, 6050323N	5	-	0
	9U, 538995E, 6050313N	6	CO Fry RB/ST Parr RB/ST Fry	3 1 1
	9U, 538981E, 6050310N	7	CO Fry RB/ST Parr	9 1
	9U, 538966E, 6050316N	8	CO Fry RB/ST Parr	9 1
	9U, 538960E, 6050315N	9	CO Fry	2
	9U, 538947E, 6050310N	10	CO Fry RB/ST Parr	1 1
	9U, 538939E, 6050311N	11	-	0
	9U, 538926E, 6050306N	12	CO Fry	12
	9U, 538917E, 6050297N	13	CO Fry RB/ST Parr	18 1
	9U, 538890E, 6050290N	14	CO Fry RB/ST Parr	1 1
	9U, 538869E, 6050293N	15	CO Fry BT/DV	5 1
	9U, 538846E, 6050282N	16	CO Fry RB/ST Parr	1 1
	9U, 538818E, 6050271N	17	CO Fry	4
	9U, 538800E, 6050269N	18	CO Fry RB/ST Parr	7 1
	9U, 538787E, 6050267N	19	CAL	3

BT=Bull Trout; CAL=Coast Range Sculpin; CO=Coho Salmon; DV=Dolly Varden Char; RB=Rainbow Trout; ST=Steelhead

Table C-4. Electrofishing Survey Parameters*

Area #	Easting	Northing	Enclosed Area (m ²)	Gradient (%)	Substrate ** (%)	Total % Cover (by type***)	Electrofishing Pass #	Electrofishing Time (s)
1 (Control)	539085	6050320	53.5	2	F 5, G 15, C 30, B 50	20 (18 B, 2 SWD)	1	543
							2	752
2	539023	6050330	24.4	3	F <5, G 15, C 5, B 75	100 (40 B, 75 OV, 3 LWD, 2 SWD)	1	330
							2	440
3	538979	6050307	29.1	1	F <5, G 15, C 5, B 75	90 (50 B, 55 OV)	1	379
							2	383

*Smithroot electrofisher, model 12B-POW, set to 400V, 70Hz, 60% Duty Cycle. Stream temperature was 12°C; conductivity 30 μ S.

**F=finer, G=gravel, C=cobble, B=boulders.

***B=boulder, LWD=large woody debris, OV=overstream vegetation, SWD=small woody debris.

Table C-5. Electrofishing Survey Results

Area#	Electrofishing Pass	Species*	Age Class**	Mortalities (included in total)	Total	Total per square meter
1 (Control)	1	CAL	unknown	0	2	0.037
		CO	0+	0	3	0.056
		RB/ST	0+	2	12	0.491
	2	CAL	unknown	0	2	0.082
		RB/ST	0+	0	4	0.137
		CO	0+	1	9	0.368
2	1	RB/ST	0+	0	8	0.327
		RB/ST	1+	0	1	0.034
	2	RB/ST	0+	0	2	0.069
		CAL	unknown	1	1	0.034
	1	CH	0+	0	1	0.034
		CO	0+	0	2	0.069
3		RB/ST	0+	0	3	0.103
		CO	0+	0	3	0.103
	2	RB/ST	0+	0	2	0.069
		RB/ST	2+	0	1	0.034

*CAL=coast range sculpin, CH=chinook salmon, CO=coho salmon, RB/ST=rainbow trout/steelhead.

**Age classes are based on Applied Ecosystem Management (2000) species histogram results for the Kleanza watershed.

Appendix D: Substrate and Spawning Areas

Table D-1. Pink Salmon Redd Survey Data, September 26th, 2014.

Point	Easting	Northing	Segment	Length (m)	Width (m)	Area (m ²)*	Segment Total
Start Survey, marker 3241	539053	6050351	-	-	-	-	
Sp 001	539056	6050284	0-50m	0.7	3.8	2.7	5.4
Sp 002	539014	6050343	0-50m	1.0	2.7	2.7	
Sp 003	539007	6050336	50-100m	1.7	0.6	1.0	29.7
Sp 004	539010	6050331	50-100m	1.2	4.0	4.8	
Sp 005	539002	6050325	50-100m	0.7	1.5	1.1	
Sp 006	538998	6050323	50-100m	1.7	1.0	1.7	
Sp 007	538976	6050331	50-100m	0.7	2.3	1.6	
Sp 008	538975	6050333	50-100m	0.8	6.0	4.8	
Sp 009	538975	6050333	50-100m	1.0	1.6	1.6	
Sp 010	538975	6050333	50-100m	1.0	6.2	6.2	
Sp 011	538975	6050333	50-100m	0.9	3.0	2.7	
Sp 012	538975	6050333	50-100m	1.0	4.2	4.2	
Sp 013	538952	6050288	100-150m	1.2	1.5	1.8	3.4
Sp 014	538937	6050274	100-150m	1.0	1.6	1.6	
Sp 015	538930	6050274	150-200m	0.4	1.5	0.6	5.6
Sp 016	538916	6050276	150-200m	0.6	3.0	1.8	
Sp 017	538883	6050267	150-200m	0.9	3.6	3.2	
Sp 018	538880	6050266	200-250m	1.5	1.2	1.8	21.8
Sp 019	538878	6050266	200-250m	1.0	6.6	6.6	
Sp 020	538868	6050265	200-250m	0.4	1.5	0.6	
Sp 021	538861	6050265	200-250m	0.7	4.8	3.4	
Sp 022	538852	6050270	200-250m	0.6	1.6	1.0	
Sp 023	538851	6050258	200-250m	0.7	1.5	1.1	
Sp 024	538842	6050265	200-250m	1.5	3.0	4.5	
Sp 025	538837	6050262	200-250m	0.8	2.0	1.6	
Sp 026	538833	6050257	200-250m	0.8	1.6	1.3	
Sp 027	538828	6050240	250-300m	1.5	1.5	2.3	36.4
Sp 028	538819	6050245	250-300m	1.3	7.1	9.2	
Sp 029	538802	6050256	250-300m	0.7	4.6	3.2	
Sp 030	538802	6050269	250-300m	2.4	2.7	6.5	
Sp 031	538793	6050261	250-300m	1.4	5.0	7.0	
Sp 032	538802	6050282	250-300m	1.5	5.5	8.3	
Sp 033	538781	6050261	300-350m	0.5	4.0	2.0	34.2
Sp 034	538782	6050259	300-350m	0.7	3.1	2.2	
Sp 035	538781	6050258	300-350m	0.5	2.5	1.3	
Sp 036	538777	6050254	300-350m	1.3	3.4	4.4	
Sp 037	538775	6050253	300-350m	0.8	3.0	2.4	
Sp 038	538773	6050254	300-350m	0.7	1.7	1.2	
Sp 039	538767	6050252	300-350m	0.6	1.0	0.6	
Sp 040	538766	6050251	300-350m	1.3	1.4	1.8	
Sp 041	538762	6050251	300-350m	0.8	1.4	1.1	

Sp 042	538757	6050250	300-350m	1.5	1.5	2.3
Sp 043	538754	6050248	300-350m	1.0	1.5	1.5
Sp 044	538750	6050251	300-350m	1.3	5.0	6.5
Sp 045	538748	6050250	300-350m	1.0	7.0	7.0
End Survey	538744	6050245	-	-	-	-
				TOTAL	136.5	136.5

*conservatively high estimate of used pink spawning area.

TableD-2: Substrate Survey Data

Distance from RT Bank (m) / Depth (cm) - Substrate			
Transect 1 (10m u/s of stn. 3241 (0+580))		Transect 2 (50 m d/s)	
0/0-c	13/18-c	0/0-b	13/46-c
.5/0-c	13.5/21-c	.5/0-b	13.5/48-b
1/0-c	14/23-b	1/0-b	14/53-c
1.5/0-c	14.5/29-f	1.5/0-b	14.5/43-g
2/0-b	15/28-b	2/0-b	15/36-c
2.5/0-c	15.5/30-c	2.5/0-b	15.5/28-b
3/0-c	16/28-f	3/0-b	16/30-c
3.5/0-c	16.5/25-b	3.5/5-c	16.5/25-c
4/0-b	17/38-c	4/0-b	17/22-c
4.5/0-g	17.5/30-c	4.5/0-b	17.5/30-g
5/0-b	18/32-b	5/0-c	18/30-c
5.5/0-g	18.5/47-c	5.5/22-b	18.5/31-g
6/3-g	19/48-f	6/20-c	19/30-g
6.5/12-f	19.5/31-c	6.5/26-c	19.5/18-b
7/7-b	20/30-b	7/25-b	20/20-b
7.5/17-f	20.5/25-g	7.5/28-g	20.5/10-b
8/19-g	21/28-c	8/27-b	21/5-c
8.5/19-c	21.5/5-c	8.5/30-b	21.5/10-c
9/22-g	22/0-b	9/40-b	22/0-b
9.5/36-g	22.5/0-c	9.5/38-b	22.5/0-c
10/31-g	23/0-c	10/42-g	23/0-c
10.5/35-c	23.5/0-g	10.5/48-g	23.5/0-c
11/32-b	24/0-g	11/41-g	24/0-b
11.5/30-g	24.5/0-g	11.5/30-g	24.5/0-g
12/30-c		12/35-c	25/0-c
12.5/22-c		12.5/36-g	25.5/0-g

Transect 3 (100m d/s)		Transect 4 (150m d/s)	
0/0-b	13.5/35-c	0/0-b	13.5/38-g
.5/10-b	14/35-c	.5/0-b	14/37-g
1/0-b	14.5/44-c	1/0-f	14.5/22-b
1.5/0-b	15/38-b	1.5/1-f	15/28-c
2/0-b	15.5/38-b	2/2-g	15.5/20-c
2.5/0-b	16/18-b	2.5/4-b	16/26-c
3/0-g	16.5/22-b	3/10-c	16.5/26-b
3.5/0-b	17/10-b	3.5/15-c	17/32-c
4/5-b	17.5/10-b	4/12-c	17.5/20-b
4.5/10-b	18/7-b	4.5/11-b	18/30-b
5/6-b	18.5/2-c	5/33-c	18.5/26-c

5.5/22-c	19/2-c	5.5/33-c	19/18-b
6/27-c	19.5/0-c	6/28-c	19.5/16-b
6.5/40-c	20/0-b	6.5/30-g	20/18-c
7/48-b	20.5/0-b	7/29-b	20.5/7-c
7.5/42-b	21/0-b	7.5/23-b	21/2-c
8/45-b	21.5/0-c	8/35-c	21.5/0-g
8.5/40-c	22/0-g	8.5/18-b	22/3-c
9/32-b	22.5/0-c	9/19-c	22.5/0-b
9.5/48-c	23/0-g	9.5/27-c	23/0-g
10/47-g	23.5/0-b	10/29-g	23.5/0-g
10.5/38-c		10.5/27-b	24/0-b
11/40-c		11/27-c	24.5/0-c
11.5/37-c		11.5/22-c	25/0-c
12/41-g		12/30-c	25.5/0-c
12.5/35-c		12.5/36-c	26/0-f
13/38-g		13/8-b	26.5/0-b

Transect 5 (200m d/s)		Transect 6 (250 m d/s)	
0/0-b	14.5/30-b	0/0-f	14.5/2-b
.5/0-f	15/32-g	.5/0-f	15/5-b
1/0-g	15.5/33-c	1/0-f	15.5/34-g
1.5/0-g	16/34-g	1.5/0-f	16/36-g
2/0-g	16.5/35-g	2/0-b	16.5/39-g
2.5/0-f	17/37-c	2.5/0-c	17/25-c
3/0-c	17.5/38-c	3/0-c	17.5/32-b
3.5/0-c	18/34-c	3.5/0-c	18/36-g
4/0-g	18.5/37-g	4/0-c	18.5/30-g
4.5/0-c	19/42-g	4.5/0-c	19/20-c
5/0-b	19.5/39-g	5/0-g	19.5/33-g
5.5/0-b	20/15-b	5.5/0-c	20/24-c
6/9-b	20.5/20-c	6/0-b	20.5/20-c
6.5/9-b	21/10-b	6.5/2-c	21/30-b
7/8-c	21.5/5-b	7/7-f	21.5/32-g
7.5/11-g	22/14-c	7.5/5-c	22/27-g
8/4-g	22.5/0-b	8/4-c	22.5/28-g
8.5/11-b	23/10-f	8.5/17-c	23/16-b
9/10-c	23.5/0-b	9/20-c	23.5/4-b
9.5/28-g	24/0-c	9.5/11-c	24/24-g
10/22-b	24.5/0-b	10/16-g	24.5/23-g
10.5/17-c	25/0-b	10.5/21-g	25/14-c
11/25-c	25.5/0-b	11/5-b	25.5/12-c
11.5/28-b	26/0-b	11.5/27-g	26/5-b
12/31-g	26.5/0-b	12/20-c	26.5/2-f
12.5/28-b	27/0-b	12.5/24-g	27/0-f
13/37-g		13/23-g	27.5/0-g
13.5/40-c		13.5/30-c	28/0-b
14/45-c		14/20-b	

Transect 7 (300m downstream)		Transect 8 (350m downstream)	
0/0-f	14.5/20-g	0/0-f	14.5/26-g

.5/0-g	15/15-b	.5/0-f	15/15-c
1/0-b	15.5/28-c	1/0-f	15.5/25-c
1.5/0-b	16/25-c	1.5/0-g	16/20-b
2/2-c	16.5/26-c	2/0-g	16.5/26-g
2.5/10-c	17/24-c	2.5/0-b	17/29-g
3/0-b	17.5/28-c	3/0-c	17.5/29-g
3.5/8-g	18/18-b	3.5/3-c	18/23-c
4/0-b	18.5/26-c	4/0-c	18.5/32-g
4.5/10-c	19/31-c	4.5/11-c	19/35-g
5/20-c	19.5/17-b	5/10-c	19.5/34-c
5.5/19-g	20/27-g	5.5/18-g	20/30-b
6/10-g	20.5/30-g	6/11-c	20.5/37-g
6.5/20-c	21/31-g	6.5/1-c	21/26-c
7/7-c	21.5/24-g	7/3-c	21.5/20-b
7.5/5-c	22/25-g	7.5/22-g	22/30-g
8/12-c	22.5/26-b	8/12-g	22.5/29-c
8.5/20-c	23/32-c	8.5/17-g	23/28-c
9/14-g	23.5/36-g	9/20-c	23.5/35-c
9.5/18-b	24/37-g	9.5/20-c	24/24-c
10/23-c	24.5/25-g	10/16-c	24.5/11-b
10.5/19-g	25/6-b	10.5/22-g	25/18-c
11/22-c	25.5/18-b	11/2-b	25.5/15-b
11.5/32-c	26/11-b	11.5/24-b	26/18-c
12/8-b	26.5/0-f	12/27-c	26.5/23-c
12.5/19-g	27/0-ac	12.5/33-g	27/10-b
13/12-c		13/19-b	27.5/2-f
13.5/27-c		13.5/30-g	28/0-b
14/20-c		14/28-c	

Transect 9 (400m d/s)		Transect 10 (450m d/s)	
0/0-b	15.5/27-b	0/0-g	15.5/19-c
.5/0-g	16/29-g	.5/5-c	16/25-c
1/0-g	16.5/23-c	1/0-b	16.5/29-g
1.5/0-c	17/28-g	1.5/23-c	17/25-g
2/1-c	17.5/21-c	2/21-b	17.5/20-g
2.5/0-c	18/21-b	2.5/23-g	18/18-g
3/10-c	18.5/9-b	3/018-b	18.5/33-g
3.5/5-b	19/26-c	3.5/3-b	19/24-g
4/6-c	19.5/27-c	4/11-c	19.5/29-g
4.5/11-c	20/24-g	4.5/19-g	20/28-c
5/5-b	20.5/27-g	5/17-c	20.5/25-g
5.5/12-c	21/24-c	5.5/16-c	21/6-b
6/4-b	21.5/30-g	6/13-c	21.5/25-g
6.5/14-g	22/30-g	6.5/19-g	22/30-g
7/11-c	22.5/26-c	7/21-c	22.5/25-c
7.5/2-b	23/10-b	7.5/14-b	23/22-g
8/11-c	23.5/15-b	8/5-b	23.5/18-c
8.5/17-c	24/10-c	8.5/22-g	24/b-12
9/18-c	24.5/12-g	9/18-b	24.5/11-c
9.5/20-c	25/16-g	9.5/21-g	25/11-g

10/13-c	25.5/0-b	10/10-c	25.5/11-g
10.5/24-g	26/10-c	10.5/10-c	26/6-c
11/21-c	26.5/0-b	11/10-c	26.5/7-c
11.5/30-b	27/0-b	11.5/12-g	27/0-b
12/35-c	27.5/0-c	12/12-c	27.5/0-b
12.5/28-c	28/0-f	12.5/11-c	28/0-b
13/37-g	28.5/0-b	13/16-c	28.5/0-b
13.5/30-c		13.5/13-c	29/0-b
14/28-g		14/27-g	
14.5/31-c		14.5/31-g	
15/26-g		15/31-g	

Appendix E: Flow Measurements

Tables E-1 to E-3. Flow Transects 1-3.

Transect #1: 09U, 539076N, 6050316E, 140m

interval	0.50	m	Flow	cms	lpm	cfs
stn start	0.00	m		3.661	219,700	129.26
stn end	16.20	m	Area	m ²		
				5.525		

STN	DEPTH m	AREA m ²	m/s				FLOW m ³ /s
			1	2	3	AVE	
0.00							
0.50	0.08	0.020	0.00	0.00	0.00	0.00	0.000
1.00	0.00	0.020	0.00	0.00	0.00	0.00	0.000
1.50	0.08	0.020	0.01	0.00	0.00	0.00	0.000
2.00	0.13	0.053	0.17	0.21	0.23	0.20	0.011
2.50	0.22	0.088	0.23	0.25	0.25	0.24	0.021
3.00	0.27	0.123	0.56	0.49	0.45	0.50	0.061
3.50	0.31	0.145	0.58	0.55	0.51	0.55	0.079
4.00	0.32	0.158	0.85	0.74	0.72	0.77	0.121
4.50	0.25	0.143	0.64	0.69	0.67	0.67	0.095
5.00	0.24	0.123	0.67	0.58	0.51	0.59	0.072
5.50	0.37	0.153	0.84	0.82	0.77	0.81	0.124
6.00	0.45	0.205	0.86	0.81	0.74	0.80	0.165
6.50	0.47	0.230	0.90	0.79	0.78	0.82	0.189
7.00	0.45	0.230	0.99	1.07	1.04	1.03	0.238
7.50	0.52	0.243	1.12	1.14	1.09	1.12	0.271
8.00	0.48	0.250	0.44	0.40	0.49	0.44	0.111
8.50	0.37	0.213	0.67	0.65	0.64	0.65	0.139
9.00	0.35	0.180	0.88	0.81	0.87	0.85	0.154
9.50	0.37	0.180	0.37	0.37	0.17	0.30	0.055
10.00	0.37	0.185	1.12	1.18	1.16	1.15	0.213
10.50	0.43	0.200	0.02	0.05	0.00	0.02	0.005
11.00	0.52	0.238	0.28	0.50	0.64	0.47	0.112
11.50	0.47	0.248	0.49	0.42	0.34	0.42	0.103
12.00	0.44	0.228	1.09	1.11	1.13	1.11	0.253
12.50	0.48	0.230	0.67	0.52	0.65	0.61	0.141
13.00	0.43	0.228	1.26	1.27	1.19	1.24	0.282
13.50	0.37	0.200	1.25	1.13	1.25	1.21	0.242
14.00	0.50	0.218	0.82	0.87	0.82	0.84	0.182
14.50	0.44	0.235	0.68	0.64	0.58	0.63	0.149

15.00	0.50	0.235	0.17	0.35	0.18	0.23	0.055
15.50	0.32	0.205	0.11	0.08	0.09	0.09	0.019
16.00	0.07	0.098	0.00	0.00	0.00	0.00	0.000
16.20	0.00	0.007	0.00	0.00	0.00	0.00	0.000

Transect #2 09U, 538956N, 6050310E, 92m

interval	0.50	m	Flow	cms	lpm	cfs
stn start	0.00	m		3.346	200,800	118.14
stn end	15.60	m	Area	m ²		
				5.614		

STN	DEPTH m	AREA m ²	m/s				FLOW m ³ /s
			1	2	3	AVE	
0.00							
0.50	0.25	0.063	0.00	0.00	0.00	0.00	0.000
1.00	0.14	0.098	0.60	0.57	0.58	0.58	0.057
1.50	0.14	0.070	0.82	0.75	0.76	0.78	0.054
2.00	0.10	0.060	0.00	0.00	0.00	0.00	0.000
2.50	0.10	0.050	0.33	0.34	0.33	0.33	0.017
3.00	0.18	0.070	0.59	0.59	0.58	0.59	0.041
3.50	0.27	0.113	0.21	0.15	0.18	0.18	0.020
4.00	0.24	0.128	0.48	0.47	0.58	0.51	0.065
4.50	0.18	0.105	0.44	0.42	0.36	0.41	0.043
5.00	0.24	0.105	0.01	0.00	0.00	0.00	0.000
5.50	0.55	0.198	0.00	0.00	0.00	0.00	0.000
6.00	0.60	0.288	0.41	0.53	0.45	0.46	0.133
6.50	0.45	0.263	0.56	0.56	0.51	0.54	0.143
7.00	0.40	0.213	0.99	1.00	0.92	0.97	0.206
7.50	0.43	0.208	1.02	0.96	0.93	0.97	0.201
8.00	0.54	0.243	0.33	0.38	0.46	0.39	0.095
8.50	0.59	0.283	0.49	0.40	0.39	0.43	0.121
9.00	0.50	0.273	0.97	0.71	0.82	0.83	0.227
9.50	0.54	0.260	0.48	0.47	0.54	0.50	0.129
10.00	0.54	0.270	0.94	1.02	1.02	0.99	0.268
10.50	0.55	0.273	0.85	0.86	0.90	0.87	0.237
11.00	0.52	0.268	0.67	0.87	0.82	0.79	0.210
11.50	0.55	0.268	0.80	0.76	0.81	0.79	0.211
12.00	0.40	0.238	1.00	1.02	1.00	1.01	0.239
12.50	0.45	0.213	0.85	0.78	0.85	0.83	0.176
13.00	0.46	0.228	0.89	0.92	0.85	0.89	0.202
13.50	0.37	0.208	0.58	0.65	0.57	0.60	0.125
14.00	0.37	0.185	0.32	0.34	0.32	0.33	0.060
14.50	0.30	0.168	0.32	0.37	0.35	0.35	0.058
15.00	0.20	0.125	0.07	0.09	0.01	0.06	0.007
15.50	0.13	0.083	0.01	0.00	0.00	0.00	0.000
15.60	0.00	0.006	0.00	0.00	0.00	0.00	0.000

Transect #3 09U, 538907N, 6050291E, 97m

interval	0.50	m	Flow	cms	lpm	cfs
stn start	0.00	m		2.854	171,300	100.77
stn end	13.80	m	Area	m ²		
				4.914		

STN	DEPTH m	AREA m ²	m/s				FLOW m ³ /s
			1	2	3	AVE	
0.00							
0.50	0.08	0.020	0.07	0.11	0.08	0.09	0.002
1.00	0.15	0.058	0.10	0.14	0.11	0.12	0.007
1.50	0.27	0.105	0.00	0.00	0.00	0.00	0.000
2.00	0.38	0.163	0.45	0.46	0.49	0.47	0.076
2.50	0.40	0.195	0.66	0.72	0.64	0.67	0.131
3.00	0.44	0.210	0.77	0.80	0.73	0.77	0.161
3.50	0.40	0.210	1.07	0.98	1.08	1.04	0.219
4.00	0.52	0.230	1.00	1.16	0.80	0.99	0.227
4.50	0.55	0.268	0.14	0.23	0.08	0.15	0.040
5.00	0.58	0.283	0.05	0.04	0.06	0.05	0.014
5.50	0.55	0.283	0.79	0.75	0.78	0.77	0.218
6.00	0.47	0.255	0.88	0.87	1.01	0.92	0.235
6.50	0.53	0.250	0.74	0.70	0.95	0.80	0.199
7.00	0.54	0.268	0.79	0.75	0.92	0.82	0.219
7.50	0.45	0.248	1.02	0.97	0.95	0.98	0.243
8.00	0.42	0.218	0.78	0.84	0.63	0.75	0.163
8.50	0.40	0.205	0.77	0.80	0.70	0.76	0.155
9.00	0.44	0.210	0.58	0.65	0.64	0.62	0.131
9.50	0.30	0.185	0.85	0.85	0.79	0.83	0.154
10.00	0.30	0.150	0.82	0.70	0.80	0.77	0.116
10.50	0.30	0.150	0.40	0.47	0.53	0.47	0.070
11.00	0.34	0.160	0.35	0.28	0.13	0.25	0.041
11.50	0.30	0.160	0.15	0.15	0.06	0.12	0.019
12.00	0.25	0.138	0.00	0.00	0.00	0.00	0.000
12.50	0.23	0.120	0.03	0.01	0.00	0.01	0.002
13.00	0.15	0.095	0.03	0.01	0.00	0.01	0.001
13.50	0.11	0.065	0.17	0.11	0.25	0.18	0.011
13.80	0.00	0.017	0.00	0.00	0.00	0.00	0.000

December 18, 2014
File: 2341-01935-00

Daryl Nolan
Manager, Environmental Services
Northern Region
BC Ministry of Transportation and Infrastructure
231 1011 4th Avenue
Prince George, BC V2L 3H9

Hydrotechnical Report for Kleanza Creek Fish Rehabilitation Project

1. Background

McElhanney Consulting Services Ltd (MCSL) was asked by the BC Ministry of Transportation and Infrastructure (BC MoT) and Hidden River Environmental Management (HREM) to review the hydrotechnical aspects of the proposed installation of rock weirs in the channel of Kleanza Creek located north of Terrace, BC. The project was funded in part by the Pacific Salmon Commission (PSC) Northern Fund and BC MoT. The project was modelled after similar work that had been carried out on Anderson Creek in Kitimat, BC.

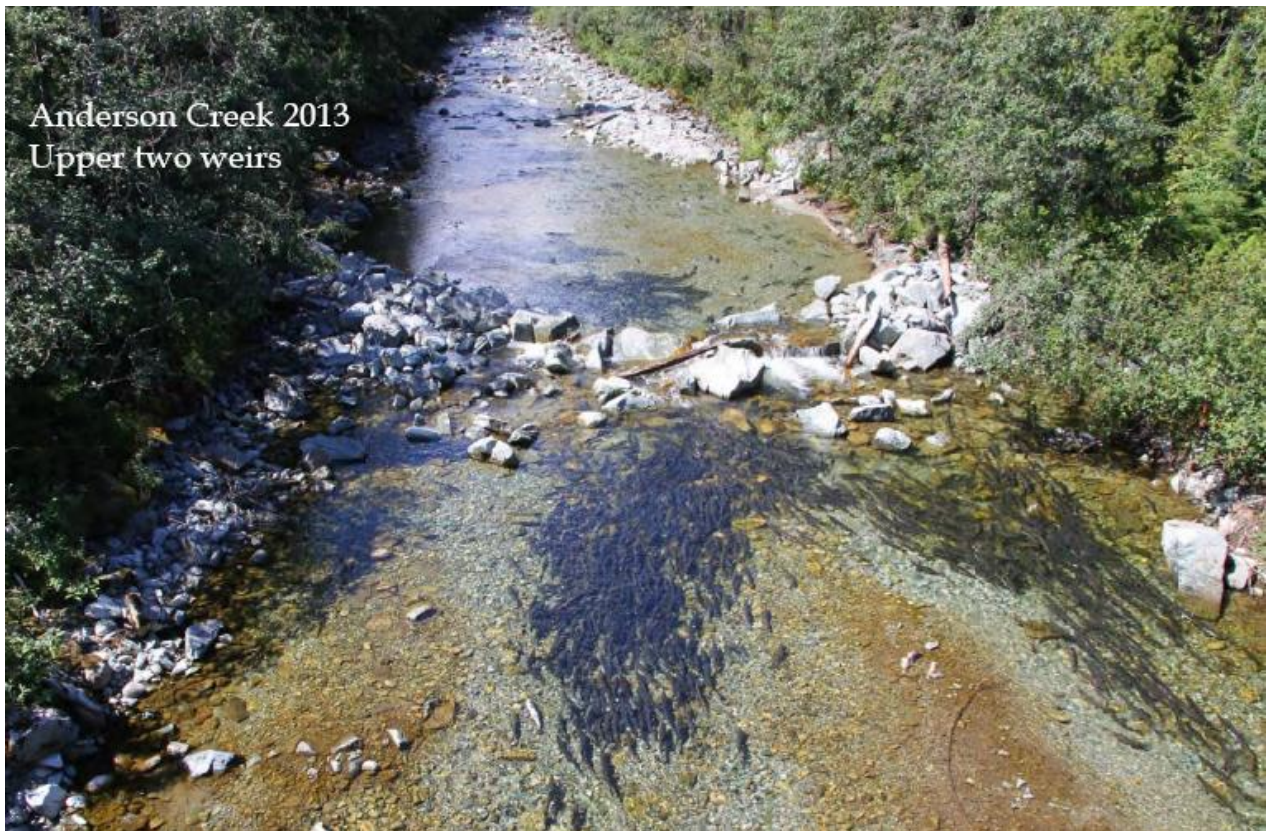


Figure 1 - Successful implementation of gravel capture through rock weir placement in Anderson Creek



2. Scope of Work

MCSL's scope of work included the following:

Survey

1. Field survey of approximately 720 m of stream channel including bottom bathymetry, high water marks, location of existing rock works, top of bank and average stream bed material size, bridge soffit elevation.
2. Velocity measurements at time of survey to assist in the calibration of the hydraulic model.
3. Preparation of a site plan with contours.

Hydrotechnical

1. Regional hydrology to determine the design flows for fish passage and also for ultimate design of instream structures. Determination of the expected seasonal flow requirements for the required species that need accommodation.
2. Development of a HEC-RAS model at the design flows to determine instream velocities.
3. Modelling of instream structures such as weirs to determine their effect on the design flows.
4. Recommendations for additional works required to support placement of improvement infrastructure.
5. Preparation of a summary report and meetings with HREM and MoT.

3. Survey and Base Plan

The initial survey of Kleanza Creek took place from April 28 to May 6, 2014. Conditions were ice-free with moderate water levels. Bathymetric information was taken by wading. The ground and creek survey was augmented by LiDAR information in order to create the base plan. The base plan was forwarded to BC MoT and HREM.

A second survey of an old dry channel was carried out at a later date upon request from HREM and added to the scope of the project.



4. Regional Hydrology

Kleanza Creek does not have any flow or water level monitoring station. Therefore, in order to estimate design flows for the creek and rock placement, a regional hydrology analysis utilizing gauged Water Survey of Canada stations was carried out.

Three nearby stations were used:

Station Number	Name	Drainage Area (sq.km)	Years of Data
08FF003	Little Wedeene River	180	45
08EF005	Zymoetz River above OK Creek	2850	48
08EE020	Telkwa River Below Tsai Creek	367	36

Extreme value flows were downloaded from the Water Survey of Canada data archive for each of these stations. Peak flows for each year were ranked in descending order, then a Log Pearson Type III analysis was used as a best fit for the data to extrapolate 1 in 200 year design flows for each drainage. A second curve fitting compared the 1 in 200 year design flow for various drainage areas to derive a relationship between drainage area and design flow.

The drainage area for Kleanza Creek was measured using GIS tools on the ImapBC web site. A screen image of the estimated drainage area is shown on the figure below.

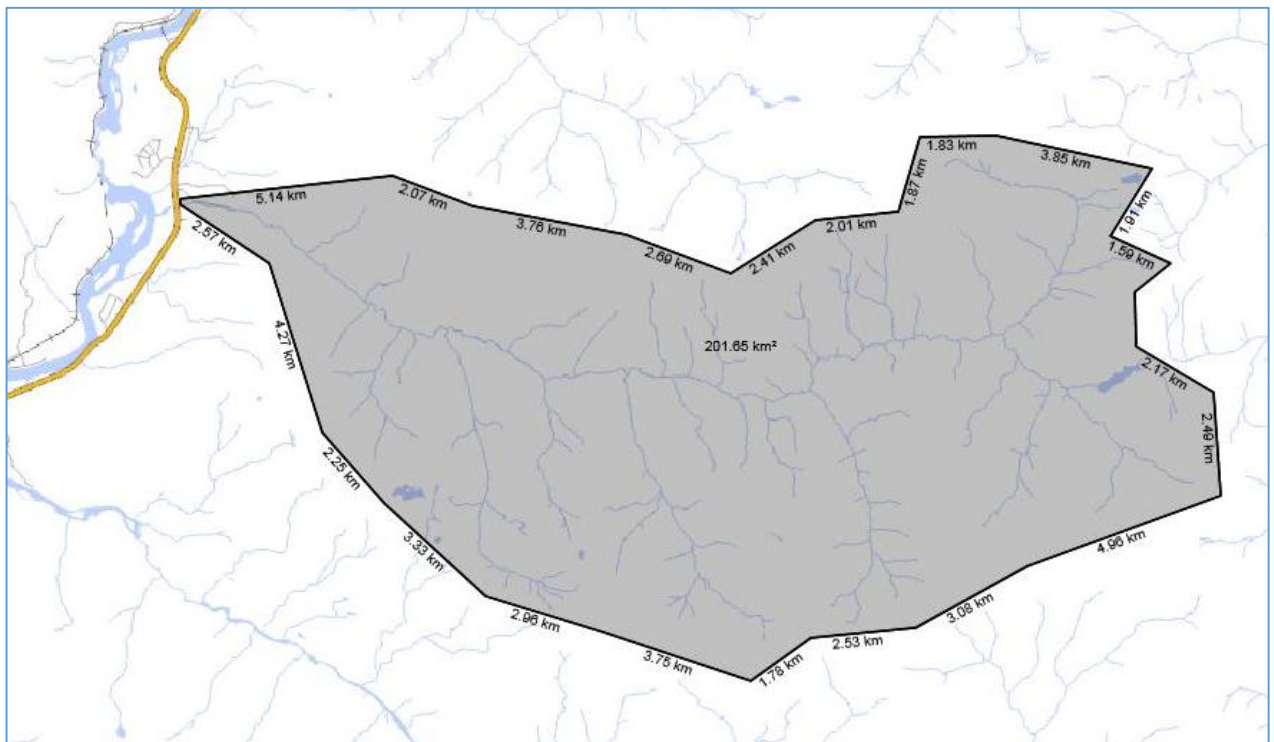
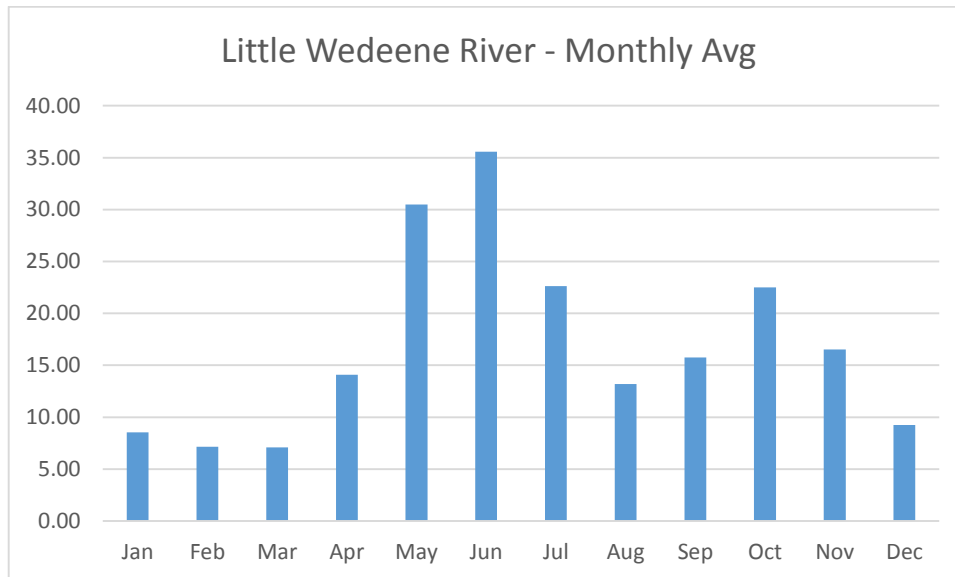


Figure 2 - Kleanza Creek - measured area - 202 sq.km

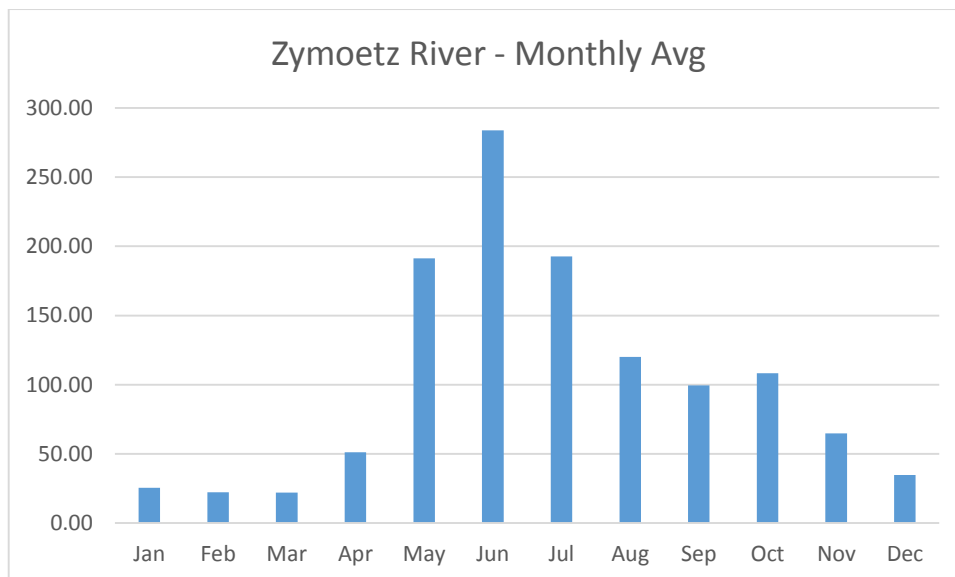


Using the relationship between drainage area and 1 in 200 year flow determined from the 3 gauged stations, the 1 in 200 year flow for Kleanza Creek (area=202 sq.km) is estimated to be 280 cu.m/s. The 1 in 200 year flow is the required design flow for assessing the Highway 16 bridge over Kleanza Creek.

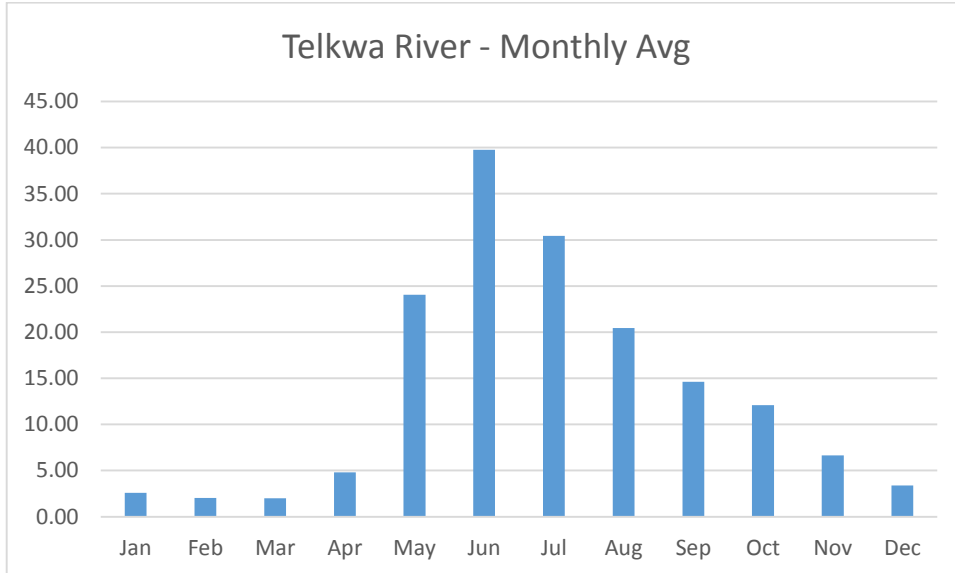
Average monthly flows are useful for determining mean water levels during times of fish passage. The average flows for the various gauged stations are shown below.



Average annual flow = 17.6 cu.m/s

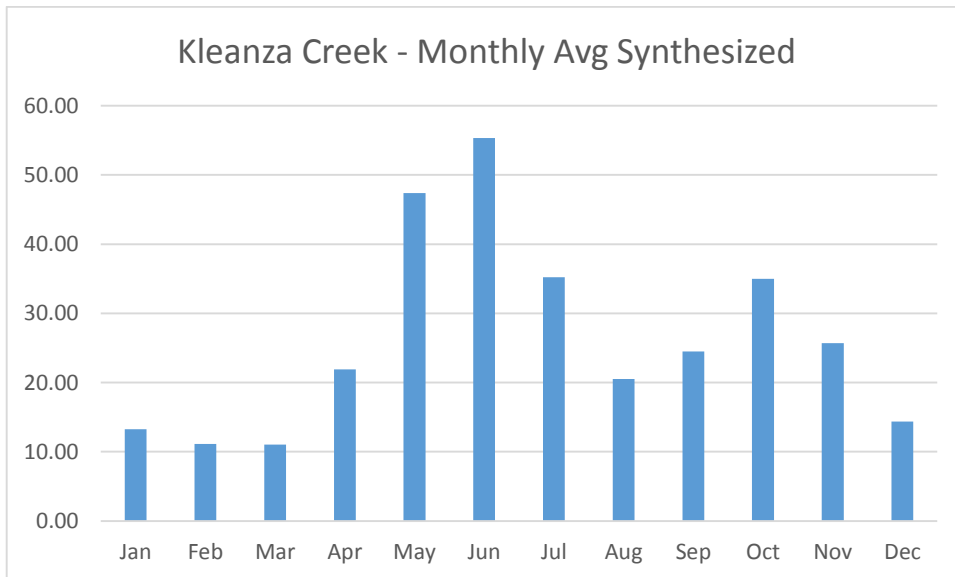


Average annual flow = 103.6 cu.m/s



Average annual flow = 14.3 cu.m/s

The Little Wedeene River is likely the most representative of the Kleanza Creek flows. Therefore, the monthly hydrograph for Kleanza Creek was synthesized using a ratio of drainage areas and the average monthly flows. The result is the graph below.



As can be seen on the Kleanza Creek hydrograph, average flows from May to October vary from a low value of 20 cu.m/s to 55 cu.m/s. We have the ability to review this in finer detail if required, for both minimum and maximum flows.



5. HEC-RAS Analysis

Peak Flow Analysis

The US Army Corp of Engineers' (USACE) HEC-RAS water surface profiling software is an industry standard method of assessing water levels in channels. The channel cross sections were determined from the survey data, and entered into the HEC-RAS model. The model used a total of 31 cross sections ranging from downstream of the highway bridge to approximately 620 m upstream. The cross sections were spaced every 20 metres.

The HEC-RAS model was first run with no channel improvements at the 1 in 200 year design flow of 280 cu.m/s. The resulting channel profile is shown below.

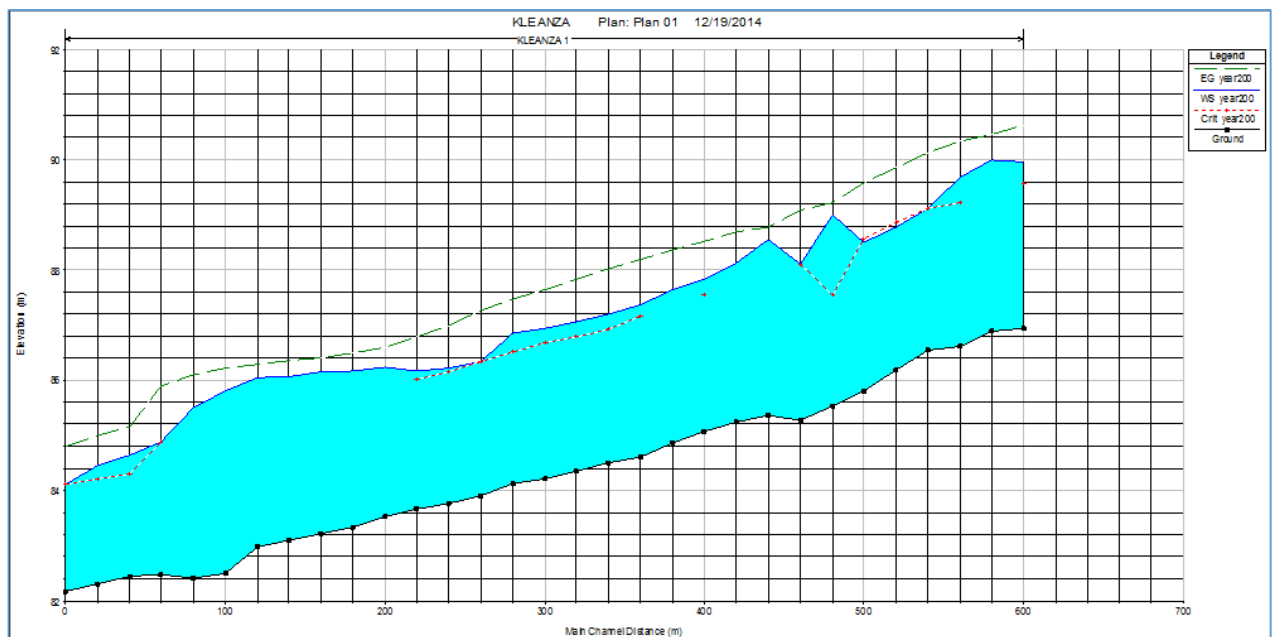


Figure 3- Kleanza Creek Channel Profile at 280 cu.m/s – bridge at approximate station 80. Bottom of bridge is approximately El. 91.45 at its lowest point.

The underside of the Kleanza Creek bridge was measured at several locations. The lowest elevation measured was El. 91.45 m near the north abutment on the downstream side. The corresponding river elevation at the design flow is 82.48 m (Table 1, Appendix A), leaving a freeboard of 8.97 m.

The channel was then re-modelled with the addition of 4 rock weirs. The weirs were geometrically defined as spanning the entire width of the channel with a top width of 1 m and a height of 1 m. Weirs were given a slight “v” shape in section view to maintain flows in the centre of the channel. An example of the model data entry is shown below.

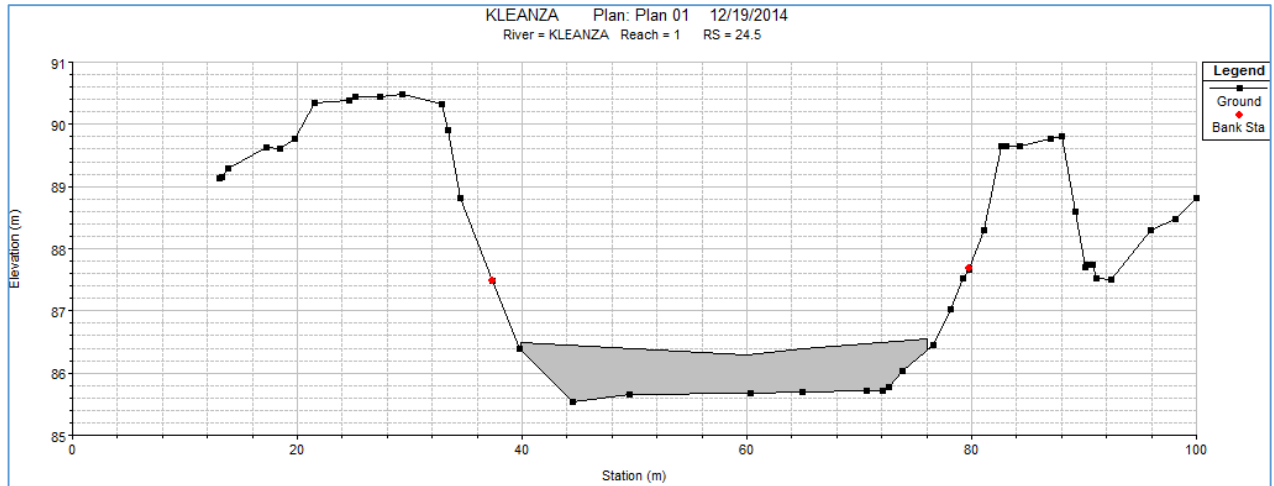


Figure 4 - Example of rock weir in HEC-RAS model

The resulting modified channel was run with the design flow of 280 cu.m/s and the resulting profile is shown in Figure 5.

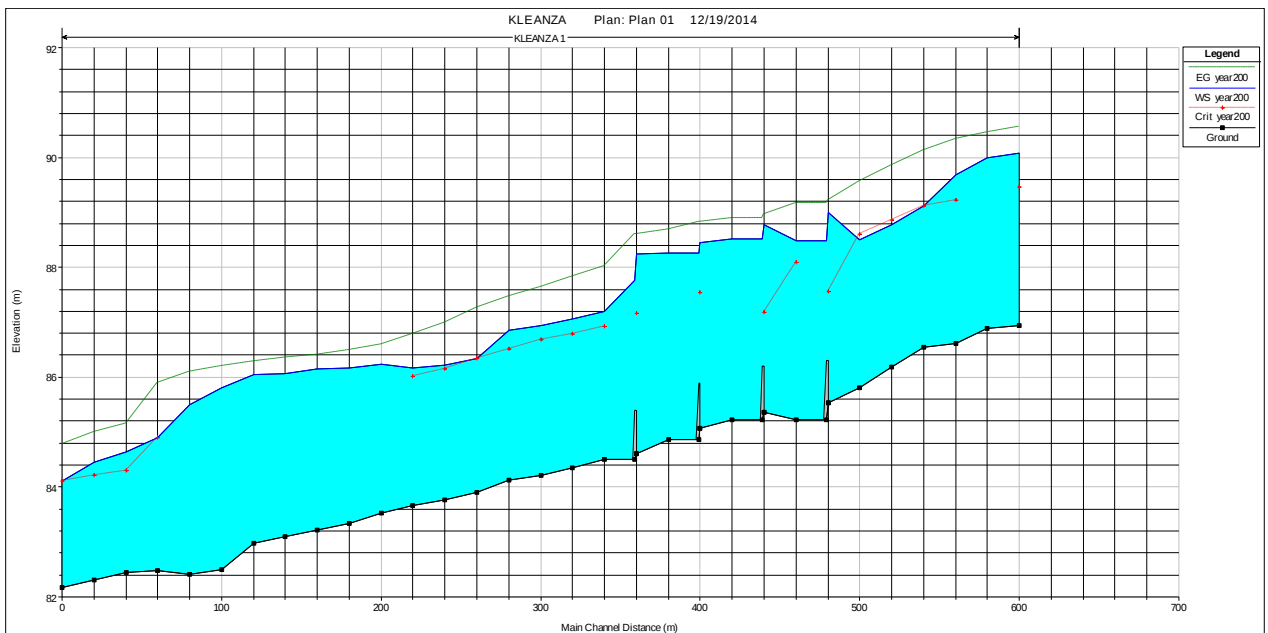


Figure 5 - Kleanza Creek with rock weirs installed - $Q = 280 \text{ cu.m/s}$

The resulting modified channel was run with the design flow of 280 cu.m/s and the resulting profile is shown in Figure 5. The summary Table 2 has been included in Appendix A.

There is no change in the water surface elevation at the bridge location. There are slight increases directly at the rock weirs but these remain constrained by the diking.

Average Monthly Flow Analysis

A series of model runs using monthly flows of 20 and 55 cu.m/s were carried out to observe the flow depths and velocities during fish passage times. These model runs were only carried out



with the rock weirs in place. Resulting profiles are shown following and summary tables are included in Appendix A.

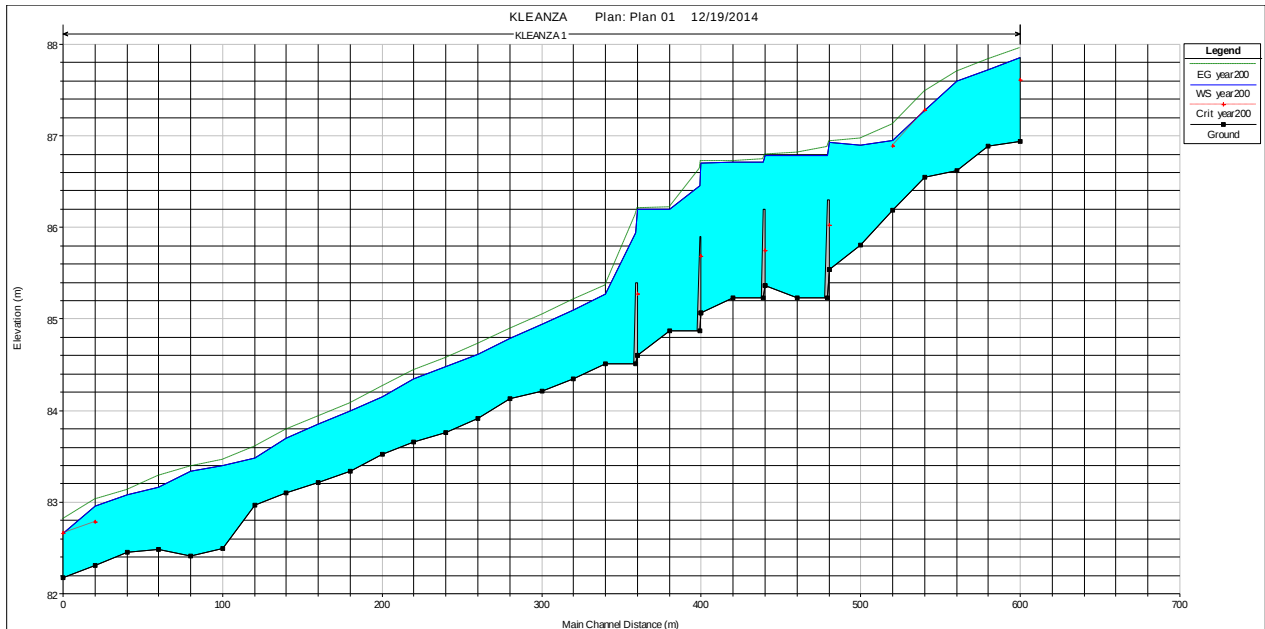


Figure 6 - Kleanza Creek with rock weirs - $Q = 20 \text{ cu.m/s}$

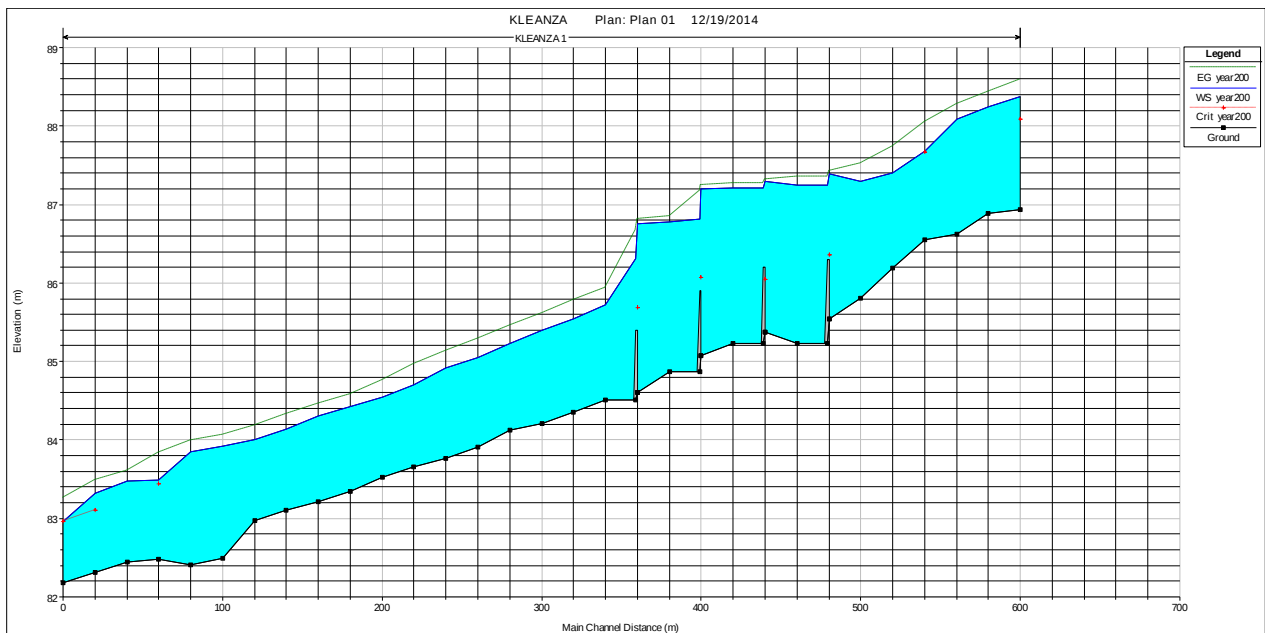


Figure 7 - Kleanza Creek with rock weirs - $Q = 55 \text{ cu.m/s}$

Appreciable reductions in flow velocity can be seen in both cases upstream of the weirs. For the 20 cu.m/s flow, the average velocity is decreased from around 1.4 m/s to 0.4 to 0.5 m/s at the weir.

We would be pleased to run other channel scenarios with different flows or rock layouts as needed.



6. Rock Sizing

The rock should be designed to withstand peak flows so that the placed rock would remain in place during flood events. We recommend that the rock be sized to withstand the 1 in 200 year design flow of 280 cu.m/s. The approach channel velocities of the modified channel were used to size the rock based on the BC MoT Rock Riprap Sizing Chart (Appendix B). Rock placed laterally across the stream warrants specification based on direct impingement. For the average approach velocity of approximately 2.8 m/s, direct impingement would require considering a design velocity of 5.6 m/s.

Since the rock is placed on the bottom of the creek, a minimum of Class 250 kg rock would be recommended for this site. Section 205 of the Standard Construction Specifications gives additional details for the rock. Since these rock weirs are not meant to be rock erosion protection, we would be less concerned about the gradation of rock that is usually specified if it were to be placed on a bank, for example.

**TABLE 205-B APPROXIMATE AVERAGE
DIMENSION OF AN ANGULAR ROCK FOR EACH
SPECIFIED ROCK CLASS MASS (Sg=2.640)**

CLASS (KG)	APPROX. AVERAGE DIMENSION (mm)		
	15%	50%	85%
10	90	195	280
25	120	260	380
50	155	330	475
100	195	415	600
250	260	565	815
500	330	715	1030
1000	415	900	1295
2000	525	1130	1630
4000	660	1425	2055

7. Summary

1. The 1 in 200 year design flow for Kleanza Creek was estimated to be 280 cu.m/s.
2. The introduction of rock weirs at the proposed locations does not increase water levels or velocities at the bridge location.
3. The introduction of rock weirs does not adversely affect the existing diking system. Flood flows remain constrained by the diking.
4. Rock weirs reduce velocities in the channel and potentially will allow for capture of spawning gravels.
5. The recommended rock size is minimum Class 250 kg.



8. Recommendations

1. Prior to final design of the weirs, the proposed locations and spacing should be reviewed in detail and construction plans prepared.
2. Construction phasing and access requirements should be reviewed.
3. Permitting for this work should be carried out.

9. Closure

This assessment has been prepared by McElhanney Consulting Services Ltd. (MCSL) for the benefit of BC MoT and Hidden River Environmental Management. The information and data contained herein represent MCSL's best professional judgement in light of the knowledge and information available to MCSL at the time of preparation.

McElhanney Consulting Services Ltd. denies any liability whatsoever to other parties who may obtain access to this report for any injury, loss or damage suffered by such parties arising from their use of, or reliance upon, this document or any of its contents without the express written consent of MCSL, BC MoT and Hidden River Environmental Management.

We thank you for the opportunity to work on this project. Please do not hesitate to contact us if you have any questions.

Yours truly,

McElhanney Consulting Services Ltd.

Bill Cheung PEng
Hydrotechnical Engineer

c. Mitch Drewes, Hidden River Environmental Management

Appendices



Appendix A

HEC-RAS Summary Data



Table 1. HEC-RAS Output table for Q = 280 cu.m/s – Existing Channel Conditions. Bridge at Station 4.

Reach	River Sta	Profile	Q Total (m ³ /s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m ²)	Top Width (m)	Froude # Chl
1	31	year200	280.00	86.94	89.96	89.57	90.63	0.006737	3.72	87.26	40.70	0.75
1	30	year200	280.00	86.89	90.00		90.46	0.004617	3.02	95.30	48.45	0.62
1	29	year200	280.00	86.62	89.68	89.22	90.33	0.006396	3.59	83.78	51.71	0.73
1	28	year200	280.00	86.55	89.12	89.12	90.13	0.012438	4.45	65.30	37.64	0.99
1	27	year200	280.00	86.19	88.77	88.86	89.85	0.014334	4.62	62.07	36.46	1.05
1	26	year200	280.00	85.81	88.50	88.58	89.58	0.013956	4.60	63.26	38.94	1.04
1	25	year200	280.00	85.54	89.00	87.55	89.23	0.001623	2.14	144.63	58.77	0.39
1	24	year200	280.00	85.27	88.11	88.10	89.09	0.011376	4.44	71.98	45.01	0.95
1	23	year200	280.00	85.37	88.56		88.78	0.001770	2.09	148.21	69.74	0.39
1	22	year200	280.00	85.24	88.12		88.68	0.006327	3.43	101.78	60.42	0.71
1	21	year200	280.00	85.07	87.83	87.56	88.52	0.008131	3.75	86.14	54.07	0.80
1	20	year200	280.00	84.87	87.65		88.36	0.007205	3.78	82.41	45.96	0.77
1	19	year200	280.00	84.60	87.38	87.17	88.19	0.009612	3.99	71.24	37.54	0.87
1	18	year200	280.00	84.51	87.20	86.92	88.01	0.008454	4.01	72.06	40.10	0.83
1	17	year200	280.00	84.35	87.07	86.79	87.82	0.008640	3.86	74.44	47.08	0.83
1	16	year200	280.00	84.21	86.94	86.68	87.64	0.007561	3.77	86.21	54.65	0.78
1	15	year200	280.00	84.13	86.86	86.52	87.47	0.006772	3.57	93.56	53.74	0.74
1	14	year200	280.00	83.91	86.34	86.33	87.27	0.012256	4.29	70.04	42.76	0.97
1	13	year200	280.00	83.76	86.23	86.15	87.00	0.009475	4.02	87.55	64.54	0.87
1	12	year200	280.00	83.66	86.17	86.01	86.79	0.007322	3.73	112.49	80.50	0.78
1	11	year200	280.00	83.52	86.23		86.59	0.004729	2.91	143.22	83.33	0.62
1	10	year200	280.00	83.34	86.17		86.49	0.003845	2.74	146.60	71.77	0.56
1	9	year200	280.00	83.21	86.15		86.41	0.002827	2.53	175.36	90.86	0.49
1	8	year200	280.00	83.10	86.07		86.35	0.002834	2.58	172.43	99.67	0.49
1	7	year200	280.00	82.97	86.05		86.29	0.002302	2.36	190.23	100.00	0.45
1	6	year200	280.00	82.49	85.81		86.21	0.003560	2.89	126.91	81.84	0.55
1	5	year200	280.00	82.41	85.50		86.10	0.006139	3.41	82.14	35.20	0.70
1	4	year200	280.00	82.48	84.89	84.89	85.89	0.013425	4.43	63.18	31.95	1.01
1	3	year200	280.00	82.45	84.65	84.30	85.16	0.007318	3.45	115.30	73.74	0.77
1	2	year200	280.00	82.31	84.46	84.22	85.00	0.008031	3.48	112.05	78.31	0.79
1	1	year200	280.00	82.18	84.11	84.11	84.79	0.011507	3.76	91.44	78.60	0.93



Table 2. HEC-RAS Output table for Q = 280 cu.m/s – Modified Channel Conditions. Bridge at Station 4.

HEC-RAS Plan: Plan 01 River: KLEANZA Reach: 1 Profile: year200												Rel
Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
1	31	year200	280.00	86.94	90.08	89.47	90.56	0.005014	3.09	92.00	44.54	0.64
1	30	year200	280.00	86.89	90.00		90.46	0.004617	3.02	95.30	48.45	0.62
1	29	year200	280.00	86.62	89.68	89.22	90.33	0.006396	3.59	83.78	51.71	0.73
1	28	year200	280.00	86.55	89.12	89.12	90.13	0.012438	4.45	65.30	37.64	0.99
1	27	year200	280.00	86.19	88.77	88.86	89.85	0.014334	4.62	62.07	36.46	1.05
1	26	year200	280.00	85.81	88.50	88.61	89.56	0.014824	4.56	63.26	38.94	1.06
1	25	year200	280.00	85.54	89.01	87.56	89.23	0.001610	2.10	144.88	58.78	0.38
1	24.5		Inl Struct									
1	24	year200	280.00	85.23	88.49	88.09	89.16	0.006436	3.72	90.16	49.77	0.74
1	23	year200	280.00	85.37	88.78	87.17	88.97	0.001380	1.93	164.16	74.21	0.35
1	22.5		Inl Struct									
1	22	year200	280.00	85.23	88.52		88.90	0.003632	2.86	130.36	79.68	0.55
1	21	year200	280.00	85.07	88.45	87.54	88.82	0.003422	2.80	130.40	80.19	0.54
1	20.5		Inl Struct									
1	20	year200	280.00	84.87	88.26		88.69	0.003261	2.95	113.12	60.43	0.54
1	19	year200	280.00	84.60	88.24	87.17	88.61	0.003102	2.74	122.64	80.61	0.52
1	18.5		Inl Struct									
1	18	year200	280.00	84.51	87.20	86.92	88.01	0.008454	4.01	72.06	40.10	0.83
1	17	year200	280.00	84.35	87.07	86.79	87.82	0.008640	3.86	74.44	47.08	0.83
1	16	year200	280.00	84.21	86.94	86.68	87.64	0.007561	3.77	86.21	54.65	0.78
1	15	year200	280.00	84.13	86.86	86.52	87.47	0.006772	3.57	93.56	53.74	0.74
1	14	year200	280.00	83.91	86.34	86.33	87.27	0.012256	4.29	70.04	42.76	0.97
1	13	year200	280.00	83.76	86.23	86.15	87.00	0.009484	4.02	87.51	64.51	0.87
1	12	year200	280.00	83.66	86.17	86.01	86.79	0.007334	3.73	112.42	80.50	0.78
1	11	year200	280.00	83.52	86.23		86.59	0.004736	2.91	143.14	83.33	0.62
1	10	year200	280.00	83.34	86.17		86.49	0.003851	2.74	146.54	71.77	0.56
1	9	year200	280.00	83.21	86.15		86.41	0.002830	2.53	175.27	90.84	0.49
1	8	year200	280.00	83.10	86.07		86.35	0.002839	2.58	172.31	99.65	0.50
1	7	year200	280.00	82.97	86.05		86.28	0.002306	2.36	190.11	100.00	0.45
1	6	year200	280.00	82.49	85.81		86.21	0.003569	2.89	126.76	81.83	0.55
1	5	year200	280.00	82.41	85.50		86.10	0.006162	3.42	82.04	35.17	0.70
1	4	year200	280.00	82.48	84.90	84.90	85.89	0.013256	4.40	63.57	32.13	1.00
1	3	year200	280.00	82.45	84.64	84.30	85.16	0.007383	3.46	114.92	73.47	0.77
1	2	year200	280.00	82.31	84.45	84.22	85.00	0.008203	3.50	111.17	78.17	0.80
1	1	year200	280.00	82.18	84.11	84.11	84.79	0.011626	3.75	91.11	78.59	0.93



Table 3. HEC-RAS Output table for Q = 20 cu.m/s – Modified Channel Conditions. Bridge at Station 4.

HEC-RAS Plan: Plan 01 River: KLEANZA Reach: 1 Profile: year200												Rel
Reach	River Sta	Profile	Q Total (m ³ /s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m ²)	Top Width (m)	Froude # Chl
1	31	year200	20.00	86.94	87.85	87.61	87.96	0.005783	1.42	14.04	21.47	0.56
1	30	year200	20.00	86.89	87.72		87.83	0.006788	1.47	13.63	22.46	0.60
1	29	year200	20.00	86.62	87.60		87.70	0.006105	1.38	14.47	24.01	0.57
1	28	year200	20.00	86.55	87.28	87.28	87.48	0.021195	2.01	9.94	24.06	1.00
1	27	year200	20.00	86.19	86.96	86.89	87.13	0.013756	1.83	10.91	21.94	0.83
1	26	year200	20.00	85.81	86.90		86.97	0.003551	1.21	16.57	22.52	0.45
1	25	year200	20.00	85.54	86.93	86.02	86.94	0.000295	0.46	43.66	39.26	0.14
1	24.5		Inl Struct									
1	24	year200	20.00	85.23	86.78		86.81	0.000923	0.78	25.67	24.30	0.24
1	23	year200	20.00	85.37	86.79	85.75	86.80	0.000165	0.37	53.53	42.12	0.11
1	22.5		Inl Struct									
1	22	year200	20.00	85.23	86.71		86.73	0.000484	0.60	33.12	28.29	0.18
1	21	year200	20.00	85.07	86.70	85.69	86.72	0.000320	0.53	38.02	30.73	0.15
1	20.5		Inl Struct									
1	20	year200	20.00	84.87	86.20		86.22	0.000691	0.67	29.86	28.62	0.21
1	19	year200	20.00	84.60	86.19	85.27	86.21	0.000441	0.59	34.05	28.28	0.17
1	18.5		Inl Struct									
1	18	year200	20.00	84.51	85.27		85.37	0.006693	1.38	14.47	25.94	0.59
1	17	year200	20.00	84.35	85.10		85.21	0.008508	1.48	13.53	26.28	0.66
1	16	year200	20.00	84.21	84.94		85.05	0.008051	1.44	13.90	26.85	0.64
1	15	year200	20.00	84.13	84.79		84.89	0.007490	1.42	14.11	26.40	0.62
1	14	year200	20.00	83.91	84.61		84.73	0.008823	1.50	13.38	26.22	0.67
1	13	year200	20.00	83.76	84.48		84.57	0.006225	1.33	15.03	27.22	0.57
1	12	year200	20.00	83.66	84.35		84.44	0.006737	1.36	14.73	27.18	0.59
1	11	year200	20.00	83.52	84.15		84.27	0.011639	1.54	14.78	39.58	0.75
1	10	year200	20.00	83.34	84.00		84.08	0.007015	1.29	18.21	37.31	0.59
1	9	year200	20.00	83.21	83.85		83.93	0.007067	1.32	17.68	40.76	0.60
1	8	year200	20.00	83.10	83.69		83.79	0.007556	1.36	15.29	32.39	0.62
1	7	year200	20.00	82.97	83.49		83.61	0.010893	1.53	13.06	28.91	0.73
1	6	year200	20.00	82.49	83.39		83.46	0.004120	1.16	17.19	27.48	0.47
1	5	year200	20.00	82.41	83.33		83.39	0.002885	1.06	18.89	26.57	0.40
1	4	year200	20.00	82.48	83.17		83.29	0.009251	1.56	12.86	24.54	0.69
1	3	year200	20.00	82.45	83.08		83.14	0.005010	1.11	21.39	45.02	0.50
1	2	year200	20.00	82.31	82.96	82.78	83.03	0.005556	1.16	17.25	36.40	0.53
1	1	year200	20.00	82.18	82.65	82.65	82.82	0.023476	1.79	11.17	34.92	1.01



Table 4. HEC-RAS Output table for Q = 55 cu.m/s – Modified Channel Conditions. Bridge at Station 4.

HEC-RAS Plan: Plan 01 River: KLEANZA Reach: 1 Profile: year200												Re
Reach	River Sta	Profile	Q Total (m ³ /s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m ²)	Top Width (m)	Froude # Chl
1	31	year200	55.00	86.94	88.37	88.08	88.59	0.006995	2.09	26.28	25.78	0.66
1	30	year200	55.00	86.89	88.25		88.43	0.007908	1.92	28.64	35.14	0.68
1	29	year200	55.00	86.62	88.09		88.28	0.007129	1.97	27.96	30.31	0.65
1	28	year200	55.00	86.55	87.68	87.67	88.05	0.017206	2.70	20.34	26.85	0.99
1	27	year200	55.00	86.19	87.41		87.74	0.012817	2.54	21.62	25.10	0.87
1	26	year200	55.00	85.81	87.30		87.52	0.006910	2.11	26.12	25.23	0.66
1	25	year200	55.00	85.54	87.39	86.36	87.43	0.000728	0.88	62.51	41.44	0.23
1	24.5		Inl Struct									
1	24	year200	55.00	85.23	87.25		87.36	0.002214	1.46	38.11	32.12	0.39
1	23	year200	55.00	85.37	87.29	86.05	87.32	0.000427	0.73	74.90	43.18	0.18
1	22.5		Inl Struct									
1	22	year200	55.00	85.23	87.21		87.28	0.001151	1.14	52.28	48.43	0.29
1	21	year200	55.00	85.07	87.20	86.07	87.25	0.000865	1.04	56.65	42.20	0.25
1	20.5		Inl Struct									
1	20	year200	55.00	84.87	86.78		86.85	0.001249	1.18	46.79	30.84	0.30
1	19	year200	55.00	84.60	86.76	85.68	86.82	0.000987	1.09	50.67	30.40	0.27
1	18.5		Inl Struct									
1	18	year200	55.00	84.51	85.72		85.94	0.007416	2.08	26.46	27.54	0.68
1	17	year200	55.00	84.35	85.55		85.78	0.008394	2.14	25.75	28.28	0.71
1	16	year200	55.00	84.21	85.39		85.62	0.007761	2.09	26.36	28.08	0.69
1	15	year200	55.00	84.13	85.23		85.46	0.007780	2.10	26.19	27.69	0.69
1	14	year200	55.00	83.91	85.05		85.29	0.008651	2.16	25.43	27.99	0.72
1	13	year200	55.00	83.76	84.92		85.13	0.007013	2.03	27.29	28.94	0.66
1	12	year200	55.00	83.66	84.71		84.96	0.009523	2.24	24.65	28.07	0.76
1	11	year200	55.00	83.52	84.55		84.76	0.009478	2.10	31.40	42.94	0.74
1	10	year200	55.00	83.34	84.42		84.59	0.006753	1.87	35.44	44.42	0.64
1	9	year200	55.00	83.21	84.31		84.46	0.005828	1.78	37.87	47.67	0.60
1	8	year200	55.00	83.10	84.14		84.32	0.006968	1.94	30.74	37.72	0.65
1	7	year200	55.00	82.97	84.00		84.19	0.006705	1.93	29.58	39.94	0.64
1	6	year200	55.00	82.49	83.92		84.07	0.004255	1.72	32.02	28.92	0.52
1	5	year200	55.00	82.41	83.85		83.99	0.003747	1.68	32.75	27.64	0.49
1	4	year200	55.00	82.48	83.49	83.44	83.84	0.014632	2.60	21.16	26.24	0.92
1	3	year200	55.00	82.45	83.48		83.61	0.005162	1.67	42.06	54.17	0.56
1	2	year200	55.00	82.31	83.32	83.11	83.49	0.006632	1.81	33.35	59.04	0.63
1	1	year200	55.00	82.18	82.97	82.97	83.26	0.019084	2.42	22.72	38.60	1.01



Appendix B

BC MoT Riprap Design Chart

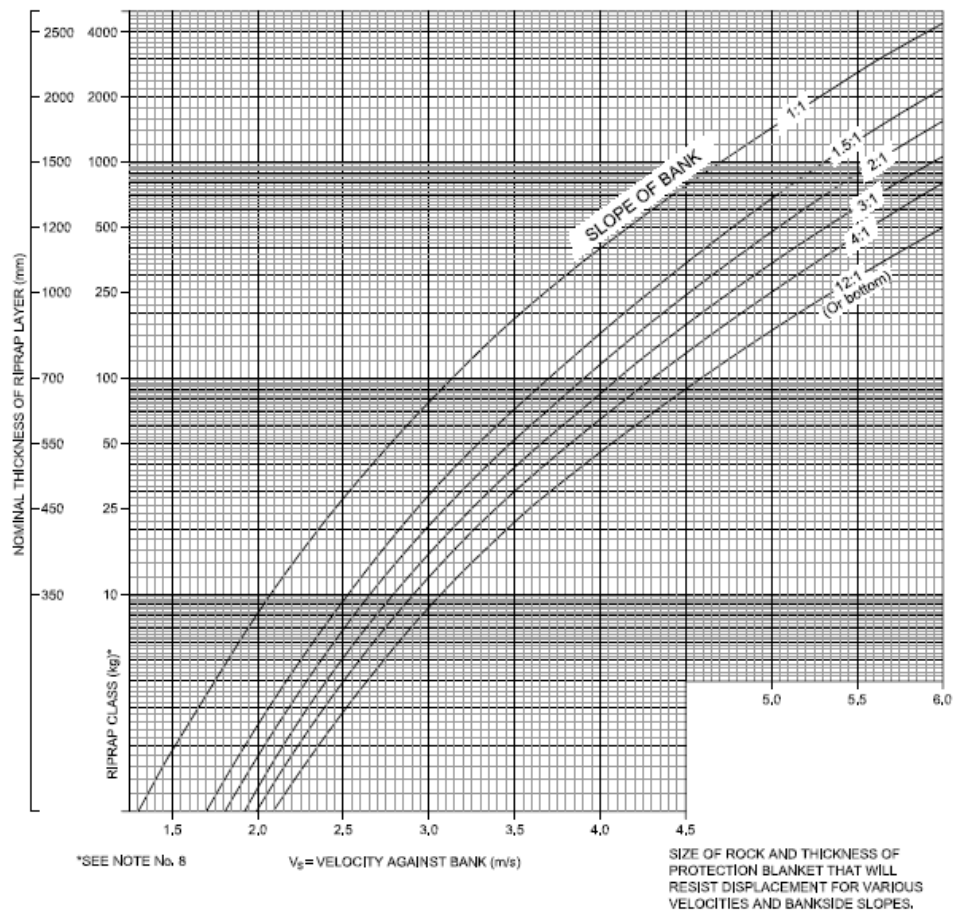


SUPPLEMENT TO TAC GEOMETRIC DESIGN GUIDE

BC MoT

MoT Section	1030	TAC Section	Not Applicable
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Figure 1030.A Riprap Design Chart



Notes:

- Adapted from report of Sub-committee on slope protection, Am. Soc. Civil Engineers Proc. June 1948.
- Density of stone assumed at $2,640 \text{ kg/m}^3$.
- Enter graph at known velocity to intersection with desired slope curve. Move horizontally to required riprap class and thickness.
- V_M = mean stream velocity.
- For parallel flow along tangent bank; $V_S = 2/3 V_M$
- For Impinging flow against curved bank; $V_S = 4/3 V_M$
- For direct Impingement on the bank; $V_S = 2 V_M$
- *8. The riprap class No. is the mass (kg) of the 50% rock size (i.e., at least half of the riprap must be heavier than its class mass). For details regarding the rock gradation see Standard Specifications - Section 205.02
- Do not interpolate between riprap classes. Use the next highest class.