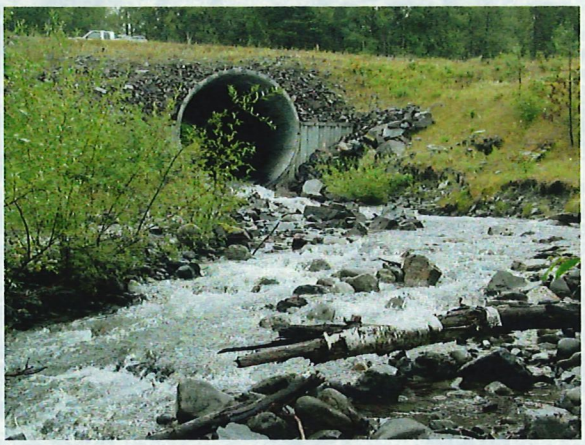
Fish Passage - Culvert Inspection where Yellowhead Highway 16 crosses Flint Creek

Contract 356CS0561



Prepared for

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March 2006

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Executive Summary

The culvert crossing located where the Yellowhead Highway 16 crosses Flint Creek (watershed code 400-316300) was assessed in August 2005. This assessment was conducted following methods outlined in the Fish Passage – Culvert Inspection (FPCI) Procedures (Watershed Restoration Technical Circular No. 11). In addition, the habitat upstream of the culvert was assessed in detail and Fisheries Priority Scores were calculated to allow a comparison of the findings, from a fisheries perspective, to other culvert obstructions that have been identified along Highway 16 between Terrace and New Hazelton.

Overall, fish habitat was identified in the lower 760 meters of the mainstem in the Flint Creek watershed. An approximately 14 meter high waterfall, located 580 meters upstream of the highway crossing, was identified as a natural, permanent barrier to fish passage. Below the falls, Flint Creek has a moderate gradient and a limited amount of suitable spawning habitat, but provides good potential rearing habitat and refuge during turbid conditions in the Skeena River (e.g. during spring snowmelt and freshets). Good juvenile rearing habitat, particularly for cutthroat trout and Dolly Varden, was noted upstream and downstream of the highway crossing, but the moderate gradient (2-7%) limits habitat suitability for juvenile salmon, and large substrate size (particularly upstream of the crossing) and channel instability limits habitat suitability for spawning.

Historical fisheries information identifies the presence of rainbow trout/steelhead and pink salmon in the lower section of Flint Creek upstream to the highway crossing located 180 meters upstream of the Skeena River. Juvenile steelhead, cutthroat trout, Chinook, coho, Dolly Varden, and possibly bull trout are suspected to utilize the habitat, at least downstream of the culvert. It is suspected that most species found in the Skeena River would be able to access and utilize the available habitat as indicated by the reported presence of pink salmon carcasses immediately downstream of the culvert. However, spawning habitat is limited between the culvert and the waterfall due to large cobble substrate, moderate gradient, naturally unstable conditions, and the presence of large gravel/cobble wedges that significantly impeded fish passage.

The culvert on Flint Creek consists of a five metre diameter, multi-plate culvert with baffles. Although the culvert diameter is less than the mean channel width of Flint Creek, the FPCI Q_{100} for this stream is within the recommended range for this culvert. The existing structure is a barrier to juvenile fish passage and at least a partial barrier to adult fish passage, at some and possibly all flows, due to the 0.5 metre drop at the culvert outfall into a 0.45 meter deep plunge pool and the high velocity flow at the outlet (3.2 m/s). Although the gradient of the culvert (5%) is not suitable for fish passage, the baffles installed in this culvert at 4 metre intervals may have made this culvert passable by adult salmonids dependent on the outlet conditions. This crossing was previously scored within the range of high priority ranking from the FPCI Matrix (Rabnett and Williams 2004), but the updated fish passage - culvert inspection score for the Highway 16-Flint Creek crossing added up to 38, which reduce the ranking of this location to moderate. The Fisheries Priority Score was the second lowest score of 13 known culvert obstructions to fish passage along the Yellowhead Highway 16 from Terrace to New Hazelton.

Improvement of fish passage at this site could restore juvenile fish access and improve adult fish passage to 580 meters of moderate habitat, which accounts for over 70% of the section of stream that would be naturally available to fish. The concept of using lock block weirs to backwater the culvert and improve fish passage has been proposed by the Department of Fisheries and Oceans Canada as one possible option to restore access to all available fish habitat in Flint Creek. Based on the moderate ranking score for this crossing, if available funds are limited, other sites obstructing fish passage to more, higher diversity and better quality of fish habitat may be more suitable for restoration than for improving access to the only moderate quantity and quality of fish habitat upstream of the Flint Creek crossing. Nevertheless, the recommended long-term objective for this crossing should be the restoration of fish passage to juveniles of all fish species suspected to use Flint Creek, or the eventual replacement of this culvert with an open bottom structure.

Acknowledgements

We wish to acknowledge the thorough review and helpful comments provided on draft versions of this report by Daryl Nolan (Ministry of Transportation), Lana Miller and Don Hjorth (Fisheries and Oceans Canada). We also thank Daryl Nolan, Don Hjorth (Fisheries and Oceans Canada) and Lana Miller for meeting with us on site, and providing insight and conceptual plans for restoration of fish access at the highway crossing. This project was jointly funded by the BC Ministry of Transportation, and Fisheries and Oceans Canada.

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1.0 INTRODUCTION

Ministry of Transportation (Northern Region) and Fisheries and Oceans Canada (Smithers) contracted SKR Consultants Ltd. to conduct a fish passage inspection where the Yellowhead Highway 16 crosses Flint Creek. This stream crossing was chosen for assessment, in conjunction with the crossings at Station Creek and Singlehurst Creek (SKR 2006a, b) since the Gitksan Watershed Authority identified these crossings as high priority sites for additional assessments during a preliminary study conducted in 2004 (Rabnett and Williams 2004).

The study area is located in north central British Columbia. Flint Creek (watershed code: 400-316300) is a third order (1:20,000 scale) tributary to the Skeena River, and is located approximately 50 km north of Terrace (Figure 1). This system enters into the Skeena River on river left between the Kleanza Creek and the Kitwanga River. This system falls within the Skeena Region of the Ministry of Environment (MoE), the Prince Rupert Region (Region 6) of Fisheries and Oceans Canada (FOC), and the Bulkley-Stikine District No. 10 of the Ministry of Transportation (MoT). Flint Creek drains the west facing slope of Weeskinisht Peak, one of the Seven Sisters Peaks. An abandoned mine is located in the headwaters of this system. The system drains an area of approximately 21.2 km^2, with a range in elevation from 140 metres to 2220 metres (Rabnett and Williams 2004). The Highway 16 crossing of Flint Creek is located approximately 180 m upstream of the Skeena River (Rabnett and Williams 2004), at UTM 9.538937.6089961. The culvert's location in the Ministry of Transportation Landmark Kilometer Inventory (LKI) system is Segment 1510 (Terrace-Kitwanga), kilometer 63.22, on Yellowhead Highway (Cypher Consulting 2005).

The main objective of this project was to give Ministry of Transportation (MoT) and Fisheries and Oceans Canada (FOC) a more detailed description of the types and relative values, from a fisheries perspective, of future efforts toward restoring fish passage at Flint Creek. The focus of this study was to assess the Flint Creek crossing for fish passage, review existing information on fish distribution to determine fish species for which fish passage is required, and determine the amount and quality of habitat upstream of the crossing. The culvert crossing where Highway 16 crosses Flint Creek was assigned a Fish Passage – Culvert Inspection (FPCI) priority ranking (Parker 2000), and a more detailed Fisheries Priority Score (Johnston and Saimoto 2003) for a relative comparison of the benefits to restoring fish passage at different culvert crossings along the portion of the Yellowhead Highway 16 between Terrace and Hazelton.

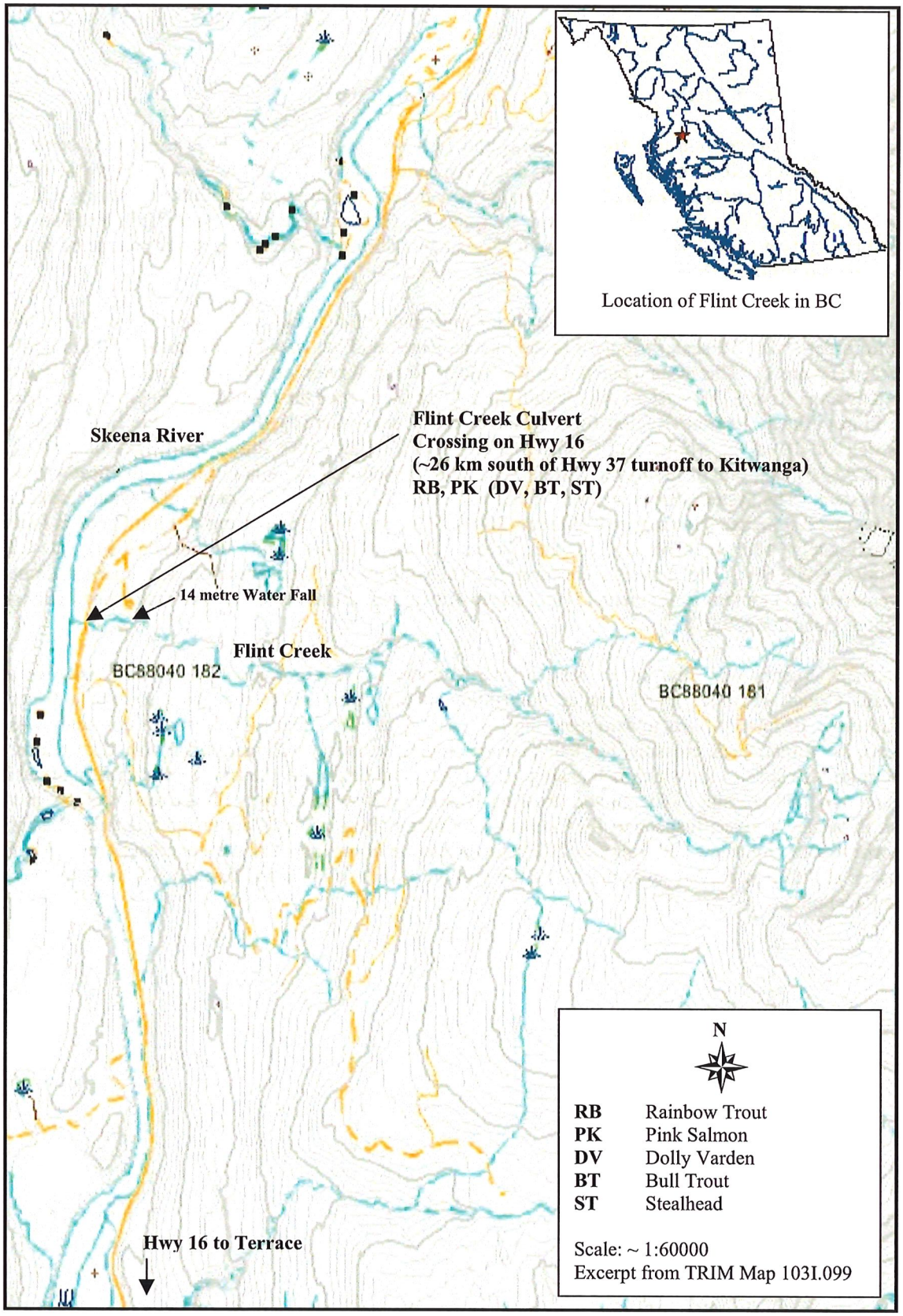

Figure 1. Location of the Highway 16 (Yellowhead Highway) crossing of Flint Creek, Skeena River Watershed.

2.0 METHODS

The following sections include a summary of the pre-field planning, the field component and methods used to rank (i.e. FPCI Score and Ranking) and provide a relative priority from a fisheries perspective (i.e. Fisheries Priority Score) for future work on Flint Creek.

2.1 PRE FIELD PLANNING

Available fisheries information for Flint Creek was compiled and reviewed prior to the initial field visit. The Fisheries Information Summary System (FISS 2005), as well as the Smithers MoE, MoT and Fisheries and Oceans Canada offices were consulted for related information. Ministry of Transportation kindly provided an excerpt of a report summarizing a previous preliminary assessment of the Flint Creek crossing (Rabnett and Williams 2004). The watershed code for Flint Creek was determined from the watershed atlas (BC Ministry of Sustainable Resource Management 2005 at http://msrm.gov.bc.ca/gis).

2.2 FIELD COMPONENT

A preliminary visit to the Flint Creek crossing was conducted on August 12th with Don Hjorth (FOC, Terrace) and a follow-up visit was conducted on August 23rd, 2005. Data were collected as per *Watershed Restoration Technical Circular #11: Fish Passage – Culvert Inspection Procedure (FPCI)*(Parker, 2000), and the data forms in the FPCI were used during the field assessment of the culvert (Appendix 1). Field investigation included field confirmation of natural limits to fish distribution to provide more accurate estimates of the suitability of sites for improvements of fish passage. The following procedures were used for collecting the required data:

- FPCI field forms (Parker 2000)
- A hip chain was used to measure culvert length, and to measure stream lengths sampled.
- A meter stick and tape measure were used to measure: culvert diameter (rise/span, width/height); culvert wetted width; culvert water depth; culvert out-fall drop; pool depth at outfall; channel width and wetted width; stream bankfull depth and stream water depth;
- Water velocities (stream and culvert) were measured using a *Global Water FP201* velocity meter. This meter is a propeller type that can be fitted with a low-flow adapter kit if required.
- Stream gradient was measured using an Abney Level or a Suunto clinometer.
- Culvert slope was measured at the upstream and downstream end using an Abney level; measurements were averaged to obtain the culvert slope.
- The UTM locations at road crossings and natural barriers to fish migration were determined using a Garmin E-trex Legend GPS. Locational reference information recorded also included the Landmark Kilometer Inventory (Cypher Consulting 2005).
- Site photographs were taken using a high-resolution digital camera (Sony Cyber-shot, 4.1 megapixel camera).
- Conductivity and temperature were recorded using an Oaktron TDStestr3 handheld conductivity meter and an alcohol thermometer, respectively.

2.3 OBSTRUCTIONS TO FISH PASSAGE

Defining the severity of obstructions to fish migration considers how culvert gradient, water velocity, outfall drop and culvert length may exceed the abilities of different species at specific life stages to migrate upstream. The interpretation of the severity of obstructions to fish passage related to culvert crossings includes consideration of fish species distribution, the jumping and swimming abilities for relevant life stages of the fish species present at each location surveyed (Table 1 and 2), and barrier classes defined by Johnston and Saimoto (2003). Specific criteria used for full and partial barrier classes for culvert gradient, water velocity, and drop are described in Appendix 2b and 2c.

Table 1. Maximum jumping height for adult salmonids known or suspected present in Flint Creek.

Species	Maximum Jumping Height *[1]	
	Adults	Juveniles
Coho	2.4 m	0.5 m (120 mm length)
Chinook	2.4 m	0.5 m (120 mm length)
Pink	1.5 m	
Cutthroat	1.5 m	0.6 m (125 mm length)
Rainbow	1.5 m	0.6 m (125 mm length)
Steelhead	3.4 m	0.6 m (125 mm length)
Dolly Varden		

*[1] Jumping heights are obtained from Whyte et al. (1997).

Table 2. Burst and prolonged swimming abilities*[1] for salmonids present in Flint Creek.

Species	Juvenile*[2]		Adult	
	Burst Speed	Prolonged Speed	Burst Speed	Prolonged Speed
Coho		0.4-0.6 m/s	3.2 - 6.6 m/s	2.7 - 3.2 m/s
Chinook		0.4-0.6 m/s	3.2 - 6.6 m/s	2.7 - 3.2 m/s
Pink			2.3 - 4.6 m/s	1.0 - 2.3 m/s
Cutthroat	0.4-1.1 m/s	0.3-0.7 m/s	1.8 - 4.3 m/s	0.9 - 1.8 m/s
Rainbow	0.4-1.1 m/s	0.3-0.7 m/s	1.8 - 4.3 m/s	0.9 - 1.8 m/s
Steelhead			4.2 - 8.1 m/s	1.4 - 4.2 m/s
Dolly Varden		0.6-1.0 m/s		

*[1] Data were obtained from Whyte et al. (1997) except for Dolly Varden. Swimming ability for Dolly Varden was obtained from Hunter and Mayor (1986) as in Anonymous (2001).

*[2] Swimming abilities depend on the size of the fish. Lower range refers to juveniles 50 mm in length, upper range refers to juveniles 120-130 mm in length

The most significant obstruction to fish passage at culvert stream crossings is due to perched outlets. In conjunction with fish sampling, the drop from culvert outlets minus the plunge pool depth at the outlet is used to evaluate the severity of obstructions to fish passage at culvert outlets (Appendix 2b and 2c). The maximum jumping heights for various species present or potentially present in Flint Creek are provided in table 1, but it has been reported that different configurations of obstacle and plunge pool can significantly influence the jumping ability of fish (Eiserman et al. 1975 as in Bjorn and Reiser 1991) and that fish also needed plunge pools to be 1.25 times as deep as the height of the fall to achieve the maximum jumping height (Whyte et al 1997). With these complications, the severity of obstructions to fish passage based on the maximum jumping abilities of relevant species (Table 1) is not very accurate for many perched culverts due to the large variability in physical configurations of the barriers at different locations. For Fisheries Priority Scores (Johnston and Saimoto 2003), 0.6 metres for drop minus pool depth at high water is considered to be a severe enough obstruction to be called a full barrier (Appendix 2b), and 0.15 – 0.6 metres to be a partial barrier to fish migration (Appendix 2c).

The severity of obstructions to fish migration due to culvert slope is based on the expected water velocities through a culvert versus burst and prolonged swimming abilities of the fish species present (Table 2). Measurements taken at the inlet and outlet of the culvert do not account for sags or settling of the culvert that may increase velocities at the outlets and inlets or create pools or holding areas in the middle sections of a culvert. Therefore, more detailed inspection of water velocity barriers are done where culvert slope and average water velocity data were not complimentary. Water depths in the culvert were also considered when evaluating the severity of obstructions to fish passage due to culvert slope. With these considerations, field data were examined to ensure that average water velocity and swimming abilities of fish species present (Table 2) are in agreement with the severity of the obstruction to fish passage based on the culvert slope criteria (Appendix 2b and 2c).

For an evaluation of the suitability of the existing structures at stream crossings for improvement of fish passage (e.g. baffles) versus replacement of the structure, a 100 year flood event (FPCI Q_{100}) was estimated and compared to FPCI recommended crossing structures (Appendix 3). For final stream crossing designs, plans should also consider detailed Q_{100} estimates, such as the BCSI and the Beaumont methods (Johnson and Saimoto 2003). The FPCI Q_{100} was estimated using the following equations described by Parker (2000):

Equation 1: $A = ((W_w+W_{bf})*D_{bf})/2$

Where: A = bankfull area at average annual peak
W_w = mean wetted width (m)
W_{bf} = mean bankful width (m)
D_{bf} = mean bankful depth (m)

Equation 2: FPCI $Q_{100} = 3(A)$

The FPCI guidelines also recommends that the FPCI Q_{100} be corrected by a factor of 1.16 for round culverts and 1.25 for elliptical culverts for a culvert to be embedded 20% with a less than 0.5% gradient stream bed (Appendix 3) (Parker 2000).

2.4 FISH PASSAGE - CULVERT INSPECTION RANKING

The Fish-Passage Culvert Inspection methodology (Parker 2000) was used to calculate a score for ranking the severity of the obstruction to fish passage at the sites assessed. FPCI points are given for fish species value, habitat value, severity of the barrier, the category of habitat to be gained, the percent of the stream barred, and whether or not the habitat to be gained is limited by other anthropogenic barriers upstream. The FPCI scoring matrix is presented in table 3, and methodologies for designating scores are as follows:

Table 3. FPCI Scoring Matrix used for designating FPCI rankings for prioritization

Fish Species Value		*Habitat Value*		*Severity of Barrier*		*Amount of new Habitat*		*% stream barred*		*Limiting to Upstream barrier*	
Multiple or Significant	10	H	10	Full	10	≥1 km	10	>70%	10	Yes	5
Single	6	M	6	Partial	6	<1km ≥500m	6	≤70% ≥50%	6	No	0
Other	3	L	3	Undeter-mined	3	<500m	3	<50%	3		

Species Value: Based on the number of target or other species present. The scoring matrix distinguishes between sites with multiple target or significant species, single target species, and other species. Target species generally include sport fish, while other species include non-listed coarse fish.

Habitat Value: Site assessor's subjective rating (high, moderate, low) of the value of habitat to be gained based in part on habitat complexity, stream characteristics, and limiting habitats in the system.

Severity of Barrier: Site assessor's subjective evaluation of the severity of the obstruction (full, partial, undetermined), substantiated by culvert characteristics, ecology of fish species present, and fish distribution information.

Amount of Habitat gained: The length of mainstem habitat (≥1 km, ≥500m to 1km, <500m) upstream of the culvert to the natural limit of fish distribution. The natural extent of fish distribution may be determined from map and airphoto interpretation, historical information, and/or field investigations.

Percent stream barred: The proportion (>70%, 51-70%, <50%) of the mainstem stream length upstream of the culvert that is obstructing fish passage.

Limiting to upstream barrier: Provides additional scores for systems where one or more additional culverts upstream are obstructing fish passage, or where fish passage remains undetermined. Where no upstream culverts are present, or where the upstream culverts are not obstructing fish passage, this category is scored as "No". For sites where upstream culverts are known or undetermined to obstruct fish passage, this category is scored as "Yes".

Based on the FPCI matrix scores, a total score is calculated using the following equation:

FPCI Score = *Species Value* + *Habitat Value* + *Severity of Barrier* + *Amount of new Habitat* + *% stream barred* + *Barrier Upstream*

A ranking for different ranges of FPCI scores is given to help categorize sites with similar needs and priorities for future attention and potentially more detailed assessments and planning. FPCI Priority Rankings for future attention to fish passage issues are as follows:

High	FPCI scores	55-39
Moderate	FPCI scores	38-26
Low	FPCI scores	25-15

2.5 FISHERIES PRIORITY SCORE FOR RESTORATION OF FISH PASSAGE

In addition to methods outlined in the Fish-Passage Culvert Inspection guidebook (Parker 2000), priority scoring from a fisheries perspective (Fisheries Priority Score) is included in this culvert assessment. The Fisheries Priority Score (Johnston and Saimoto 2003) is used to help prioritize sites based on benefits that restoring fish passage may provide. This methodology incorporates the certainty of fisheries information (*Fish Presence Factor*), the importance of species with special concern (*Species Status Factor*), the severity of the barrier to fish passage (*Barrier Factor*), and the habitat value based on the types of habitat present (*Habitat Type*), the quantity of each habitat type (*Amount of Habitat*), and the value to the species expected to use the habitat type (*Habitat Factor*).

The equation used to calculate the Fisheries Priority Score for future work on restoring fish passage is:

Fisheries Priority Score = [*Fish Presence Factor*] x [*Species Status Factor*] x [*Barrier Factor*] x [Habitat Value]

where:

Habitat Value = [Habitat Type] Σ [*Amount of Habitat* (km)] x [*Habitat Factor*]

The default values used for the Fisheries Priority Scoring for future attention to fish passage issues are presented in Appendix 2. General descriptions of the different factors in the equations are as follows:

Fish Presence Factor: Factor used to give higher priority for sites where fish are known present and lower priority where fish are not likely present (*for details see* Appendix 2f).

Species Status Factor: Factor used to give higher priority for sites with species of special concern (i.e. Provincial or Regional) (*for details see* Appendix 2g).

Barrier Factor: Factor used to give higher priority for sites with more severe obstructions to fish based on outfall drop, water velocity through a culvert, culvert gradient, or culvert length (*for details see* Appendix 2a).

Habitat Value: Factor used to estimate the habitat value specific to species present or suspected to use the habitat upstream of the barrier based on *habitat type*, *amount of habitat*, and *habitat factor*

- *Habitat Type:* Categories used to differentiate the value of fish habitat based on stream size (1st, 2nd and 3rd order or greater) and stream gradient (High (0-5%), Moderate (5-10%), and Low (>10%)) using 1:20,000 TRIM map interpretation and historical information.
- *Amount of Habitat*: The amount of habitat (km) upstream of each culvert from site analysis that used gradient classes and stream order to differentiate habitat types (*for details see* Appendix 2e).
- *Habitat Factor*: Factor used to give different habitat value for different habitat types based on species preference and species distribution (*for details see* Appendix 2f).

3.0 RESULTS AND DISCUSSION

The Highway 16 crossing of Flint Creek was visited on August 12th, and August 23rd, 2005. Flint Creek was walked from the Skeena River to 580 meters upstream of the Highway 16 crossing. The following sections summarize culvert characteristics and stream characteristics at the crossing location, as well as fish distribution, and fish habitat values in the Flint Creek drainage. Summaries of Fish Passage – Culvert Inspection Rankings (Parker 2000) and Fisheries Priority Scores (Johnston and Saimoto 2003) are included in this section for future cost benefit comparisons to other sites in the Skeena Watershed that require more detailed assessments, improvements or restoration of fish passage.

3.1 FISHERIES INFORMATION

Based on historical information, coho (*Oncorhynchus kisutch*), Chinook (*O. tsawytscha*), sockeye (*O. nerka*), and pink salmon (*O. gorbusha*) have been reported in Flint Creek, or at the large Skeena River back eddy adjacent to the mouth of Flint Creek (Rabnett and Williams 2004, FISS 2005). The culvert where Highway 16 crosses Flint Creek is located about 180 metres upstream of the Skeena River, and has previously been reported to be a significant obstruction to even adult fish migration (Rabnett and Williams 2004, FISS 2005). Fish distribution in Flint Creek is naturally limited by a 14 m high water fall (Figure 2), approximately 580 meters upstream of the Highway 16 crossing (UTM 9.539431.6089997, Figure 1). This is likely the same waterfall identified as a 50' fall about 1 mile upstream of the Skeena River during previous surveys (Allen 1975, Anonymous no date), and the 16 m high falls noted 1.3 km upstream of the highway by Rabnett and Williams (2004). A gravel/cobble wedge (Figure 2) located about 300 metres upstream of Highway 16 (Figure 2) indicates some channel instabilities, and this sediment wedge was also a significant barrier to fish migration at the time of survey.

Figure 2. Upstream view of 1.4 metre high sediment wedge located approximately 300 metres upstream (left) and 14 meter waterfall located about 580 meters upstream (right) of where Highway 16 crosses Flint Creek.

Table 4. BC Conservation status, Global and Provincial ranking for fish species at Flint Creek (B.C. Species and Ecosystem Explorer 2005).

Species	Reference	Global	Provincial	BC Status
Dolly Varden *(Salvelinus malma)*	*Suspected*	Secure (G5)	Vulnerable/Apparently Secure (S3S4)	Blue
Cutthroat trout *(Oncorhynchus clarki clarki)*	*Suspected*	Apparently Secure (G4T4)	Vulnerable/Apparently Secure (S3S4)	Blue
Bull trout *(Salvelinus malma)*	*Suspected*	Vulnerable (G3)	Vulnerable (S3)	Blue
Rainbow trout/steelhead *(O. mykiss)*	FISS 2005	Secure (G5)	Secure (S5)	Yellow
Pink salmon *(O. gorbusha)*	Drewes 2005	Secure (G5)	Secure (S5)	Yellow
Coho salmon *(O. kisutch)*	*Suspected*	Apparently Secure (G4)	Apparently Secure (S4)	Yellow
Chinook salmon *(O. tsawytscha)*	*Suspected*	Secure (G5)	Apparently Secure (S4)	Yellow

Rainbow trout have been captured (Resource Inventory Branch 1976, FISS 2005) and pink salmon have been noted immediately downstream of the Highway 16 (Drewes 2005). Dolly Varden (*Salvelinus malma*), bull trout (*Salvelinus confluentus*) and cutthroat trout (*O. clarki*) may also be present in the system due to uncertainties in species identification in past studies, and the availability of suitable habitat. Fish species documented or suspected in Flint Creek, and their conservation status are summarized in table 4.

3.2 CULVERT ASSESSMENT

A detailed culvert assessment, including the completion of the Fish Passage - Culvert Inspection form (FPCI form), as outlined by Parker (2000) was conducted on August 23rd, 2005 where Highway 16 crosses Flint Creek. The Highway 16 crossing at Flint Creek consists of a 5 metre diameter, 35 metre long, multi-plate culvert with baffles at approximately 4 metre intervals (Figure 3). The physical characteristics and the conditions at this location during the site assessment are summarized in table 5. The culvert is perched 50 cm, and the pool at the culvert outfall is 45 cm deep. Similar to Rabnett and Williams' (2004) previous assessment, the culvert was identified as a partial obstruction to fish passage.

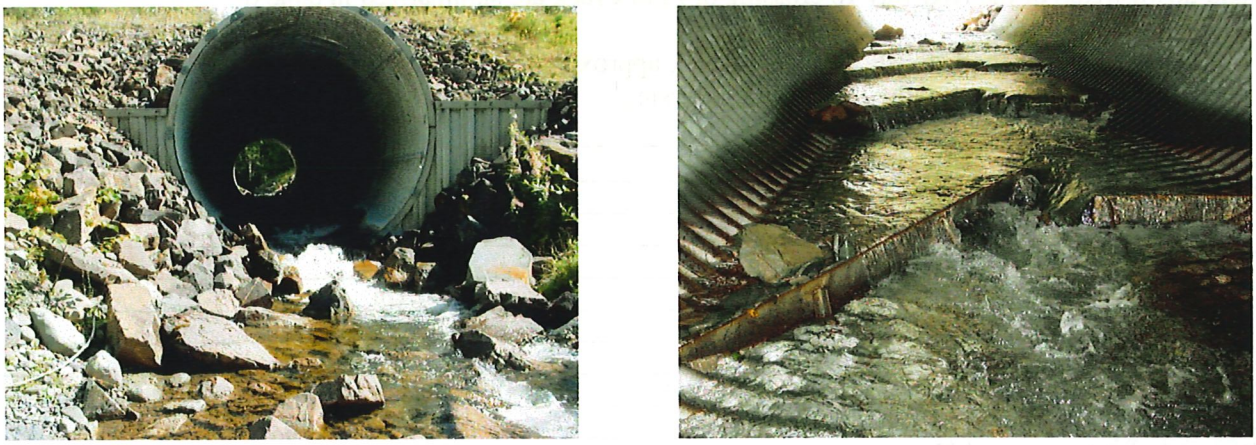

Figure 3. Upstream view at culvert outlet (left) and upstream view through culvert showing baffles (right).

Table 5. Culvert dimensions at the Highway 16 crossing of Flint Creek[1].

Criteria	Description
Culvert Shape:	Round
Culvert Material:	Multi-plate
Culvert Size:	5000 mm diameter
Culvert Length:	35 m
Culvert embedded:	No
Culvert slope:	5%
Culvert wetted width:	220 cm
Culvert water depth:	28 cm
High water mark:	45 cm
Outfall drop:	50 cm
Culvert water velocity:	3.2 m/s at outlet and 1.1 m/s at inlet, but culvert was baffled
Fill Slope Depth:	1.0 m
Culvert Maintenance Required:	Improvement/repair of rock weirs downstream of culvert
Pool depth at outfall:	45 cm
Sediment source:	None observed
FPCI Q_{100}	8.88 m^2 which recommends culvert diameter to be > 3700 mm

[1] For details see attached culvert assessment form in Appendix 1.

3.3 FISH HABITAT ASSESSMENT

An assessment of fish habitat in Flint Creek was conducted upstream and downstream of the highway crossing on Flint Creek. Fish habitat and stream characteristics were assessed for 200 meters upstream and 180 meters downstream of the Highway 16 crossing. Some additional information on fish habitat in Flint Creek was obtained from a previous culvert assessment (Rabnett and Williams 2004), and a point sample conducted in 1976 (Resource Analysis Branch 1976). The stream data for Flint Creek at Highway 16 from a preliminary culvert assessment (Rabnett and Williams 2004) were not comparable due to their use of point sampling at exactly 25 metres and 50 metres upstream and downstream of culverts where stream characteristics may have been representative of anthropogenic disturbances, and not habitat quality or reach characteristics. Channel measurements obtained on August 233rd, 2005 were not taken in sections of stream significantly influenced by the culvert crossing in an attempt to best represent the undisturbed stream habitat upstream and downstream of the highway. Stream characteristics upstream and downstream of the Highway 16 crossing of Flint Creek are summarized in table 6.

Table 6. Stream characteristics of Flint Creek approximately 100 m upstream and 100 m downstream of the culvert at the Highway 16 crossing[1].

Criteria	Below culvert	Above culvert
Wetted Width:	767 cm	715 cm
Water Depth:	9 cm	13 cm
Water Velocity:	1.33 m/s	0.76 m/s
Bankfull Width:	940 cm	982 cm
Bankfull Depth:	33 cm	37.3 cm
Stream Gradient:	4 %	6 %
Substrate:	Gravel, cobble (2-300 mm)	Cobble, boulder (10-1000 mm)
Fish Habitat Quality:	Moderate	Moderate
Beaver Activity:	None	None

[1] For details see attached culvert assessment form in Appendix 1.

Figure 4. Downstream view of Flint Creek downstream of Highway 16 (left) and upstream view of Flint Creek upstream of Highway 16 (right).

For FPCI scoring and ranking, the habitat value for Flint Creek was assessed upstream and downstream of Highway 16 (Figure 4). Flint Creek, in conjunction with other stable, non-glacial tributaries to the Skeena River, provide important refuge habitat during peak flow events when discharge and turbidity in the mainstem present marginal conditions for fish. The moderate gradient (2% to 6%) downstream from the culvert provides some good potential rearing habitat for juvenile fish (e.g. rainbow/steelhead), but only limited pockets of habitat appeared suitable for spawning. The moderate gradient of the creek may deter some species from using this system, however, the reported presence of pink carcasses (Drewes 2005) indicates that adults of all salmonid species present in the Skeena River have access to fish habitat in Flint Creek downstream of the culvert. Upstream of the culvert, habitat suitability for spawning further declines due to the moderate gradient (4% - 7%), relatively large substrate size, and the apparent instability of the channel (i.e. gravel/cobble wedges). A 1.4 metre high gravel wedge behind large woody debris was identified approximately 300 metres upstream of the culvert and appeared to be a barrier to fish migration at the time of survey (*see* Figure 2). Rearing habitat upstream of the culvert appears suitable for Dolly Varden and cutthroat trout due to the presence of small pools, but the moderate gradient (4% to 7%) and only small pockets of suitable gravels limit the availability of potential spawning habitat. In agreement with a previous culvert assessment in 2004 (Rabnett and Williams 2004), fish habitat upstream and downstream of the culvert was rated as moderate for the FPCI scoring matrix, largely due to the moderate gradient, the relatively large substrate size, and evidence of channel instability. More detailed breakdowns of habitat value for the Fisheries Priority Score are provided in Section 3.6.

3.4 OBSTRUCTIONS TO FISH MIGRATION

The culvert located where Highway 16 crosses Flint Creek was previously visited in 2004, when Rabnett and Williams (2004) reported the culvert to be an obstruction to fish migration. This site was re-assessed on August 23rd, 2005 to provide more detailed analysis of costs and benefits relative to the fish habitat value upstream of the obstruction, and to identify the severity of this obstruction for the FPCI scoring matrix and Fisheries Priority Score. Although the culvert is baffled, channel confinement upstream, water velocity within, and the drop from the outlet of the culvert were identified to create a significant obstruction to fish passage.

Flint Creek has been channelized for approximately 40 metres upstream of the culvert, with a gradient of approximately 6% (Figure 5). In this section of creek, the channel is confined to approximately 60% of

the natural channel width of Flint Creek and is a long continuous cascade over cobble and angular boulder substrate. Although this cascade appeared passable to adult fish of all species, stream gradient, water velocities, and lack of holding pools in this section appeared to be a notable obstruction for juvenile fish.

The gradient of the culvert (5%) was not suitable for fish passage, but baffles in the culvert at approximately 4 metre intervals created a cascade pool morphology. The baffles were creating shallow and turbulent pools and were reducing water velocities through most of the culvert at the time of survey. However, water depth within the culvert was 0.28 metres, which is not optimal for adult fish migration (Parker 2000) and the lack of adequate backwatering has caused a high water velocity below the last baffle (3.2 m/sec) (Figure 5) that is greater than burst swimming abilities reported for juvenile salmonids (Table 2). This water velocity is within the range of burst swimming velocities reported for adult salmonids (1.8-4.3 m/s), indicating at least some fish would be able to swim through this four metre section at some flows.

The drop at the culvert outlet was 0.5 meters over an approximately 1.0 metre section of boulder cascade into a 0.45 metre plunge pool (Figure 5). Although the plunge pool depth was less than the height of the drop from the culvert, the relatively short distance of this steep cascade may be passable by adult fish, at least under lower flow conditions. The high water velocity, and reports of pink salmon carcasses being observed downstream but not upstream of this culvert (Drewes 2005), indicates that this culvert is a barrier to at least adult pink salmon during some flows. The drop of 0.5 metres is equivalent to maximum jumping height of juvenile salmonids 120 mm in length (*see* Table 1), and the lack of sufficiently deep plunge pool indicates that this culvert is impassable to juvenile fish.

In summary, the culvert located where Highway 16 crosses Flint Creek was identified to be a significant obstruction to adult fish migration due to the boulder cascade at the outlet, and a full barrier to juvenile fish. For the purpose of the FPCI scoring matrix, the combination of the confined channel upstream of the culvert, shallow depths during low flows, and the cascade at the outlet were considered to create a partial barrier to fish migration.

Figure 5. Upstream view of culvert outlet (left) and downstream view of culvert inlet and channelized portion of the stream (right) where Yellowhead Highway 16 crosses Flint Creek.

3.5 FISH PASSAGE – CULVERT INSPECTION SCORING MATRIX AND RANKING

In order to prioritize culverts assessed in a variety of areas and by various agencies, the data collected for Flint Creek were used to calculate the FPCI matrix score for FPCI Rankings for the stream crossing at Highway 16. Data were assessed using the FPCI scoring matrix (Parker 2000, see Appendix 1). The FPCI score is a sum of the sub-score values for fish species present, habitat value, barrier type (full, partial, undetermined), length of habitat upstream, proportion of stream habitat barred, and the presence of further upstream barriers to determine if the culvert is within the range of low, moderate or high priority for further efforts toward restoring fish passage.

The Flint Creek crossing at Highway 16 received a FPCI matrix score of 38 (of a maximum possible score of 55). Scoring information for the Flint Creek crossing at Highway 16 are summarized in the FPCI summary table (Table 7) below. The FPCI score obtained during our assessment of the Flint Creek culvert at Highway 16 is an update of the one by Rabnett and Williams' (2004), who calculated a score of 46 (high ranking). The amount of habitat to be gained between the culvert and the impassable falls was determined to be 580 meters (measured by hipchain) and was given a moderate scoring (6 points) for the length of new habitat. The amount of habitat gained used by Rabnett and Williams (2004) assessment was based on historical information (Allen 1975), which we speculate to have been a rough estimate based on map interpretation or aerial estimates that resulted in their higher score (10 points) for the length of new habitat. The effective baffles in this culvert, the 0.5 metre drop or cascade from this culvert does not appear to make this culvert impassable at all flows for adults of all species; thus the barrier rating was given a moderate ranking (6 points). Rabnett and William's (2004) report states that this culvert is "passable by adult fish at various discharge stages", but scored this culvert to be a full barrier to fish migration which is probably not indisputable due to the severity of this obstruction. Due to the close proximity of this culvert to the confluence of Flint Creek with the Skeena River, the percent of available habitat barred did not differ from previous scoring (> 70% barred) and still received its maximum score (10 points). Habitat value was given a moderate ranking score (6 points) based on characteristics discussed above (*see* 4.4 Fish Habitat Values). Based on our assessment of the culvert structure, and fish habitat upstream of the crossing, the Highway 16 crossing at Flint Creek falls within the *moderate ranking score* category for its priority for restoration activities.

Table 7. Fish passage - culvert inspection (FPCI) summary table for the Highway 16 crossing of Flint Creek.

Fish Species* (suspected species) *(score)*	**Habitat Value** *(score)*	**Barrier** *(score)*	**Stream Length Gained** *(score)*	**% stream barred** *(score)*	**Barrier Upstream**	**FPCI Ranking**
RB/ST, PK (DV/BT, CT)	Moderate	Partial	< 1 km ≥ 500 m (580 metres)	>70% (76%)	No	**Moderate Priority**
(10)	*(6)*	*(6)*	*(6)*	*(10)*	(0)	**38**

** See Appendix 2 for Species Codes*

3.6 FISHERIES PRIORITY SCORES FOR RESTORATION OF FISH PASSAGE

In addition to the FPCI Matrix Score and Ranking, we also determined the Fisheries Priority Score for the culvert crossing of Flint Creek at Highway 16, which incorporates a more detailed evaluation of fish habitat quantity and quality. The Fisheries Priority Score is used to describe the fisheries value upstream of road crossings that are obstructing fish passage in more detail than the FPCI Rankings by incorporating species preferences for different habitat types (stream order and gradient) and the quantity of different habitat types in the upstream portion of the mainstem and its tributaries. The fish habitat value upstream of the Highway 16 crossing is limited by the 14 meter high falls located 580 meters upstream of the Highway and no tributaries flow into Flint Creek in this section of the mainstem.

The Fisheries Priority Score was determined for the Highway 16 crossing at Flint Creek by multiplying the habitat value score (Table 8), by factors for species characteristic (Fish Presence and Species Status) and the severity of the obstruction (barrier) as summarized in table 9. The fisheries priority score for the Highway 16 crossing at Flint Creek is 4.6, reflecting that the structure is a partial obstruction, that a relatively small amount of moderate quality habitat is present upstream of the culvert, and that there is a potential for the presence of blue listed species.

Table 8. Habitat Value upstream of Highway 16 used for calculating prioritization scores for future work, from a fisheries perspective.

Stream Order	Habitat Quality Class (% Gradient)	Species	Species Factor*	Amount of habitat (km)	Habitat Value
≥ 3rd	Good (0-5)	CO,PK,RB,ST,CT,DV	3	0	0
≥ 3rd	Moderate (5-10)	CO, RB/ST, CT, DV	2	0.58	1.6
≥ 3rd	Limited (10-20)	RB/ST, DV, CT	1	0	0
2nd	Good (0-5)	CO, RB/ST, CT, DV	3	0	0
2nd	Moderate (5-10)	CT, DV, RB/ST	2	0	0
2nd	Limited (10-20)	CT, DV	1	0	0
1st	Good (0-5)	CO, RB/ST, CT, DV	1	0	0
1st	Moderate (5-10)	CT, DV, RB/ST	0.5	0	0
1st	Limited (10-20)	CT, DV	0.25	0	0
Total Habitat Value upstream of Highway 16					**1.16**

** Highest Species Factor for species present or suspected present (See Appendix 2 for Species Codes)*

Table 9. Fisheries Priority Scores for future work at culvert crossings at Highway 16 from a fisheries perspective.

Location	Fish Presence (Factor)	Species Status (Factor)	Barrier (Factor)	Upstream Habitat Value	Fisheries Priority Score
Yellowhead Highway 16	Known (3)	Blue listed (1.33)	Partial (1)	1.16	**4.6**

4.0 RECOMMENDATIONS FOR RESTORING FISH PASSAGE

The long-term plan for this culvert should be to re-establish fish passage for juvenile and adult fish to the 580 metres of habitat, including a large pool at the base of the 14 metre waterfall, located upstream of Highway 16. The eventual replacement of the culvert at Flint Creek with an open bottom structure that does not restrict the stream channel or impede fish passage will be a difficult and expensive task. It is important to consider that the present drop from this culvert appears to be only a partial barrier to adult fish migration to only moderate quality habitat (*see* 4.4 Fish Habitat Value) where juvenile migration would also be significantly impeded by two natural obstructions (i.e. gravel/cobble wedges). Due to present shortages of funding for projects of this nature, any exorbitant costs targeted at temporarily re-establishing fish passage through this culvert for both juvenile and adult fish may not be a constructive effort toward restoring fish production in the Skeena River. A short term plan to allow adult fish and some larger juveniles to pass through this culvert at more than just optimal flow conditions may be appropriate, in conjunction with regular maintenance, to allow longer term planning and budgeting for the eventual replacement of this structure.

Fisheries and Oceans Canada has conducted a site survey and provided a conceptual design (Figure 6) and example photos (Figure 7) for the improvement of fish passage at Flint Creek (Hjorth 2005). This conceptual design suggests the placement of four lock block weirs to eliminate the 0.5 metre drop from the culvert outlet. This design would be intended to last the remaining lifetime of the existing culvert, with the intent to allow adult fish to spawn and larger juveniles to migrate upstream of the culvert in order to adequately seed the available rearing habitat. Depending on the available funds, placement of some additional rock weirs or boulder clusters upstream of the culvert to improve juvenile fish migration, or perhaps improvement of spawning habitat immediately upstream or downstream of the culvert are some additional options that could be considered. Depending on the estimated structural integrity of this culvert, it may also be possible to consider increasing the number and height of the lock block weirs to backwater and partially embed the existing culvert in order to reduce the stream gradient to less than one percent through the entire length of this culvert. Although Parker (2000) does not recommend embedding round or elliptical culverts for streams of this size (i.e. the culvert width should be no less than the mean bankful width) or with high 100 year flood events (FPCI Q_{100} estimate for Flint Creek = 10.30, *see* Appendix 3), this 5 metre diameter culvert appears to be large enough to consider further investigation and engineering of backwatering in conjunction with modification or replacement of the existing baffles to restore both juvenile and adult fish migration at this location. These temporary improvements of fish passage may be a practical short-term approach as it would be more cost-effective than structure replacement for the relatively small amount of moderate quality habitat available upstream. However, given the amount and quantity of habitat available upstream, limited funds available for this type of work may be better spent at other sites eligible to any applicable funding sources.

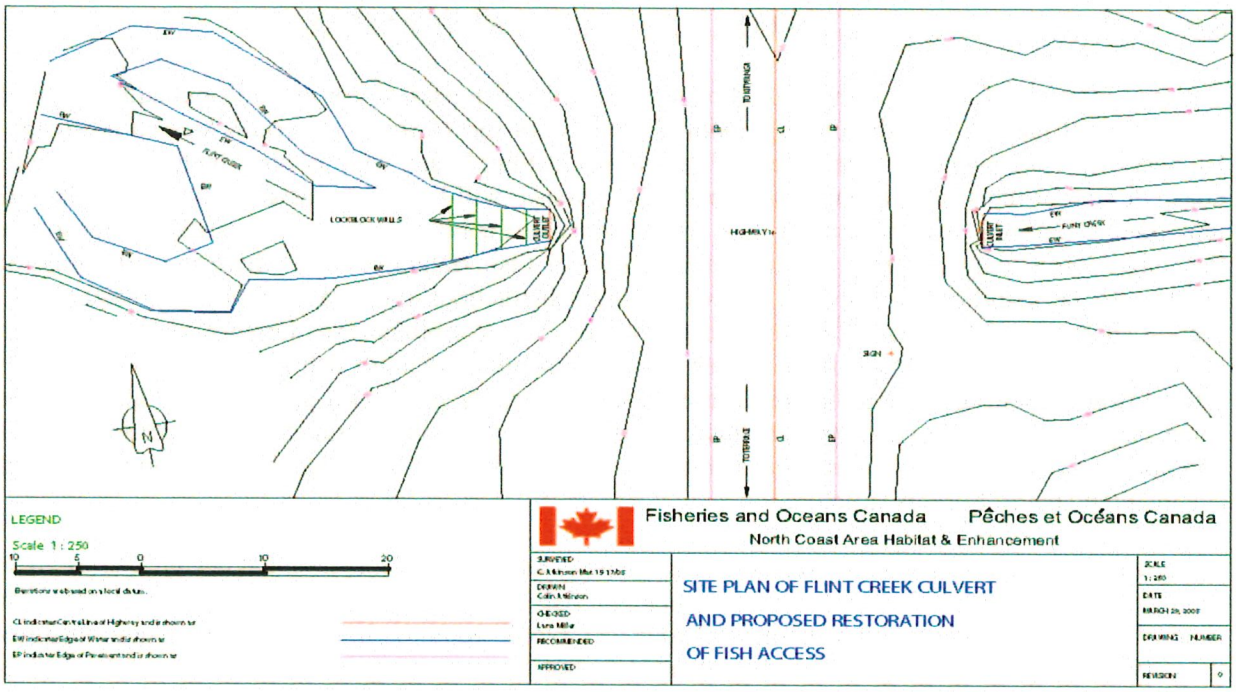

Figure 6. Conceptual design for installation of lock block weirs at the outlet from Flint Creek (for more details, contact Don Hjorth, FOC).

Figure 7. Example of lock block weir construction (courtesy of Don Hjorth).

5.0 PRIORITIZATION FOR IMPROVING FISH PASSAGE

The Highway 16 culvert at Flint Creek was identified as a moderate priority site according to the Fish Passage - Culvert Inspection scoring matrix. However, this scoring matrix does not provide prioritization of this crossing in relation to other culverts on Highway 16 where fish passage issues have been identified. The Fisheries Priority Score for the Highway 16 crossing at Flint Creek was compared to other culvert crossing on Highway 16 between Terrace and New Hazelton that were assessed in previous and concurrent studies. In total, fish passage issues have been identified at 13 stream crossings along this section of Highway 16, and Fisheries Priority scores have been determined for each of these crossings (Table 10). Of the 13 crossings where fish passage issues have been identified, the Flint Creek crossing received the second lowest score, indicating its relatively low priority compared to other structures on this section of Highway 16, from a fisheries perspective.

Table 10. List of culvert crossings along Yellowhead Highway 16 from Terrace to New Hazelton that are impeding fish passage.

Stream (Hwy Section)	LKI (km)+	Barrier	FPCI Ranking	Fisheries Score*	Comments
Station (Mission) Creek [1] (Kitwanga-Hazelton)	40.18	Full	High	**478.8**	
Andimaul Creek [2] (Kitwanga-Hazelton)	10.84	Full	High	**103.2**	The priority rating for this site requires consideration of the anthropogenic disturbance causing significant instabilities of the mainstem upstream of Highway 16 (SKR 2003b).
Singlehurst Creek [3] (Terrace-Kitwanga)	15.64	Partial	High	44.3	Priority for work at this site may be higher because the weirs, previously constructed to provide fish passage at this location, are presently breaking down (SKR 2006a).
Unnamed Creek [4] (Terrace-Kitwanga)	39.42	Full	High	**24.6**	This culvert appears to impede fish passage to excellent juvenile fish rearing habitat (Rabnett and Williams 2004).
Comeau Creek [4] (Kitwanga-Hazelton)	30.40	Partial	High	**30.3**	Channel width is only 2.6 metres upstream of culvert. A more detailed field assessment of habitat upstream of this partial barrier appears necessary to more accurately assess the habitat value. An apparent obstruction to anadromous fish downstream of this culvert may reduce the impact of this partial obstruction. No fish passage issues were identified at this site (Rabnett and Williams 2004).
Waterfall Creek [4] (Kitwanga-Hazelton)	43.18	Partial		**14.7**	The Fisheries Priority Score was based on it being a full barrier due to length of culvert, but the culvert appears passable by fish at most flows (SKR 2006b).
Chicago Creek [4] (Kitwanga-Hazelton)	35.88	Partial	NA	**12.6**	Rabnett and Williams (2004) did not identify any fish passage issues at this site. There is a resident population of cutthroat trout in Seeley Lake, upstream of Highway 16.
Gershwin Creek [4] (Kitwanga-Hazelton)	30.65	Partial	NA	**11.2**	Rabnett and Williams (2004) identified no fish passage issues but recommend that the old beaver guard be replaced, and fish sampling be conducted.
Shandilla Creek [5] (Kitwanga-Hazelton)	3.71	Full	High	**11.0**	FPCI Priority Ranking was high due to the close proximity of this culvert to its confluence with the Skeena. Only 460 metres of moderate gradient habitat is available upstream of this culvert (SKR 2003a).
Gossen Creek [4] (Terrace-Kitwanga)	13.09	Full	High	**9.0**	Estimate of available habitat is likely an underestimate as Valhalla Creek appears to have been redirected into this drainage. A more detailed field assessment of this location is recommended to confirm fisheries value (Rabnett and Williams 2004).
Noble Five Creek [4] (Terrace-Kitwanga)	13.52	Full	Low	**6.8**	
Flint Creek [6] (Terrace-Kitwanga)	**63.22**	**Partial**	**Moderate**	**4.6**	**Only 580 metres of moderate gradient habitat is available upstream of this culvert.**
Skovens Creek [4] (Terrace-Kitwanga)	19.81	Partial	Low	**2.7**	

+ LKI refers to MoT's Landmark Kilometer Inventory (Cypher Consulting 2006)
* Fisheries Scores are from MoT Stream Crossing Database representing priority based on the relative benefit to fish production in the Skeena River watershed.

Site specific data for Fisheries Priority Scoring and FPCI scores obtained from [1] SKR 2006b, [2] SKR 2003a, [3] SKR 2006a, [4] Rabnett and Williams 2004, [5] SKR 2003b, [6] current study

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Appendix 1. Fish Passage - Culvert Inspection Forms

Culvert where Yellowhead Highway 16 crosses Flint Creek, 2005

Fish Passage – Culvert Inspection

Highway 16 – Flint Creek

Date (mm/dd/yy)	08/23/2005	**Stream Name**	Flint Creek
Road Name/ID#	Highway 16	**Road Location (MoF district)**	MoT L.K.I. Segment 1510: km 63.22 E
UTM/GPS Location	9.538937.6089961	**Watershed Code**	400-316300
1:20 000 Map Sheet	103I.099	**Recorders Name**	Ron Saimoto
Site Number	1		

Culvert Characteristics: culvert outfall is a significant obstrtuction to fish passage despite baffles in culvert

Culvert Diameter (mm)	5000 mm			**Culvert Slope (%)**	Us 5	Ds 5	5 %
Culvert Length (m)	35 m			**High Water Mark (cm)**	45 cm		
Culvert Material	Multi-plate			**Culvert Water Depth (cm)**	28 cm		
Culvert Water Velocity (m•sec-1)		outlet 3.2	Inlet 1.1	Ave 2.15	**Culvert Outfall Drop (cm)**	50 cm	
Culvert Shape	Round			**Culvert Maintenance**	Moderate		
Culvert Wetted Width (cm)	220 cm			**Fill Slope Depth (m)**	1.0 m		

Stream Characteristics: habitat quality upstream of the culvert is limited due to channel instability (gravel wedges up to 1.4 m high). An approximately 14 meter high waterfall is located 580 meters upstream of the culvert.

Stream Reach	1	**Stream Classification**	S2
Pool Depth at Outfall (cm)	45 cm	**Blue Listed/Significant**	DV may be present downstream (unconfirmed)
Sediment Source/Degree	No		

Measure	**Measurement(s) Below Culvert**			**Measurement(s) Above Culvert**			**Average Measurement**
Wetted Width (m)	5.4	8.6	7.8	5.2	9.5	6.75	7.21 m
Bankfull Width (m)	9.2	8.7	10.3	8.0	12.1	9.45	9.63 m
Water Depth (cm)	12	8	7	20	7	12	11 cm
Bankfull Depth (cm)	37	33	29	45	32	35	35.2 cm
Stream Water Velocity (m•sec-1)	1.1	1.5	1.4	1.4	0.1	0.8	1.05 m•s-1
Stream Gradient (%)	4			6			5 %
Fish Presence	Yes			No survey			NA
Fish Sampling Method	Historical information			Historical information			NA
Sampling Effort (time)							NA
Species Present	RB, PK. DV suspected present			DV suspected present			NA
Beaver Activity/Type	None			None			NA

Barrier Evaluation:

Barrier	**Partial**
Barrier Type	The culvert is a partial barrier to fish passage due to the 50 cm drop at the outlet of the culvert, and the relatively shallow plunge pool (45 cm). Gradient of the culvert and water velocity may also obstruct fish passage, though the recent installation of baffles in the culvert provide better fish passage than previously noted (Rabnett and Williams 2004). Backwatering of the culvert to assist fish passage should be considered at this site.

Site Photos:

Roll # MoT Roll 1

Inlet upstream photo	# 36, 59	Inlet downstream photo	# 40, 58
Outlet upstream photo	# 37, 60	Outlet downstream photo	#39

1.4 m high gravel wedge	# 34
~14 metre high waterfall	# 35
Baffles	# 38

Comments: Historical information documents the presence of rainbow trout downstream of the highway. Pink salmon carcasses have been observed downstream of the culvert crossing. Sediment wedges upstream of the culvert indicate channel instability. An approximately 14 metre high waterfall was located upstream of the culvert is a natural and permanent barrier to fish passage.

Office Calculations: (*to be completed for full and partial barriers only)

Q100 Diameter Estimate (mm)	Q100 = 8.88 (estimated as 3700 mm round multi-plate)	**Stream Length Above Barrier**	580 m accessible
Road Responsibility	Ministry of Transportation	**% Stream Barred**	76 %

Prioritization Calculations – FPCI Scoring Matrix:

Fish species		**Habitat value**		**Barrier**		**Length of new habitat**		**Stream barred (%)**		**Limiting to upstream barrier**	
Multiple or significant	10	H		Full		≥1 km		>70%	10	Yes	
Single		M	6	Partial	6	<1 km ≥500 m	6	51–70%		No	0
Other		L		Undeter		<500 m		<50%			

Total Score: **38**

Ranking: **Moderate**

Appendix 2. Summary of default settings for criteria and priority scoring factors used to ranking sites for their potentially impact on fish and fish habitat.

Note: The following list of codes for fish species are used in tables throughout this report

Species Code	Common Name	Scientific Name
BT	Bull trout	*(Salvelinus confluentus)*
CH	Chinook salmon	*(Oncorhynchus tsawytscha)*
CO	Coho salmon	*(O. kisutch)*
CT	Cutthroat trout	*(O. clarki clarki)*
DV	Dolly Varden	*(S. malma)*
PK	Pink salmon	*(O. gorbusha)*
RB/ST	Rainbow trout/steelhead	*(O. mykiss)*

Appendix 2a. Scoring Factors based on the Severity of Barriers

Appendix 2b. Barrier Criteria used for identifying significant obstructions to fish passage (i.e. "B1" Severity)

Appendix 2c. Barrier criteria used for identifying partial obstructions to fish passage (i.e. "B2" Severity)

Appendix 2d. Scoring Factors for the potentially for fish use upstream of culverts impeding fish passage

Appendix 2e. Habitat Units used to evaluate the quality of fish habitat upstream of culverts based on map interpretation

Appendix 2f. Scoring Factors used to calculate the value of habitat upstream of the culvert dependent on specific species that are either present or suspected present.

Appendix 2g. Scoring Correction Factors based on Species status

Appendix 2a. Scoring Factors based on the Severity of Barriers

[Severity of Barrier]	[Code Description]	[Barrier Factor]	[Barrier Factor Description]
B1	A significant obstruction/barrier to upstream fish migration of all age classes and species present or suspected upstream of the culvert (*for details see* Barrier Criteria)	**3**	The default barrier factor for "B1" is 3 to raise immediate attention toward sites that are known to be limiting fish production. This factor is used to differentiate the priority scores for sites where culvert replacements or repairs may be appropriate without further assessment and sites where immediate work will be the most beneficial for fish without additional assessments of fish distribution.
B2	Partial obstruction to fish migration at any time and for any age class of fish present or suspected present upstream of the culvert [*for details see* Barrier Criteria]	**1**	The default barrier factor for "B2" is 1 to help differentiate the high priorities for immediate repair or replacement of culverts at sites from the priorities for more detailed assessments of fish presence, the severity of the obstruction, and the quantity and quality of habitat upstream of the obstruction. Because the severity of partial obstructions is so variable and dependent on a multitude of factors, culverts of this status are grouped together and the habitat value upstream of the culvert becomes the predominant value used to determine priorities for future work (i.e. Fish Presence Factor, Habitat Units, and Species Factors).
B3	No Obstruction to fish migration could be identified if none of the above criteria are met	**0**	This value is 0 and should not be modified. To reduce the number of sites that receive this value, adjustments should be made to [Barrier Criteria]

Appendix 2b. Barrier Criteria used for identifying significant obstructions to fish passage (i.e. "B1" Severity)

[Barrier Type]	[Code Description]	[Barrier Criteria]	[Barrier Criteria Description]
B1_GR	Culvert Gradient is a significant Obstruction/Barrier to fish migration [Severity of Barrier] = "B1"	**3%**	The default value is 3% and tries to account for inconsistent gradients through the culvert that may provide some holding areas for fish or if where the water velocity was measured was not representative of the total length of the culvert. Although it is possible that some large adult fish may be able to pass through this gradient if the culvert is not too long, this default value for culvert gradient is considered to obstruct fish passage enough to qualify a site to be "B1" for severity.
B1_VEL	Velocity in culvert is a significant Obstruction/Barrier to fish migration [Severity of Barrier] = "B1"	**2.5 m/sec**	The default value is 2.5 m/s based on average prolonged swimming abilities for adults of the species that were identified during this study (range: 1.8 to 4.2 m/sec, Whyte *et al.* 1997). Water velocity through most of the culverts were measured during only moderate discharge, thus this criteria value intends to recognize that flows may be higher during higher flow conditions. Although the prolonged swimming ability of some species is less than 2.5 m/sec, this value considers the variability of velocity within the entire length of each culvert that often allows burst-swimming capabilities to play a significant role. Although some species may be able to migrate through this velocity (prolonged swimming abilities up to 4.2 m/sec), this default value for velocity is considered to obstruct even stronger swimming fish enough to qualify a site to be "B1" for severity.
B1_DR	Vertical drop from outlet is a barrier if width or diameter of the culvert is < 2 metres [Severity of Barrier] = "B1"	**0.6 m**	The default value is a 0.6 metre drop at the outfall from any culvert less than 2 metres in diameter is a significant obstruction/barrier to juvenile and adult fish migration. Although the maximum jump height for various species is greater than 0.6 metres, this default value is considered to obstruct fish passage enough to qualify a site to be "B1" for severity regardless of the pool depth. Detailed reviews of the severity of these drops should be conducted on all sites with culvert size greater than or equal to 2 metres.
B1_D-P	Drop – pool depth at the outlet of a culvert is a significant Obstruction/ Barrier to fish migration if width or diameter of culvert is <1.5 metres [Severity of Barrier] = "B1"	**0.3 m**	The default value is >0.3 since a drop of less height than the criteria for "B_DR" from a relatively small culvert will obstruct fish passage enough to qualify a site to be "B1" (i.e a significant obstruction). Detailed reviews of the severity of drops should be conducted on all sites with culvert size greater than or equal to 1.5 metres.
B1_Lgth	Length of culvert	**45**	The default value is 45 metres to ensure that attention is given to all long culverts regardless of dropp from the outlet or gradient.

Appendix 2c. Barrier criteria used for identifying partial obstructions to fish passage (i.e. "B2" Severity)

[Barrier Type]	[Code Description]	[Barrier Criteria]	[Barrier Criteria Description]
B2_GR	Culvert Gradient is suspected to be a partial obstruction to juvenile and/or adult fish migration if width or diameter of culvert is < 2 metres [Severity of Barrier] = "B2"	**2%**	The default value is 2% to identify where migration by juvenile and some adult species is being significantly obstructed. This criteria value is set to ensure that even minor obstructions are considered for future attention. The priority for attention at these sites will be based mostly on the quality and quantity of habitat upstream of the culvert.
B2_VEL	Culvert Velocity Gradient is suspected to be a partial obstruction to juvenile and/or adult fish migration if width or diameter of culvert is < 2 metres [Severity of Barrier] = "B2"	**1 m/sec**	The default value is 1 m/sec based on estimated prolonged swimming abilities for juvenile adults of the species that were identified during this study. Water velocity through most of the culverts were measured during only moderate discharge, thus this value intends to recognize that flows may be higher during higher flow conditions. Although the prolonged swimming ability by juveniles of some species is less than 1 m/sec, the criteria value considers the variability of velocity within the entire length of each culvert that often allows burst-swimming capabilities to play a significant role in fish passage. This criteria value is set to ensure that even minor obstructions are considered for future attention based on the quality and quantity of habitat upstream of the culvert.
B2_D-P	Drop – pool depth at the outlet of a culvert is considered to be a Partial Obstruction/ Barrier to fish migration if width or diameter of culvert is <1.5 metres [Severity of Barrier] = "B2"	**>0.15**	The default value is 0.15 metres to allow this scoring matrix to identify minor obstructions to fish passage. This criteria value is set to ensure that even minor obstructions are considered for future attention based on the quality and quantity of habitat upstream of the culvert.
B2_LGTH	Length of culvert if width or diameter is <2 metres [Severity of Barrier] = "B2"	**35**	The default value is for culverts >35 metres long to ensure that sites with very long lengths of culvert are considered when priorities for culvert replacement or maintenance are being reviewed. This criteria value is set to ensure that no potentially obstructions to fish passage are ignored.

Appendix 2d. Scoring Factors for the potentially for fish use upstream of culverts impeding fish passage

[Fish Presence Type]	[Code Description]	[Fish Presence Factor]
FP	Fish Present based on Historical Records	**3**
SFP1	Fish Suspected based on reach gradient < 10%)	**2**
SFP2	Fish Suspected based on Gradient 10-20%, or potentially barrier downstream	**0.5**
FA	Fish Absent based on Historical Records, or reach gradient > 20%)	**0**

Appendix 2e. Habitat Units used to evaluate quality of habitat upstream of culverts based on map interpretation

[Habitat Unit]	[Code Description]	[Map Gradient Criteria]	[Description of Map Gradient Criteria]
≥ 3rd order streams			
3_G	Good Quality, Suitable Habitat	<5	Good: 5% units are used due to their easy identification based on 20m contours on TRIM
3_M	Moderate Quality, Suitable Habitat	5-10	Moderate: Considered moderate due to the significantly lower quantity and quality of rearing habitat present as stream gradient increases.
3_L	Limited Quality due to Gradient	10-20	Low: designated to sections of stream with 10-20% gradient sections or sections upstream of a likely obstruction to fish passage based on airphoto and TRIM map interpretation
2nd order streams			
2_G	Good Quality, Suitable Habitat	<5	Good: 5% units are used due to their easy identification based on 20m contours on TRIM
2_M	Moderate Quality, Suitable Habitat	5-10	Moderate: Considered moderate due to the significantly lower quantity and quality of rearing habitat present as stream gradient increases.
2_L	Limited Quality due to Gradient	10-20	Low: designated to sections of stream with 10-20% gradient sections or sections upstream of a likely obstruction to fish passage based on airphoto and TRIM map interpretation
1st order streams			
1_G	Good Quality, Suitable Habitat	<5	Good: 5% units are used due to their easy identification based on 20m contours on TRIM
1_M	Moderate Quality, Suitable Habitat	5-10	Moderate: Considered moderate due to the significantly lower quantity and quality of rearing habitat present as stream gradient increases.
1_L	Limited Quality due to Gradient	10-20	Low: designated to sections of stream with 10-20% gradient sections or sections upstream of a likely obstruction to fish passage based on airphoto and TRIM map interpretation

Appendix 2f. Scoring Factors used to calculate the value of habitat upstream of the culvert dependent on specific species that are either present or suspected present.

[Species Code]	[Habitat_Species Factor] *(default settings)*								
	≥3rd order streams			*2nd order streams*			*1st order streams*		
	3_G	**3_M**	**3_L**	**2_G**	**2_M**	**2_L**	**1_G**	**1_M**	**1_L**
BT	3	2	1	1	0.5	0.25	0	0	0
CH	3	1	0	.05	0	0	0	0	0
CM	3	1	0	0	0	0	0	0	0
CO	3	2	0	3	1	0.5	1	0.5	0.25
CT_C	3	2	1	3	2	1	1	0.5	0.25
CT	3	2	1	3	2	1	1	0.5	0.25
DV	3	2	1	3	2	1	1	0.5	0.25
GR	3	1	0	0	0	0	0	0	0
MW	3	1	0	0	0	0	0	0	0
PK	3	1	0	0	0	0	0	0	0
RB	3	2	1	3	2	0.5	1	0.5	0.1
SK	3	1	0	0	0	0	0	0	0
ST	3	2	1	3	2	0.5	1	0.5	0.1
ST_NS	3	2	1	3	2	0.5	1	0.5	0.1
RB/CT	3	2	1	3	2	1	1	0.5	0.25
RB/ST	3	2	1	3	2	0.5	1	0.5	0.1

Note: The Scoring Query will be designed to select only the highest scoring species for each category

Appendix 2g. Scoring Correction Factors based on Species status

[Species Status]	[Code Description]	[Species Correction Factor]	[Factor Description]
PS_R	Provincially Significant Red listed	**1.5**	
PS_B	Provincially Significant Blue listed	**1.33**	
RS	Region Significant	**1.33**	
FPC	Forest Practice Code Listed Species	**1**	
Other	Not Forest Practice Code Listed	**0**	

Appendix 3. Effective culvert area/diameter relationship for round and elliptical culverts (adapted from Parker 2000).[a]

Round Culverts		Elliptical arch culverts	
Diameter of culvert (mm)	**Total culvert area required (m^2)**	**Diameter of culvert (mm)**	**Total culvert area required (m^2)**
500	0.19	560 x 420	0.19
600	0.27	680 x 500	0.27
700	0.37	800 x 580	0.37
800	0.48	910 x 660	0.48
900	0.61	1030 x 740	0.61
1000	0.74	1150 x 820	0.74
1200	1.06	1350 x 870	1.06
1400	1.44	1630 x 1120	1.44
1600	1.87	1880 x 1260	1.87
1800	2.36	2130 x 1400	2.36
1810	2.58	2060 x 1520	2.49
1970	3.04	2249 x 1630	2.90
2120	3.54	2440 x 1750	3.36
2280	4.07	2590 x 1880	3.87
2430	4.65	2690 x 2080	4.49
2590	5.26	3100 x 1980	4.83
2740	5.91	3400 x 2010	5.28
3050	7.32	3730 x 2290	6.61
3360	8.89	3890 x 2690	8.29
2000	3.14		
2200	3.80		
2400	4.52		
2700	5.73		

[a] Shading indicates multi-plate culvert.