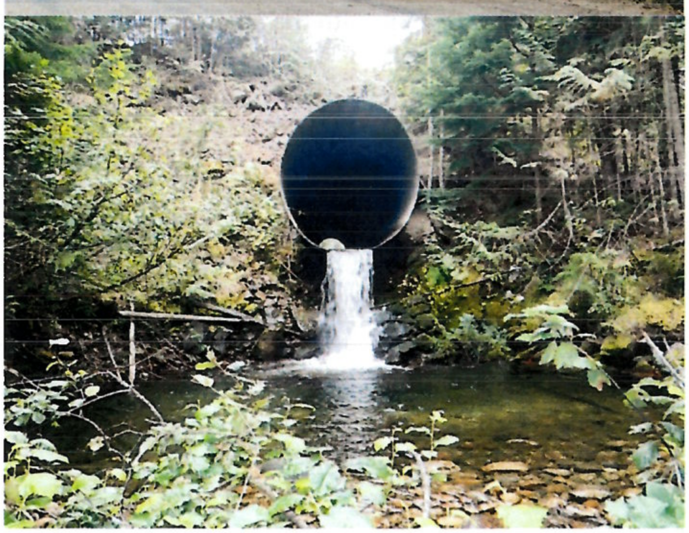
Heart Creek Fish Passage Improvements – Phase 2



Heart Creek Fish Passage Improvements – Phase 2

COL-F17-F-1400

Prepared for:

Fish and Wildlife Compensation Program

By

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Regional Manager Environmental Services

Ministry of Transportation and Infrastructure

Prepared with financial support of the Fish and Wildlife Compensation Program on behalf of its program partners BC Hydro, the Province of BC, Fisheries and Oceans Canada, First Nations and public stakeholders

15-Mar-2017

FISH AND WILDLIFE COMPENSATION PROGRAM

BRITISH COLUMBIA

Ministry of Transportation and Infrastructure

Executive Summary

With thanks in part to the Fish and Wildlife Compensation Program's grant of $20,000, the Ministry of Transportation and Infrastructure was able to let two contracts; one to Northwest Hydraulic Consultants for a Hydrotechnical Assessment of Replacement Options Report and the other to Sea to Sky Drilling for a drill rig to give us a sample of what soils are at the crossing site. These reports will be used in helping narrow down our options for structures proposed for the Heart Creek Fish Passage Improvements – Applegrove Road Project. The Applegrove Road Project will work towards the Fish and Wildlife Compensation's Large Lakes Action Plan where they have identified key limiting factors for fish in Arrow Lakes as habitat quantity and quality, provide access to habitats (I.E. passage), and predation (Fish and Wildlife Compensation Program, 2012). When we commence construction of the project in 2018 the new structure will address all of these issues by opening up 1.2 kilometres of additional good quality habitat, ensure passage in perpetuity, and reduce the predation on fish species by opening up this additional habitat.

Under the contract for Northwest Hydraulic Consultants they assessed three options to pass fish through the Applegrove Road barrier on Heart Creek. The options included reconstruction of the channel up to the invert of the existing pipe making it fish passable; construction of a new multi-plate culvert at the existing location; or construction of a bridge. The highest cost/benefit solution to ensuring fish passage in perpetuity was a bottomless arch culvert, which we will be designing for.

A second contract to Sea to Sky Drilling was to produce drilling records for our Geotechnical Engineer who will be passing his recommendations onto our design team for the design the footing of the bottomless arch culvert. The drill logs determined that we will be dealing with the same problematic soils that we experienced on the Highway 6 crossing.

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Introduction

In 2016 the accessible fish habitat on Heart Creek was doubled with the replacement of a perched 3.0 metre wide culvert with an 18 metre long clear span bridge (figure 1, and 2). This bridge was jointly funded by the Ministry of Transportation and Infrastructure, the Fish and Wildlife Compensation Program, the Department of Fisheries and Oceans, Recreational Fisheries Conservation Partnership Program and the Nakusp Rod and Gun Club. The Heart Creek Project was a huge success with Kokanee making it through to a reach of stream they hadn't seen in 35 years, even before construction was completed at the site.

Figure # 1 - Culvert under Highway 6 – September 2014

Figure # 2 – New Bridge over Highway 6 – September 2016

The construction of the Highway 6 clear span bridge was big in itself, but the real gains of the project come from the elimination of the second barrier on Heart Creek, the Applegrove Road Crossing (Figure 3). Similar in nature to the Highway 6 crossing, there is a 3.3 metre wide culvert that is perched approximately 3 metres above the stream channel making it impossible for fish to access the upper reaches of the stream. With the elimination of this barrier an additional 1.2 kilometres of good quality fish habitat is available upstream.

Figure 3 – Applegrove Road Barrier

The Ministry made application to the Fish and Wildlife Compensation Program for a grant to assist in the development of the plans for the Applegrove Project. The Applegrove Road barrier removal will ultimately result in unrestricted accessibility to approximately 1.2 kilometres of good quality stream habitat upstream, a reach of stream that has not seen fish in 35 years. By removing this barrier it will reduce the predation on other fish species as it will greatly open up the quantity of habitat available. The Fish and Wildlife Compensation Plan has identified a number of limiting factors in the Arrow Lakes system including habitat quantity, quality, access to habitats (i.e passage), and predation (Fish and Wildlife Compensation Program, 2012). All of these limiting factors will, in part, be addressed by the removal of this barrier.

Goals and Objectives

Unlike the Highway 6 crossing where the Ministry had the plans “shelf ready” waiting for funding to become available, the Applegrove Road crossing design has to start from the beginning. In 2016 the initial surveys and studies were completed to fill in the knowledge gaps for our design staff. In 2017 we have started our project team, with a Project Manager who will bring together the internal components of the team and have each team member execute their roles and responsibilities in the delivering of the project, with the final design tender ready by 2018, with construction occurring in 2018.

In order to meet the goals of 2016 two consultants were used to address the gaps of what type of structure would be the best fit for the site and what soils were we building on. Northwest Hydraulic Consultants looked at the options on how to pass fish through the barrier, while Sea to Sky Drilling was used to drill bore holes on either side of the existing culvert to determine the soil make up where the proposed structure will be constructed.

Figure #4 – Construction Sign with partner's logos

Study Area

The study area is located 265 metres upstream of the new clear span bridge on Highway 6 where Applegrove Road crosses over Heart Creek; the site is approximately 275 metres southwest of the Village of Fauquier (See figure 5). Heart Creek drains an area of 30.5 square kilometres and is a tributary to Lower Arrow Lake. The study area for the Northwest Hydraulics study included the entire watershed but specifically looked at 100 metres upstream and downstream of the culvert crossing to determine the channel characteristics. The Sea to Sky Drilling contract was limited to immediately either side of the existing culvert where the proposed footings for the structure will be placed.

Figure #5 – Google Earth Image of the study area.

Methods

For the Northwest Hydraulic Consultants (NHC) contract the Project Engineer contacted the local Bridge Area Manager to review past Condition Inspection Reports and then went out on site to assess the culvert, and channel conditions of Heart Creek. NHC assessed the hydrology of the creek and calculated the Peak Flood Flow estimates that helped to determine if the existing structure is adequately sized, or if the replacement structure needed to be enlarged. The Ministry of Transportation and Infrastructure follows the Canadian Highway Bridge Design Code, which is basically the building code for bridges and structures, with these codes and design flows required by those codes NHC compared three potential options for the potential crossing: rehabilitation of the existing culvert, replacement of a new culvert, or replacement with a bridge. With the three crossing options NHC put some rough costs and pros and cons around each of the three options.

The Sea to Sky contract was pretty straight forward; drill two bore holes on either side of the existing culvert to determine the presence of soil where the proposed footing would be placed for the structure.

Results and Outcomes

The result of the NHC contract determined the most cost efficient method of passing fish past the Applegrove Road barrier was a properly sized bottomless arch culvert. This option was approximately $750,000 cheaper than the bridge option which was second in terms of the cost/benefit analysis. The structure will be designed to the Ministry standard of a 75 year life span.

The result of the Sea to Sky contract was the soil types that could be expected throughout the depth of the proposed piles. We did discover that the problematic soils that we experienced on the Highway 6 crossing, which required a different piling design, and much longer pile depth, are also found at this site. This information will be invaluable in designing the support for the structure, and help with the Ministry to adjust the estimated Ministry costs.

Discussion

Now that the survey data, Archaeological assessment, options report, and geotechnical drilling have been completed we can start work on the design of the project. The Ministry has assigned the Project Manager duties to Robbie Kalabis, who has experience as the Project Manager for the Highway 6 crossing. Robbie has set up a project team, from all the Ministry disciplines (design, structural design, environment, geotech, hydrology, properties, FN Consultation) and will start to have regular meeting and milestones to develop the plan and secure the resources to complete the project.

Recommendations

Robbie Kalabis has been given direction to have this project ready for construction by 2018. The two reports commissioned through funding from the Fish and Wildlife Compensation Program will start off the design phase of the work and will ultimately provide for a better cost estimate, and product for the Ministry and their funding partners on this project.

Acknowledgements

The Ministry would like to thank the Fish and Wildlife Compensation Program, for their support of commissioning the two above mentioned reports, and the ongoing support offered by Crystal Klym and Trevor Oussoren. The Ministry is very excited about delivering the final Applegrove Road phase of this project opening up considerable fish habitat on Heart Creek.

References

Fish and Wildlife Compensation Program. 2012. Columbia Basin Large Lakes Action Plan. Available at: http://fwcp.ca/app/uploads/2016/07/Large-Lakes-Action-Plan-Web-FNL-June-20121.pdf

Appendix A – Northwest Hydraulics Options Report

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nhc
northwest hydraulic consultants ltd

NHC Ref. No. 300003.21.2

12 July 2016

BC Ministry of Transportation and Infrastructure
447 Columbia Street,
Kamloops, BC
V2C 2T3

Attention: **Mike Sullivan, P.Eng.**
Senior Hydrotechnical Engineer

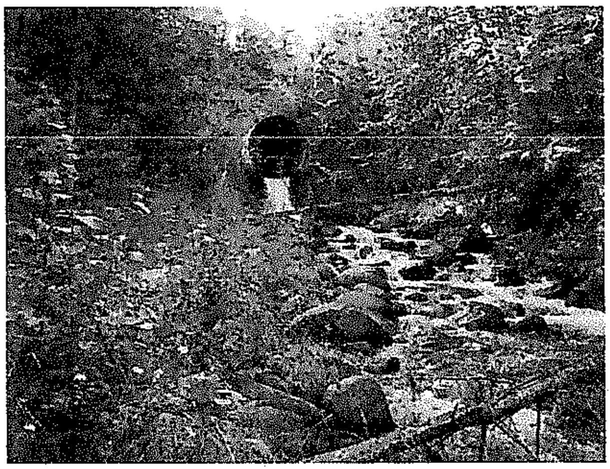
Re: **Heart Creek Culvert No. 2 (07240) Replacement Project**
Hydrotechnical Assessment of Replacement Options - Draft

Dear Mr. Sullivan:

Northwest Hydraulic Consultants (NHC) is pleased to provide this letter report summarizing conditions in Heart Creek and the assessment of three (3) options being considered for rehabilitation or replacement of the Heart Creek No. 2 Culvert (Structure 07240). The objectives of rehabilitation or replacement will be to: i) improve the hydraulic performance of the structure, thus reducing associated risks to the structure itself and downstream infrastructure; and ii) re-establish fish passage through the structure.

1 EXISTING CULVERT

Structure 07240 is a 3300 mm diameter, structural steel plate pipe culvert. It is not adequately sized for the passage of sediment and debris in Heart Creek. The small size and low barrel roughness of the culvert, relative to size and roughness of the natural stream, have caused considerable instability in Heart Creek both upstream (aggradation and channel mis-alignment) and downstream (perched culvert and severe scour and degradation). In addition, there are clear signs of soil piping underneath the culvert barrel and in the fill slope to the east of the culvert, where a portion of the fill slope sloughed during a flood in 2004. The shape of the pipe has begun to warp slightly due to the loss of supporting fill and the bolts and plates of the culvert are worn. The deficiencies of the culvert are well documented in past Condition Inspection Reports prepared by MoTI's Bridge Area Manager, Arn Von Maydell and in the Scour and Erosion Evaluation Report (SER) prepared by NHC in 2011.



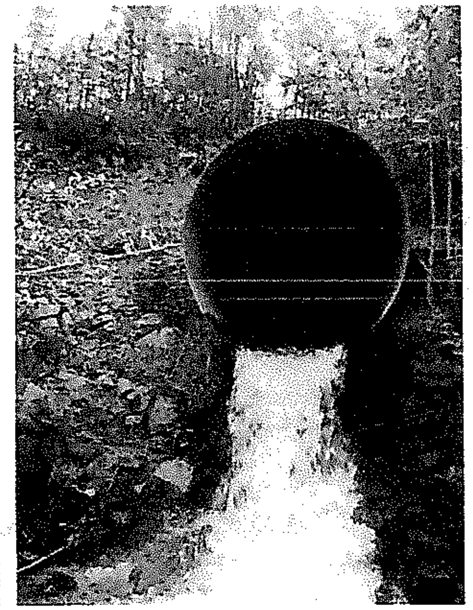


Photo 1 and 2. Looking upstream to the outlet

2 CHANNEL CONDITIONS IN THE STUDY REACH

Heart Creek has a drainage area of 26 km^2 upstream of the Applegrove Road crossing. The watershed has a west/ northwest aspect with headwaters originating in the valley between Mount Rollins and Naumulten Mountain in the Columbia Mountain range. Maximum and mean elevations in the watershed are El. 2,525 m and El. 1,648 m (GSC)[1], respectively. The streambed elevation at the upstream (inlet) side of the Applegrove Road crossing is approximately El. 470 m. In the mid-to upper elevations, the valley is narrow and U-shaped with steep tributary gullies. In the lower elevations, downstream of Structure 07240, the creek flows within a partially incised channel on a forested alluvial fan. 280 m downstream of Applegrove Rd the creek flows under Highway 6 through a recently constructed bridge. Downstream of the Highway 6 Bridge (08519) the creek is unnaturally confined by high (4+ m) rip rap protected banks, flanked on both sides by a golf course. A low elevation watermain bridge crosses the creek 30 m downstream of Highway 6 and a pedestrian bridge owned by the golf course crosses the creek about 90 m downstream. A truncated, unvegetated portion of alluvial fan exists at the mouth of the creek, about 120 m downstream of the highway, where the creek flows into Lower Arrow Lake.

[1] Elevations are in geodetic

Forest harvesting activity has occurred in the watershed during the span of human habitation in the area. Clear cut harvesting and drainage issues associated with spur and mainline road development has resulted in mass wasting in the upper watershed and sedimentation throughout the lower reaches at various times. In 2000-2001, a project was undertaken to stabilize two landslide sites in the upper watershed (Terra Erosion Control Ltd., 2004).

The reach of interest begins at the Applegrove Culvert (Structure No. 7240) and extends roughly 50 m downstream.

As noted in Section 1, Structure 07240 at Applegrove Road is too small to pass the high sediment and debris loads that can occur during large floods and as a result the channel upstream has some history of aggradation and lateral instability. The size of the culvert also results in very high flow velocities during floods. In July 2004, an avulsion occurred upstream of the culvert after the culvert was partially blocked by debris. The creek formed a new channel that ran parallel to and caused scour at the upstream (south) toe of the high road embankment. At the outlet, clear water scour has removed a large section of the downstream (north) embankment toe, which has cantilevered the culvert and left its invert perched about 3 m above the creek bed (Photo 2). Scour also removed a considerable amount of streambed material from the channel downstream of the culvert, leaving it in a degraded state from which is has never recovered. This degradation persists because Structure 07240 typically interrupts the transport and re-supply of sediment during floods.

Downstream of Applegrove Road the average channel slope is 5 % (0.05 m/m) and the bed material is comprised of mostly cobbles and small boulders; however, the full gradation of materials in the creek ranges from silt up to 1 m diameter boulders. The natural stream channel proximal to Applegrove Rd channel tends to be moderately incised with banks that are 1 m to 2 m high and rarely overtopped on a reach scale. The bank material has the same composition as the creek bed material, which is indicative of an alluvial fan channel.

Areas of channel instability (widening) occur where large trees have toppled into the stream and formed stationary jams, causing erosion opposite or adjacent to the obstruction.

3 HYDROLOGY

For the purpose of this report, hydrologic estimates for Heart Creek are based on a comprehensive report on hydrology in the Kootenay Region (Obedkoff, 2002). A more thorough review of hydrology would be prudent during preliminary design of the preferred option, at the very least to ensure the regional data presented in the 2002 report is updated based on flow records acquired since its publication.

The regional 10-year curves provided by Obedkoff (2002) are parallel straight lines which envelop the 10-year annual peak flows estimated for the Water Survey of Canada (WSC) gauges analysed. Heart Creek is located within Hydrological Zone 13, Subzone 'g' and it's envelop line is defined by 10-year peak flows for watersheds that have very steep and rugged (high relief) topography (e.g. Kuskanax – Nakusp [WSC 08NE006] and Stitt Creek [WSC 08ND018]) compared to Heart Creek. The 10-year peak flow for Heart Creek was therefore estimated by drawing a line a line that parallels the envelop line but intercepts the 10-year peak flows for WSC watersheds with physical characteristics more similar to Heart Creek (e.g. Hidden Creek [08NE114] and Goldstream River [08ND012]); Figure 2).

The 2-, 100- and 200-year peak flow events are estimated by applying 2:10-, 100:10- and 200:10-year ratios for physiographical similar WSC watersheds (Table 1). For the higher return periods, higher-end ratios were chosen because they are thought to reflect the locally intense, spring and summer rainstorms that trigger extreme floods on smaller creeks in the Kootenays.

The low flows provided in Table 1 are based on the regional 10-year annual low flow curve and 10-year June to September low flow curve suggested by Obedkoff (2002).

Table 1. Peak Flood Flow estimates for Heart Creek at Highway 6.

Flow Condition	Ratio to 10-year Peak Flow	Estimated Flow (m^3/s)
10-year Annual Low Flow	N/A	0.05
10year June to September Low Flow	N/A	0.08
Mean Annual Flow (MAF)	N/A	0.85
2-year peak flood	0.70	9.4
10-year peak flood	1.00	13.2
100-year peak flood	1.85	24.4
200-year peak flood	2.00	26.4

3.1 Potential effect of climate change

Recent studies conducted by NHC for MoTI and other clients have shown that increases in extreme flow as a result of climate changed can be expected to range from 10 percent to 25 percent, give or take, and that affects can vary depending on existing hydrologic regimes, region etc. At this time, NHC has not conducted a detailed analysis of potential climate change effects on floods in Heart Creek, but recommend using a 20% increase for the purpose of assessment and conceptual design of rehab or replacement options for Structure No. 07240. A more detailed assessment of climate change effects should be carried out during preliminary design.

3.2 Recommended Design Discharge

NHC recommends that the future 100-year peak discharge, 29 m^3/s (24.4 m^3/s + 20%) be used as the design discharge for assessment of replacement options for Structure No. 07240.

4 CULVERT REPLACEMENT OPTIONS

The following three options are being considered as upgrades for the existing Heart Creek No. 2 Culvert:

1. **Rehabilitation of existing culvert.** Leave the existing culvert in place, recognizing its size limitations, and construct channel improvements downstream, upstream and within the culvert to improve fish access and passage.

2. **Replacement with a new culvert.** Remove the existing culvert and replace with a larger, open bottom culvert.

3. **Replacement with a bridge.** Remove the existing culvert and replace with a bridge and open channel below.

5 HYDROTECHNICAL DESIGN CRITERIA AND CONSTRAINTS

The following hydrotechnical design criteria and, hydrotechnical (items 1 to 3) and environmental (items 4 to 7) constraints apply to the options being considered:

1) Hydraulic design for structures is done in accordance with the procedures outlined in the TAC Guide to Bridge Hydraulics and in compliance with the MoT Supplement to Canadian Highway Bridge Design Code (CHBDC), the CAN/CSA-S6-14 Canadian Highway Bridge Design Code and The Handbook of Steel Drainage and Highway Construction Products (CSPI, 2007).

2) Both replacement structures (Options 2 and 3) must be able to pass the design 100-year peak flow (29 m^3/s) with a minimum 1.5 m of flood clearance between the upstream headwater/ flood elevation and the upstream soffit of the structure. Although Applegrove Rd. is a local road with lower traffic volumes that a highway, we recommend using the highway minimum flood clearance standard since the fill slopes are quite high, and the risks associated with a debris related failure are transferred downstream to the Highway 6 Bridge (08519) and privately held lands.

3) New culverts (Option 2) should have a span comparable to the width of the natural stream so they do not substantially alter the hydraulics (depth and velocities) present within the natural channel, thus allowing them to pass normal sediment and debris loads effectively.

4) Scour must be accommodated for in the design of channel armouring for all options and for the design of culverts. The depth of inlet scour for culverts and scour along the toe of streambanks is estimated to be approximately 1 m for conceptual design purposes. Scour potential should be re-assessed during preliminary design of the preferred option.

5) The grade of any new constructed stream channel (or culvert) should be, to the extent possible, at or below five (5) percent.

6) Steps incorporated into new or re-contoured channels shall not exceed 30 cm in height.

7) Target velocities at mean annual and mean monthly flows shall be in the range of 0.8 to 1.0 m/s for optimal fish passage. In areas where projected velocities may be higher, a tighter spacer of pools with be required to allow for additional resting areas for fish as they move upstream; in general, spacing no more than 5 to 6 m apart for the steps is considered appropriate.

8) The depth of natural substrate within the open bottom culvert (Option 2) is a criterion that may have some flexibility during detailed design of the replacement structure; however, for purposes of comparing the three options a depth of 1 m should be assumed.

6 SIZING AND HYDRAULIC PERFORMANCE OF THE OPTIONS

The sizing and hydraulic performance of all options has been evaluated with the use of a one-dimensional, steady-state hydraulic model using HEC-RAS software (USACE; V. 4.1). The model was originally developed during the previous Scour Evaluation Study (NHC, 2010). Conceptual drawings showing all three options are provided in an Appendix at the back of this report.

For Option 1 (rehabilitation), re-grading of the channel downstream of the existing outlet is modeled using 5 m long segments of boulder-lined, channel at 5% to 6% grade, with 0.3 m vertical drops between segments. The banks of this channel are projected up at 2H: 1V slopes to the Q100 water level plus 0.6 m freeboard. This re-graded channel would extend from the existing outlet at a continuous 5-6% until it meets and transitions with the existing bed. The new channel would be founded upon a base of compacted pit-run material, placed following sub-excavation of the existing degraded and scoured streambed that currently exists downstream of the culvert. Due to limited availability of downstream survey, the length and configuration of this new length of channel would likely require refinement during preliminary design to optimize the tie-in to the natural channel downstream.

For Option 2 (culvert replacement), the required size of the new culvert has been determined through a process of iteration until all of the criteria and constraints listed in Section 4 were satisfied. The sizing analysis for the culvert replacement option (Option 2) assumes its inlet will be hydraulically improved by adding a headwall or reinforced collar, and mitering the end plates to form a 2:1 slope at the inlet. The resulting culvert is an open bottom, corrugated steel multi-plate arch (CSMPA) culvert measuring 6.3 m in span and 3.68 m in rise. The bed load abrasion level is Level 3 (CSPI, 2007), so the culvert material should be ideally be aluminized steel or have a greater steel thickness to withstand abrasion. A closed bottom pipe arch would also be an option here; however, that would not necessarily result in a less expensive structure since it would have to be partially buried, be constructed of thicker steel, and or be outfitted with steel abrasion plates in order to achieve a 75 year design life. An outlet pool will be required to optimize fish access to the new culvert. Beyond the pool, 250 kg MoT rip rap would be used to construct the pool and protect the existing channel some distance of downstream of the culvert; for costing purposes (Section 6) a length of 15 m is assumed.

For the bridge (Option 3) a minimum bottom width of 6 m is recommended. This matches the typical bottom width of the natural channel a few hundred metres upstream of Applegrove Rd., and is confirmed by established channel regime relationships (NHC, 1982). The bridge option assessed in this study is a single-span structure over a trapezoidal channel with 1.5H: 1V fill slopes. Flatter side slopes may be required to satisfy geotechnical requirements at the site. A multi-span bridge would be feasible as well, provided the piers were pile supported, located within the sloping portion of the fill (i.e. not in the channel) and protected by rip rap.

Table 2 summarizes the size of culvert (or channel) for the rehab and replacement options and the hydraulic performance of each against the design criteria and constraints (Section 5). The last three columns in Table 1 show the 100-year, 2-year, and MAD average flow velocity, depth of flow and clearance between the upstream flood level and soffit of the bridge or culvert. Velocity has been identified as a specific criteria or constraint on design as it determines whether an option is suitable for fish passage.

Table 2. Summary of sizes and hydraulics for rehab and replacement options.

Option	Dimensions (m)	U/S Invert[a]	D/S Invert[a]	Length[b]	Slope	100-Year (29 m^3/s)[c]			2-Year (9.4 m^3/s)		MAF[h] (0.85 m^3/s)	
		(m, El.)	(m, El.)	(m)	(%)	Clearance[e] (m)	Depth[f] (m)	Velocity[g] (m/s)	Depth[f] (m)	Velocity[g] (m/s)	Depth[f] (m)	Velocity[g] (m/s)
1. Rehab. Existing[d]	3.30 CSMP	96.2	94.5	48	5	-0.7	2.0	4.4	0.9	3.1	0.3	1.1
2. Replace w/ Culvert	6.30(S) x 3.68(R) Arch	94.6	92.2	50	5	1.6	1.3	4.0	0.6	2.8	0.1	1.0
3. Replace w/ Bridge	Trap. Channel 6 m wide w/ 1.5H: 1V Slopes	94.6	92.2	50	5	>>1.5	1.5	3.3	0.7	2.4	0.2	0.8

Notes

a. The invert elevations given are conceptual; for Option 2, this is the invert of the finshed streambed within the new culvert.
b. Length of culverts or length of channel through highway embankment, below the bridge
c. The 100-year flow reflects an increase of 20% for preliminary accounting of potential climate change effects
d. Option 1 assumes no addition to the length of the existing culvert.
e. Clearance = Distance between U/S flood level and soffit of bridge or culvert (negative number indicates surcharge).
f. Depth of flow within barrel of culverts or within trapezoidal channel
g. Average velocities shown are maximums within barrel of culverts or within trapezoidal channel
h. MAF = Mean Annual Flow

7 CONSTRUCTION ELEMENTS AND COSTS

This section describes elements unique to the hydrotechnical design of each option, and is followed by Table 3, which summarizes and compare the expected cost (+/- 35%) of each option. Not all construction elements are described below; however, Table 3 does show a comprehensive breakdown of cost. Cost estimates are based on estimates prepared for other recent MoTI projects including: the Luxor Creek Culvert Replacement Project (CWMM, 2013) and the Grizzly Creek Culvert Replacement Project (MCEL, 2014), as well as the 2013 Construction and Rehabilitation Cost Guide (MoTI 2013).

7.1 Channel re-grading upstream

The inlet a new culvert (Option 2) and upstream end of a proposed bridge waterway channel (Option 3) are at elevation 94.6 m (local elevation; not geodetic). For tie-in purposes, the natural channel upstream of Applegrove Rd. will require re-grading. This would be done by excavating the existing bed at a slope of 5% a distance upstream that meets the existing bed grade. Alternatively, boulder steps can be used to minimize the distance of re-grading required. Former avulsion channels upstream of Applegrove Rd. could also be sealed/ closed off as part of this process. For costing purposes NHC has used $1,500/ linear meter of channel.

7.2 Re-Grading and rip rap lining of downstream channel for Option 1

Option 1 requires the scoured downstream channel be raised to the elevation of the existing outlet and consist of 5m steps sloping at 6% before dropping 0.3 m to the next step. Prior to building the new channel, the existing scoured channel will have to be stripped. Compacted pit run would then be placed to form a trapezoidal channel with banks that slope up from the bed at a grade of 2H:1V to an elevation of the Q100 water level plus a 0.6 m freeboard; beyond the channel the pit run would be sloped upward to meet the existing gully banks. An outlet pool will be required as a resting area for fish, though details of this pool are not shown on the drawing for Option 1. For preparation and construction of the pit run channel base, NHC has used $350/ cubic meter of material. The new creek channel lining will then be constructed to a 6 m bottom width. The bed material should consist of 700 mm rounded boulders for the 0.3 m high steps with a cobble and gravel mix being used to line the remainder of the bed. The banks of the channel will be armoured with 250-kg rip rap. For costing purposes NHC has used unit costs of $3,000/ linear meter of channel for rip rap and $2,000/ linear metre of channel for the construction of the lining material.

7.3 Outlet pool and downstream rip rap lining for Options 2 and 3

Options 2 and 3 are assumed to require up to 15 linear metres of rip rap beyond the downstream extent of the new culvert or channel in order to provide adequate erosion protection and tie-in with the existing channel. An alternative to this for Option 2 could be an outlet pond constructed from rip rap if velocities are found to be excessive during the preliminary design phase. For costing purposes NHC uses $3,000/linear metre.

7.4 Debris Control for Option 1

It is recommended that an arrangement of cross-braced piles be installed at the inlet of the existing culvert for Option 1. This device will capture debris and still allow flow to enter the culvert without building an excessive hydraulic head on the upstream embankment. For the time being a lump sum of $35,000 is recommended for costing purposes.

7.5 Option 1 baffles and other repairs

Option 1 should have metal baffles welded or bolted along the bottom of the culvert to act as velocity breaks and to create resting areas for migrating fish. There may also be other repairs that are considered necessary to extend the life of the culvert as much as possible. For costing purposes NHC uses a lump sum estimate of $30,000 for the baffles and $15,000 for any other repairs that may be necessary. It should be pointed out that baffles may not last more than 5- to 10 years in a creek like Heart Creek, which transports large amounts of coarse bedload during floods.

7.6 Head- and cut-off walls for Options 1 and 2

We recommend that a reinforced concrete headwalls and cut-off walls be constructed at the culvert inlets for Options 1 and 2. This will help stiffen the outer edge of the culverts and prevent them from being deformed by debris impacts or maintenance activities. The cut-off walls will help to limit seepage. Lump sum costs of $80,000 and $160,000 are used for Options 1 and 2, respectively.

7.7 Channel Lining for Options 2 and 3

Options 2 and 3 will require new, rock-lined channels within the arch culvert and beneath the bridge respectively.

For the open-bottom high profile arch on spread footings (Option 2), NHC recommends installing a scour resistant sub-floor comprised of large boulders (700 mm diameter) embedded in a 0.35 m depth of concrete. Above the concrete there should be a minimum 0.75 m depth of loose gravel, cobble and boulder material, similar to what exists in the natural channel. For costing purposes we recommend using $4,000/ linear metre for construction of the culvert lining.

For the bridge (Option 3) NHC recommends a 1 m depth of gravel-cobble-boulder mixture along the bed of the open channel. Boulder size stones would be incorporated to provide stability for the finer particles and to act as velocity breaks/resting areas for fish. Buried rip rap aprons will likely be required for grade control. Class 250 kg rip rap would be require to protect the fill slopes from erosion. For costing purposes we recommend using $2,000/ linear metre for construction of the channel lining.

7.8 Tie-in rip rap for all options

All options also require a small amount of 250 kg rip rap be placed at the inlet of the culverts or open channels to tie the new works into the existing channel or fill slopes. For costing purposes we recommend using $2,500/ linear metre for Option 1 and $1,500/ linear metre for Options 2 and 3.

7.9 Option 3 Bridge

We mention the bridge hear only because it is the bulk cost for Option 3. NHC has assumed an approximate length of 48 m for a single span bridge, and a deck width of 9.2 m (two, 3.6 m wide lanes and 1 m wide shoulders). A unit cost of $3,500/ square meter of deck is used based on the 2013 cost guide.

7.10 Life cycle costs

Estimates of life-cycle maintenance costs for all options have been made based on the following assumptions:

- All options have a total life span of 75 years
- All options will require routine maintenance. NHC has assumed 5-year average maintenance costs of $10,000 and $20,000 for culverts and bridges, respectively. This would include things like routine and non-routine inspections, debris removal, riprap maintenance, structural maintenance etc. We are unsure whether our cost assumptions are reasonable, so recommend that they be checked by the areas bridge and/ or operations manager.
- Option 1 (a rehabilitated, existing culvert), is expected to have a higher, 5-year routing maintenance cost than a new culvert (Option 2): $20,000 every 5 years vs. $10,000. Also, we assume the existing culvert, even if full retrofitted, will likely on last another 15 years at the most before a full replacement is required (at a cost of $2.5M).
- Inflation and discount rates of 3 and 4 percent, respectively, have been assumed in determining the present values of the life cycle costs.

Table 3 Option Cost Estimate

Option	**Option 1**	**Option 2**	**Option 3**
Category	Culvert Rehabilitation	Culvert Replacement	Bridge Replacement
Engineering	$75,000	$150,000	$300,000
Project Management	$20,000	$30,000	$30,000
Quality Management	$30,000	$40,000	$50,000
Environmental	$35,000	$55,000	$50,000
Mobilization	$30,000	$75,000	$125,000
Site access	$75,000	$150,000	$150,000
Traffic Management	$10,000	$10,000	$10,000
Property Impacts	$50,000	$50,000	$50,000
Stream Diversion	$20,000	$20,000	$20,000
Inlet Riprap	$15,000	$15,000	$15,000
Excavation (bulk)	N/A	$260,000	$260,000
Backfill (road prism)	N/A	$330,000	N/A
Outlet Riprap	(included in DS Channel)	$45,000	$45,000
US Channel Grading	$15,000	$75,000	$75,000
DS Channel Exc. And Pitrun Base	$412,305	$0	$0
DS Channel Riprap	$156,660	$0	$0
DS Channel Lining	$105,160	$0	$0
Channel Riprap	$0	$0	$150,000
Channel Lining	$0	$200,000	$100,000
Culvert Supply	N/A	$261,100	N/A
Culvert Foundation	N/A	$323,764	N/A
Culvert Backfill	N/A	$92,500	N/A
Culvert Baffling	$30,000	N/A	N/A
Culvert Inlet head/ cutoff walls	$80,000	$160,000	N/A
Existing Culvert Repair	$15,000	N/A	N/A
Bridge	N/A	N/A	$1,557,500
Pile Trash Rack	$35,000	$0	$0
Life cycle costs (75 years)	$2,276,818	$122,759	$208,303
TOTAL	**$3,486,000**	**$2,465,000**	**$3,196,000**

NOTES:

1. Costs estimated using recent MoTI Projects of similar scale as a guide (Luxor Creek Culvert Replacement and Grizzly Creek Culvert Replacment) as a guide.
2. Life cycle cost for Option 1 includes replacement of structure after 15 years (at a cost of $2.5M)
3. All life cycle costs assume 3% annual inflation and a 4% annual discount rate; average 5-year routine routine maintenance for a culvert is assumed as $10,000, and for a bridge $20,000 (these should be verified by bridge/ operations manager). Life of all structures = 75 years

8 CROSSING OPTIONS COMPARISON

The crossing options considered not only vary in cost, but also in constructability and performance. A comparison of total cost, plus advantages and disadvantages for each option is shown in Table 4.

Table 4. Advantages and disadvantages of the crossing options.

Option	Advantages	Disadvantages
Rehab. Exisitng Culvert	• Fastest to implement • Least disruption to traffic (no detour required)	• Highest overall cost (75 year life. • Less favourable for fish passage • Highest flood, scour, erosion risk • Embankment issues not addressed • Constructability issues related to rehab/ repair of existing pipe
Culvert Replacement	• Least costly over the design life • Meets fish passage requirements • Scour/ erosion less of a concern • Incorporates rebuild of the embankment, which has been compromised in the past	• Higher maintenance cost due to confined access. • May be some unforeseen constraints that will affect fish passage (e.g. geotechnical feasibility of slab footings) • Probably a shorter design life than a bridge but 75 years is attainable • Some scour risk but can be manager with sub-floor and bedding design
Bridge Replacement	• Provides best hydraulic opening with least amount of scour/ erosion risk • Incorporates rebuild of the embankment, which has been compromised in the past • Most favourable for fish passage • Likely the longest lifespan • Easiest access for structure maintenance	• Higher engineering cost/ longer design and construction schedule • Highest up-front cost

8.1 RECOMMENDED CROSSING

In NHC's opinion the choice comes down to a new culvert or a new bridge. The rehabilitation option makes little sense when thinking long term. Fish passage improvement is a major driver for the Project and it is doubtful that good fish passage can be achieved and sustained through the existing culvert. Flood risk is another key consideration, with flow capacity and embankment deficiencies at the site having been well documented. Having just built a new bridge on Highway 6 a few hundred metres downstream, it is risky to continue to rely on the stability of the existing crossing.

Of the remaining two options, Option 2 is preferred as it is less costly and likely a little quicker to construct than a bridge. The major question with Option 2 however, is whether slab footings are feasible from a geotechnical perspective. The soils in the area are expected to be a mix of alluvium and colluvium, and predominantly granular, but there may be surprises. Certainly, if for some reason the culvert option had to be pile supported it would quickly loose favour.

* * * * *

9 CLOSURE

I trust this reports meets with your expectations for this stage of the Project. If you have any questions, please do not hesitate to contact Des Goold at 604.980.6011.

Sincerely,

Northwest Hydraulic Consultants Ltd.

Prepared by:

Graeme Vass, EIT
Project Engineer

Principal-in-Charge

ENCLOSURE

Conceptual Drawings, Options 1, 2 and 3

10 REFERENCES

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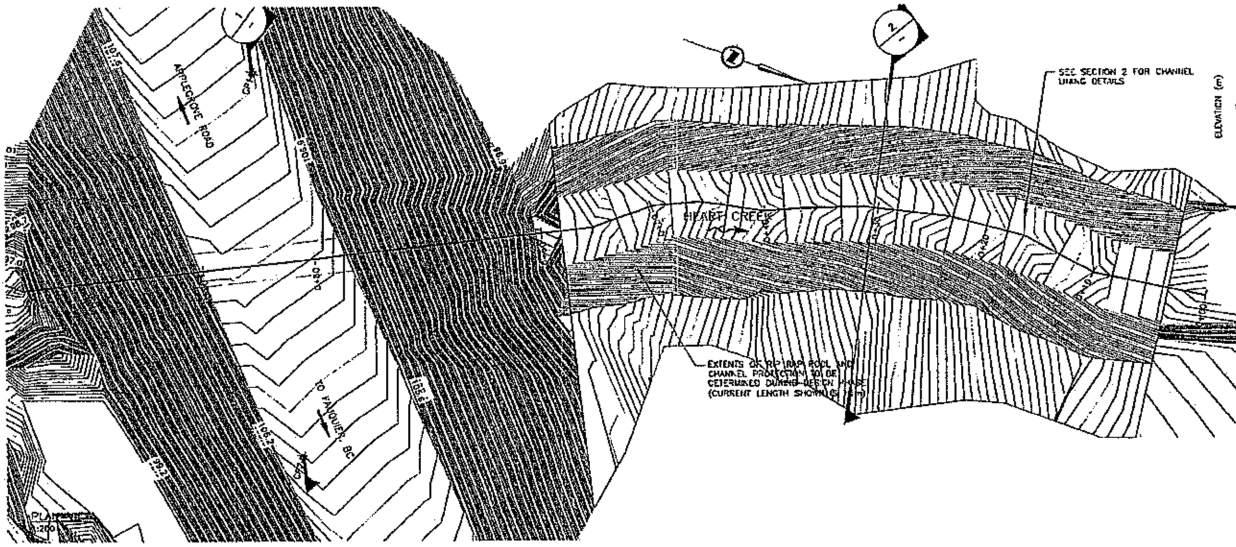

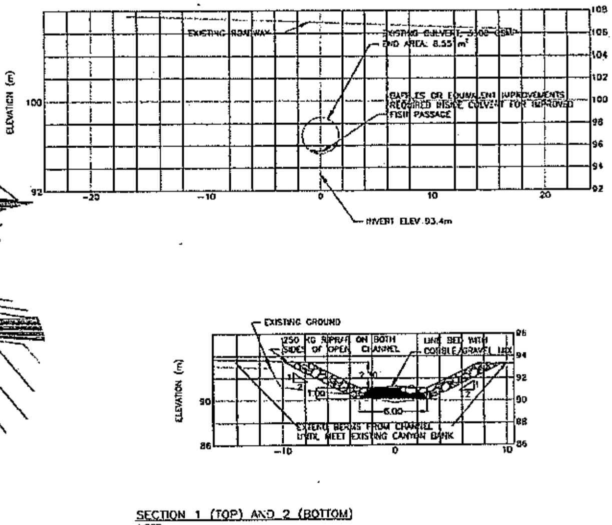

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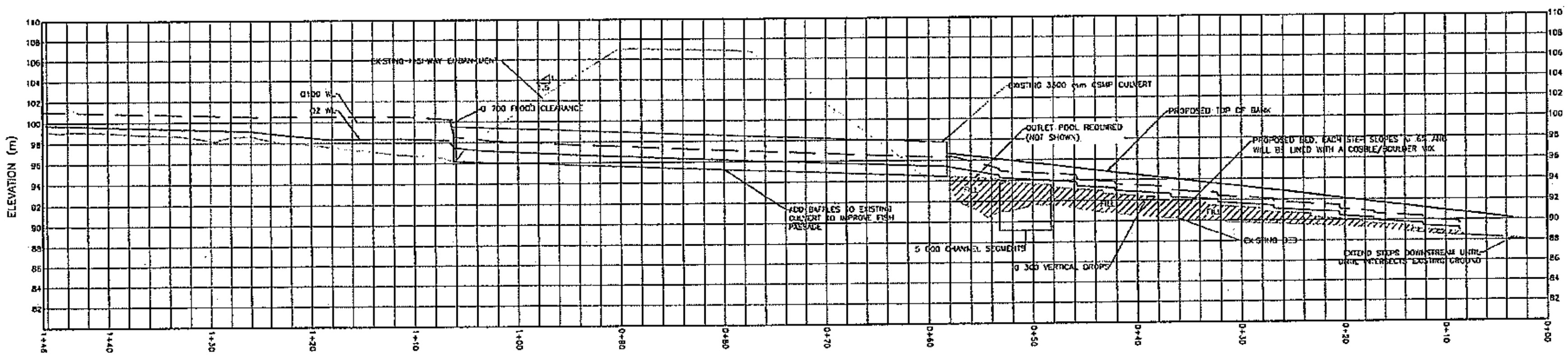

PROFILE VIEW
1:200

NOTE:

1. SURVEY COMPLETED IN SEPTEMBER 2010
2. ALL ELEVATIONS AND DISTANCES ARE GIVEN IN METRES.
3. THE VERTICAL DATUM OF THIS DRAWING DOES/ DOES NOT MATCH THE DATUM SHOWN ON MINISTRY RECORD DRAWINGS.
4. THE HORIZONTAL DATUM OF THIS DRAWING IS IN A LOCAL COORDINATE SYSTEM. SURVEY CONTROL IS PROVIDED IN TABLE 1.
5. CROSS-SECTIONS ARE PLOTTED LOOKING DOWNSTREAM.

nhc Northwest Hydraulic Consultants
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Office. 604.980.6011 Fax 604.980.9264 www.nhcweb.com

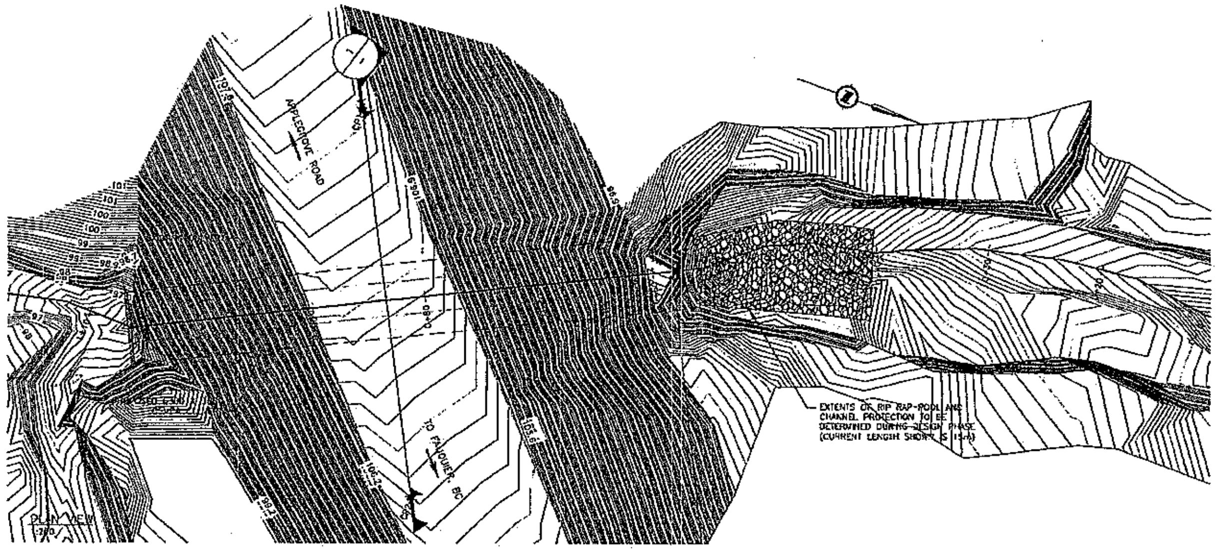
SCALE AS SHOWN

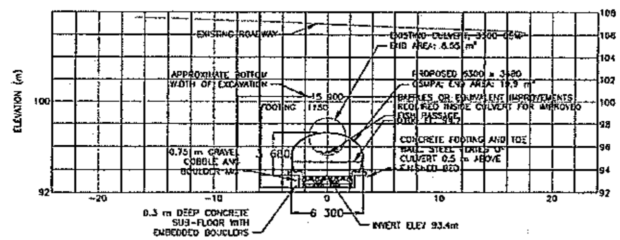
REV	DATE	REVISIONS	SIGNATURE
A	11-02-11	CONCEPT FOR REVIEW	

BRITISH COLUMBIA
MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE
SOUTHERN INTERIOR REGION

CENTRAL KOOTENAY DISTRICT
HEART CREEK NO. 2 (07240) REPLACEMENT
REPLACEMENT OPTIONS ANALYSIS STUDY
OPTION 1 - REHAB EXISTING CULVERT

FILE NAME	PROJECT NUMBER	REG	DRAWING NUMBER	REV
	722CS4591	2	3-21-07240-001	A





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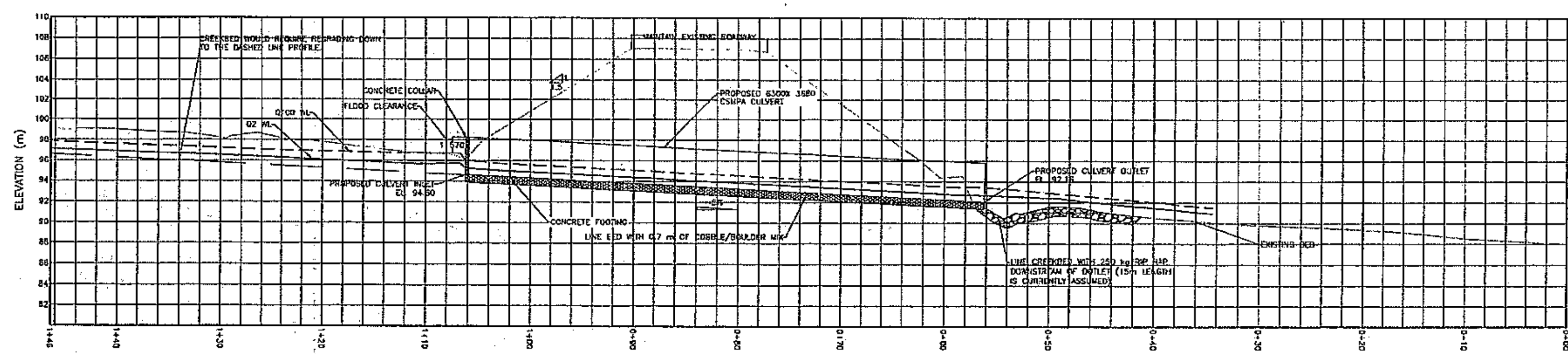

PROFILE VIEW
1:200

NOTE:

1. SURVEY COMPLETED IN SEPTEMBER 2010
2. ALL ELEVATIONS AND DISTANCES ARE GIVEN IN METRES.
3. THE VERTICAL DATUM OF THIS DRAWING DOES/ DOES NOT MATCH THE DATUM SHOWN ON MINISTRY RECORD DRAWINGS.
4. THE HORIZONTAL DATUM OF THIS DRAWING IS IN A LOCAL COORDINATE SYSTEM. SURVEY CONTROL IS PROVIDED IN TABLE 1.
5. CROSS-SECTIONS ARE PLOTTED LOOKING DOWNSTREAM.

nhc Northwest Hydraulic Consultants
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SCALE AS SHOWN

REV	DATE	REVISIONS	SIGNATURE
A	11-07-11	CONCEPT FOR REVIEW	

BRITISH COLUMBIA
MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE
SOUTHERN INTERIOR REGION

CENTRAL KOOTENAY DISTRICT
HEART CREEK NO. 2 (07240) REPLACEMENT
REPLACEMENT OPTIONS ANALYSIS STUDY
OPTION 2 - REPLACE WITH NEW CULVERT

PROJECT NUMBER	FILE	DRAWING NUMBER	REV
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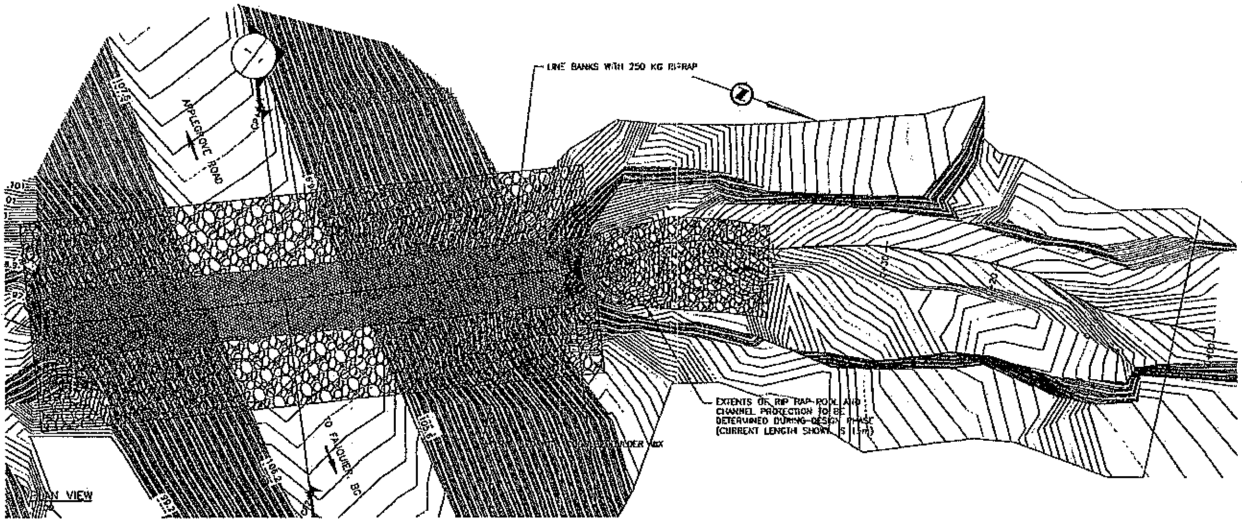
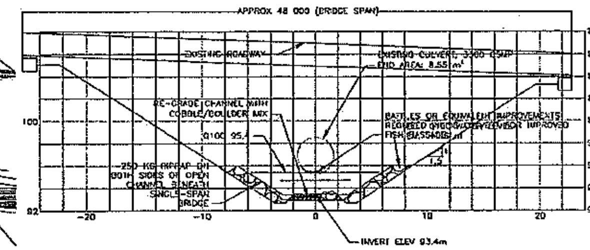
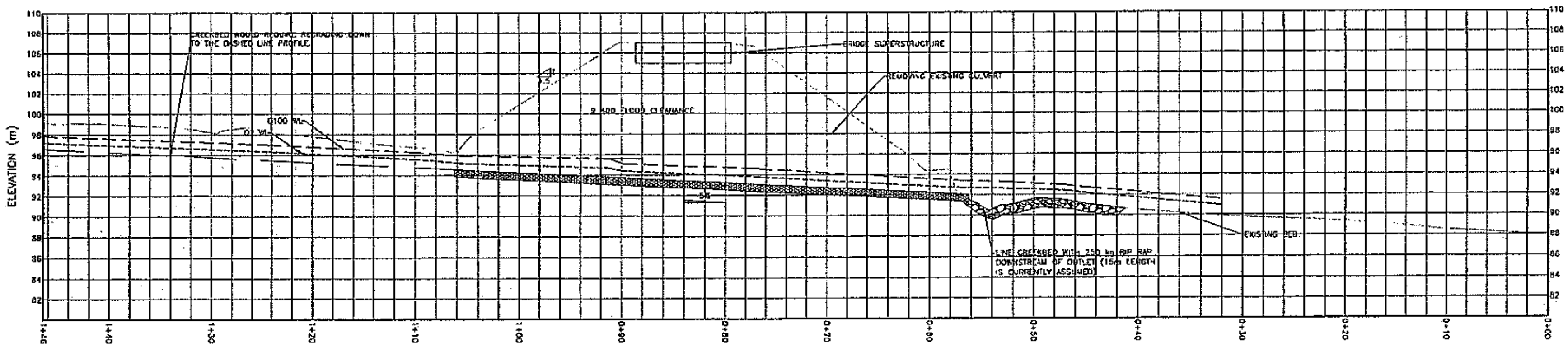




SECTION 1
1:200



PROFILE VIEW
1:200

NOTE:

1. SURVEY COMPLETED IN SEPTEMBER 2010
2. ALL ELEVATIONS AND DISTANCES ARE GIVEN IN METRES.
3. THE VERTICAL DATUM OF THIS DRAWING DOES/ DOES NOT MATCH THE DATUM SHOWN ON MINISTRY RECORD DRAWINGS.
4. THE HORIZONTAL DATUM OF THIS DRAWING IS IN A LOCAL COORDINATE SYSTEM. SURVEY CONTROL IS PROVIDED IN TABLE 1.
5. CROSS-SECTIONS ARE PLOTTED LOOKING DOWNSTREAM.

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SCALE AS SHOWN

REV	DATE	REVISIONS	SIGNATURE
A	10-03-11	CONCEPT FOR REVIEW	

BRITISH COLUMBIA

MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE

SOUTHERN INTERIOR REGION

CENTRAL KOOTENAY DISTRICT
HEART CREEK NO. 2 (07240) REPLACEMENT
REPLACEMENT OPTIONS ANALYSIS STUDY
OPTION 3 - REPLACE WITH BRIDGE AND OPEN CHANNEL

PROJECT NUMBER	REV	DRAWING NUMBER	REV
722CS4591	2	3-21-07240-001	A

Appendix B – Sea to Sky Drilling Logs

DRILLER'S LOG-SOILS

MINISTRY OF TRANSPORTATION AND HIGHWAYS

Page 1 of 4

Test Hole. No. TH16-01

Project: Heart Creek@Applegrove
Project No.
C.P.S.
Region
Station: See sketch
T.H. elev.
Weather: Cloud
Date start drilling: March 08 2016
Date finish drilling: March 09 2016

Drilled by: Sea to Sky Drilling
Drilling details: Mobile B53 · Wash Rotary.
HW Rods 0' → 131'
BQ Core 131' → 135'
AW sample rods
140 lb Auto Hammer.

NOTES.— Under moisture condition for (1) granular soils quote dry, damp, or saturated, and (2) fine-grained soils quote above or below P.L. or L.L. dry or fluid.

Quik Gel 3'6" →

Sampling Details						Water Conditions			Soil Description				Estimated Gradation			Soil Boundaries		
Depth From	Depth To	Sample No.	Type	Blow Count or Pressure	Recovery	Amount of Water (Gain or Loss)	Daily Water Level before Work	Mar Date	Density	Colour	Dilatancy	Moisture Condition	Fines	Sand	Gravel or Boulders and Max. Size	Depth From	Depth To	General Soil Types 0'→6' GP-SB Boney
9'	9'8"	1	SPT	18-50 (2" Refusal)	3"	100% loss	—	08th	V Dense	Brown	—	Damp		65	35 (3/4")	6'	9'8"	SP
14'	14'7"	2	"	39-30 (1") Refusal	Nil	"	—	"	"	"	—	—	—	—	—	9'8"	18'	GP
19'	21'	3	"	8-14-13-8	14"	"	—	"	Compact		—	"	5	60	35 (1")	18'		SP → (with GP)
24'	26'	4	"	4-8-17-16	10"	"	—	"	"	"	—	"		70	30 (3/4")			SP → (")
29'	31'	5	"	5-6-7-6	6"	"	—	"	"	"	—	"		85	15 (1")			SP → (")
34'	36'	6	"	8-13-13-12	12"	"	—	"	"	"	—	"		90	10 (1")			SP
39'	41'	7	"	9-7-6-6	8"	"	—	"	"	"	—	"		85	15 (1")		42'6"	SP
44'	45'	8	"	26-55	5"	"	—	"	V Dense	Grey	—	"		35	65 (1")	42'6"	48'	GP-SB wood in sample.
49'	51'	9	"	3-3-2-3	12"	"	—	"	Firm	"	Med	-PL	100			48'		CL
54'	56'	10	"	2-2-2-2	24"	"	—	"	Soft → Firm	"	Med Slow	"	100					CL → CH
59'	61'	11	"	1-2-2-3	24"	"	—	"	"	"	Med	"	100					CL
64'	66'	12	"	2-3-2-3	24"	"	—	"	Firm	"	"	"	100					CL

Remarks: Lost return @ 4'
Tricone 3'6" → 9'. 10" SB @ 3'6". Tricone 10' → 14'. Boney. Tricone 45'6" → 49'. Creek bed 42'6" → 48'

FIELD WORK SHEET

[signature]
Foreman or Inspector.

H.487 (96/03)

DRILLER'S LOG-SOILS

MINISTRY OF TRANSPORTATION AND HIGHWAYS

Test Hole No. TH16-01

Project: Heart Creeke Applegrove:
Project No.
C.F.S.
Region
Station
T.H. elev.
Weather
Date start drilling: March 08 2016
Date finish drilling: March 09 2016

Drilled by: Sea to Sky Drilling
Drilling details: Mobile B53 Wash Rotary

NOTES.— Under moisture condition for (1) granular soils quote dry, damp, or saturated, and (2) fine-grained soils quote above or below P.L. or L.L. dry or fluid.

Sampling Details						Water Conditions			Soil Description				Estimated Gradation			Soil Boundaries		
Depth		Sample No.	Type	Blow Count or Pressure	Recovery	Amount of Water (Gain or Loss)	Daily Water Level before Work	Mar Date	Density	Colour	Dilatancy	Moisture Condition	Fines	Sand	Gravel or Boulders and Max. Size	Depth		General Soil Types
From	To															From	To	
69'	71'	13	SPT	1-1-2-3	24"	100% loss	—	08	Soft	Grey	Slow	+PL	100					CH
74'	76'	14	"	1-2-3-3	24"	"	—	"	Firm	"	Med Slow	-PL	100					CL → CH
79'	81'	15	"	2-2-4-4	24"	"	—	"	"	"	"	"	100					CL → CH
84'	86'	16	"	2-3-3-3	24"	"	—	"	"	"	Slow	+PL	100					CH
89'	91'	17	"	2-3-3-4	24"	"	—	"	"	"	Med Slow	-PL	100					CL
94'	96'	18	"	2-3-4-5	24"	"	—	"	"	"	Med	"	100					CL
99'	101'	19	"	2-3-3-4	24"	"	—	"	"	"	Med Slow	"	100					CL → CH
104'	106'	20	"	4-6-6-8	16"	"	—	09	Stiff	"	Med	"	95	5				CL
109'	111'	21	"	2-6-7-6	22"	"	—	"	"	"	Med Quick	"	90	10				CL
114'	116'	22	"	3-4-5-7	24"	"	—	"	"	"	"	"	95	5				CL
120'	122'	23	"	4-4-3-3	24"	"	—	"	Firm	"	Med	"	95	5			1236'	CL
124'	126'	24	"	11-12-9-27	2"	"	—	"	V Stiff	"	Quick	"	50	10	40 (1")	1236'	1286'	CL with GP

Remarks

Foreman or Inspector.

FIELD WORK SHEET

H.487 (96/03)

DRILLER'S LOG-SOILS

MINISTRY OF TRANSPORTATION
AND HIGHWAYS

Page 3 oF 4

Test Hole No. TH16-01.

Project Heart Creek @ Applegrove.
Project No.
C.F.S.
Region
Station
T.H. elev.
Weather
Date start drilling March 08 2016
Date finish drilling March 09 2016

Drilled by Sea to Sky Drilling
Drilling details Mobile B53 - Wash Rotary.

NOTES.-- Under moisture condition for (1) granular soils quote dry, damp, or saturated, and (2) fine-grained soils quote above or below P.L. or L.L. dry or fluid.

Sampling Details						Water Conditions			Soil Description				Estimated Gradation			Soil Boundaries		
Depth From	Depth To	Sample No.	Type	Blow Count or Pressure	Recovery	Amount of Water (Gain or Loss)	Daily Water Level before Work	Mar Date	Density	Colour	Dilatancy	Moisture Condition	Fines	Sand	Gravel or Boulders and Max. Size	Depth From	Depth To	General Soil Types
129'	130'	25	SPT	37-88 Refuse	8"	100% loss	—	09th	V Dense	Grey	—	Damp	10	25	65 (1")	128'6"	130	GC→GP-Bedrock
																130'	→	Bedrock

Remarks

H.487 (96/08)

Foreman or Inspector

FIELD WORK SHEET

Page 1 of 2

DRILLER'S LOG-CORING

Page 4 oF 4

Test Hole No. TH16-01

PROJECT Heart Creek Culvert @ Applegrove FILE No. ______
COST CODE No. ______
REGION ______ DISTRICT ______
STATION ______ OFFSET ______
T.H. ELEV. ______ WEATHER Cloud.
DATE STARTED Mar 08/16 DATE COMPLETED Mar 09/16

Direction of hole: Bearing 90°
Dip ______ Vertical ______
Depth of overburden 130'
Depth drilled in solid rock 5'
Total depth 135'
Core recovery ______ Water table ______
Cased to 131' Casing left ______

Type of drill Mobile B53
Type of bit Diamond Impregnated.
Type of core barrel Wireline.
Size of bit BQ
Drilled by:
Contractor Sea to Sky Drilling
Runner Chad Brown.
Hole logged by Smallwood.

Depth of drill-run (ft. in.) from	to	Length of drill run	Recovery Length	Recovery %	Rock type & Condition	Casing & reaming Use of mud and cement Water packer test	Depth from	Depth to	Drill bits & Core Barrells Size	Type & Condition	Drill pressure Screw feed Trans. gear	Feed gear revs in.	Hydraulic feed Trans. gear	Rel. drill resistance	Water table	Drill water Pump gauge press. psi	Return % (estimate)	Wash water clarity & color	Erratic drill pressure Depth from	to	Abrupt changes or complete or partial loss	Probable cause of change	REMARKS Mechanical breakdowns and operating promblems. Probable reasons for core loss, and broken core. Other comments.
131'	132'6"	18"	18"		Bedrock V. Broken				BQ	Wireline Good			3H	Med		50 PSI	Nil	N/A					
132'6"	135'	30"	30"		Broken				"	"			"	"		"	"	"					

Remarks

Smallwood

DRILLER'S LOG-SOILS

MINISTRY OF TRANSPORTATION AND HIGHWAYS

Test Hole No. TH16-02

Project: Heart Creek @ Applegrove
Project No.
C.P.S.
Region
Station: See Sketch
T.H. elev.
Weather: Cloud
Date start drilling: March 09 2016
Date finish drilling: March 10 2016

Drilled by: Sea to Sky Drilling
Drilling details: Mobile B53 - Wash Rotary
HW Rods 0' → 127'
AW Sample rods
140 lb Auto Hammer

NOTES.– Under moisture condition for (1) granular soils quote dry, damp, or saturated, and (2) fine-grained soils quote above or below P.L. or L.L. dry or fluid.

Quik Gel 4' →

Sampling Details						Water Conditions			Soil Description				Estimated Gradation			Soil Boundaries		
Depth From	Depth To	Sample No.	Type	Blow Count or Pressure	Recovery	Amount of Water (Gain or Loss)	Daily Water Level before Work	Date (Mar)	Density	Colour	Dilatancy	Moisture Condition	Fines	Sand	Gravel or Boulders and Max. Size	Depth From	Depth To	General Soil Types
4'6"	5'2"	1	SPT	21-30 (2") Refusal	Nil	100% loss	—	09th	V Dense	Brown	—	—	—	—	—	0'	7'6"	GP→SB→LB (Very boney)
9'	11'	2	"	10-16-13-22	10"	"	—	"	Compact	"	—	Damp	5	35	60 (1")	7'6"	13'	GP Cobbles
—	—	—	—	—	—	"	—	"	—	—	—	—	—	—	—	13'	18'	GP→SB (Boney)
19'	21'	3	SPT	5-12-15-11	9"	"	—	"	Compact	Brown	—	Damp	5	55	40 (3/4")	18'	23'6"	SP with GP:SB
24'	26'	4	"	11-10-11-17	10"	"	—	"	"	"	—	"		80	20 (1")	23'6"		SP
29'	31'	5	"	6-8-7-6	3"	"	—	"	"	"	—	"		70	30 (1")			SP
34'	36'	6	"	7-8-7-6	9"	"	—	"	"	"	—	"		95	5 (1/2")			SP
39'	41'	7	"	6-3-2-3	12"	"	—	10th	Loose	Grey	—	Damp Sat		95	5 (3/4")		42'	SP Grey
—	—	—	—	—	—	"	—	"	V Dense V Boney	—	—	—	—	—	—	42'	47'6"	GP→SB Very boney
49'	51'	8	SPT	2-2-3-4	Nil	"	—	"	Firm	Grey	—	—	—	—	—	47'6"		CL
54'	56'	9	"	2-2-3-3	10"	"	—	"	"	"	Med Slow	-PL	100					CL→CH
59'	61'	10	"	2-3-2-3	12"	"	—	"	"	"	Slow	+PL	100					CH

Remarks: Lost return @ 3'.
Tricone 2' → 4'6". 12" SB @ 2'. 8" SB @ 3'6". Tricone 5'2" → 9' 10" SB @ 5'2".
Tricone 13' → 19'. 10" SB @ 13'. Tricone 22'6" → 24' 10" SB @ 22'6"
Tricone 43'6" → 49'. Very dense; boney from 42' → 47'6" Creek bed.
Sam #8 Driving a rock stuck in shoe. Drill action indicates clay.

[illegible]
Foreman or Inspector.

FIELD WORK SHEET

DRILLER'S LOG-SOILS

MINISTRY OF TRANSPORTATION AND HIGHWAYS

Page 2 of 2

Test Hole No. TH16-02

Project: Heart Creek @ Applegrove
Project No.
C.P.S.
Region
Station
T.H. elev.
Weather
Date start drilling: March 09 2016
Date finish drilling: March 10 2016

Drilled by: Sea to Sky Drilling
Drilling details: Mobile B53

NOTES.— Under moisture condition for (1) granular soils quote dry, damp, or saturated, and (2) fine-grained soils quote above or below P.L. or L.L. dry or fluid.

Sampling Details						Water Conditions			Soil Description				Estimated Gradation			Soil Boundaries		
Depth From	Depth To	Sample No.	Type	Blow Count or Pressure	Recovery	Amount of Water (Gain or Loss)	Daily Water Level before Work	Date (Mar)	Density	Colour	Dilatancy	Moisture Condition	Fines	Sand	Gravel or Boulders and Max. Size	Depth From	Depth To	General Soil Types
69'	71'	11	SPT	3-3-3-4	6"	100% loss	—	10th	Firm	Grey	Med Slow	+PL	100					CH → CL
79'	81'	12	"	3-4-4-4	6"	"	—	"	Firm Stiff	"	Med	-PL	100					CL
89'	91'	13	"	3-4-5-8	24"	"	—	"	Stiff	"	Med Quick	"	100					CL
99'	101'	14	"	3-4-4-6	24"	"	—	"	Firm Stiff	"	"	"	95	5				CL
109'	111'	15	"	2-4-6-9	22"	"	—	"	Stiff	"	Quick	"	85	15				CL
119'	121'	16	"	4-6-7-8	18"	"	—	"	"	"	"	"	85	15			122	CL
																122'	126'	GC Boney Easily drilled.
																126'	127'	Bedrock? Drilled with open face bit

Remarks

Foreman or Inspector. [signature]

FIELD WORK SHEET

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