COTTON CREEK CULVERT REPLACMENT

Integrating Mobility with Environmental Innovation

Located along a scenic section of Highway 3/95 in British Columbia, Moyie Bluffs, a 6.5 km stretch of inland highway had a extraordinarily high accident rate provoking the BC Ministry of Transportation (MoT) to make improvements. The problems associated with this curvilinear section of highway are exasperated by the physical constraints associated with the site. A CP Railway is located immediately down slope from the highway and Moyie Lakes, a valuable recreational fisheries resource and vital link in the local ecosystem, is located next to the railway. The environmental challenges associated with major highway improvements were significant.

This submission documents an innovative and creative design for the Cotton Creek culvert crossing located within the Moyie Bluffs project limits. The following few pages will highlight the key features of the culvert design and demonstrate the environmental enhancements on Cotton Creek that resulted from the creative application of engineering principles and environmental science.

Background

Years of accidents and negative publicity prompted the BC MoT to reconstruct 6.5 kilometers of existing highway through Moyie Bluffs at the cost of $16M. McElhanney Consulting Services Ltd. was retained as the prime engineering consultant to provide design services for the project. This section of highway, located above the shores of Moyie Lake, is approximately 20km south of Cranbrook, as shown in Figure 1. Highway 3/95 as the main north/south transportation route for Cranbrook is vital to the economic health of the region. The lake is valued environmental commodity supporting a variety of fish species, fish habitat, riparian vegetation, and wildlife resources.

Cotton Creek, a tributary watercourse, feeds into Moyie Lake from the steep Moyie Bluff slopes above. Prior to construction, Cotton Creek consisted of a well-defined channel upstream and downstream of the highway, however flood flow discharge was not readily conveyed underneath the highway. The upslope and downslope channels were connected via a natural rock fissure that could not accommodate high volumes of water resulting in downstream and ditch line erosion and siltation as the runoff made its way to the lake below.

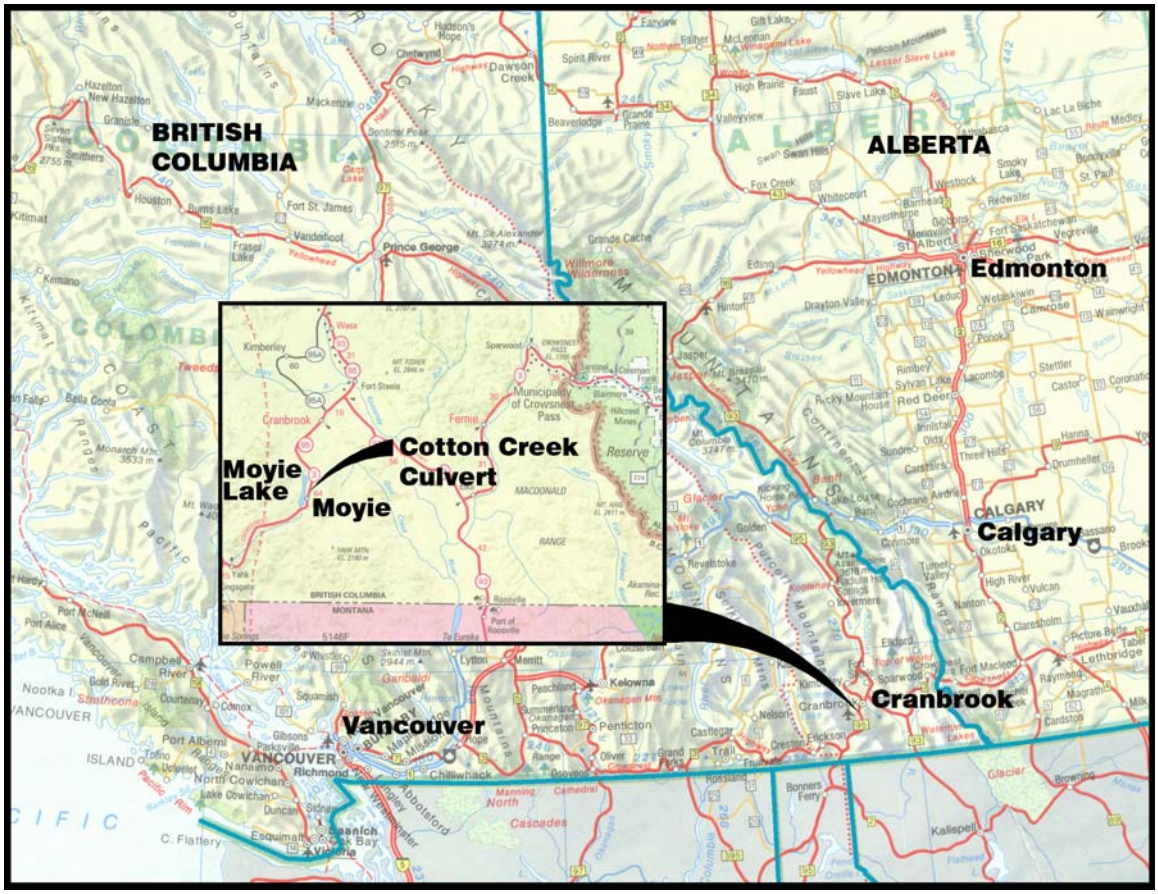

FIGURE 1 - LOCATION MAP

Moreover, the cast-in-place concrete box culvert that was constructed in 1909 under the CN Railway prevented fish passage from the lake to the portion of the Cotton Creek channel below the highway. A set of twin corrugated steel pipe culverts were retrofitted into the box culvert opening since its original construction. These perched culverts were undersized resulting in discharge velocities that were not amenable to the resident fish species.

Competing objectives revealed during the design process constrained the range of environmentally friendly solutions for the site. Project constraints included: irregular steep terrain, the location of Moyie Lake, the proximity of the CP Railroad, property access to lake front lots and environmental considerations of Cotton Creek.

Evaluating Drainage Structure Alternatives:

Typically in British Columbia, the traditional methods of enhancing fish bearing creeks and rivers that intersect roadways is to lengthen the channel by increasing its sinuosity through the introduction of back channels or habitat construction along the main reach of the primary channel. In effect, this serves to reduce the gradient of the watercourse reducing the velocity of flow to a level acceptable to resident species of fish. Gradient reductions or channel lengthening are the typical solutions in BC since the terrain is fairly mountainous and many creeks and streams have natural barriers to fish.

Back channels, if selected as a rehabilitation technique for Cotton Creek, would have significantly increased property acquisition requirements. The requirement to maintain access to a number of private properties adjacent to Cotton Creek combined with back channel installation would have presented unacceptable demands on available property. Several lots would have required expropriation resulting in negative public relations without a significant increase in habitat production. In addition, back channel construction alone would not have eliminated the fish passage barriers associated with the retrofitted culverts installed under the CP Railway.

Habitat construction along the primary reach of the channel, such as the installation of plunge pools would have been of limited value at Cotton Creek. Illustrated in Figure 2, plunge pools, typically constructed of cast in place concrete, are also designed to mitigate the adverse effects of steep slopes along an existing channel. The concrete boxes are backfilled with gravel, providing a place for the fish to spawn and rest during upstream migration.

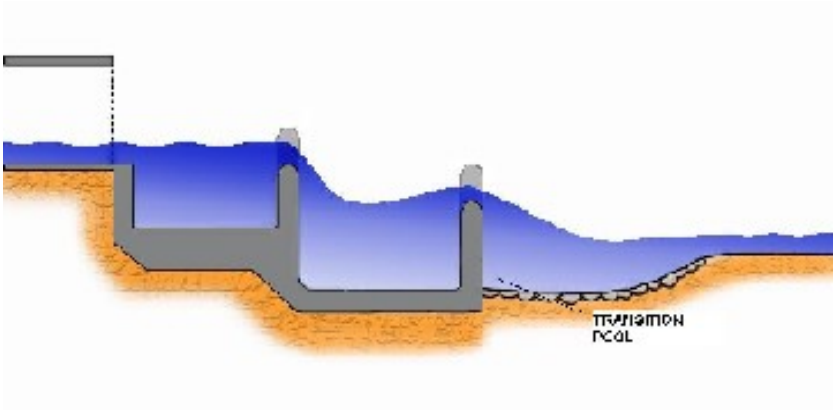

FIGURE 2 – TYPICAL PLUNGE POOL INSTALLATIONS

It was acknowledged that the traditional creek enhancement methodologies would not adequately address the unique site characteristics of Cotton Creek. A bridge or large culvert would be required at the highway crossing location to accommodate the design discharge without impacting the highway or compromising the integrity of the down stream infrastructure or environment.

Bridge and culvert options were investigated however, based on the design discharge, it was quickly determined that a ±30m long bridge would be required. A structure of this magnitude would require ±10m high abutments and would present difficulties in connecting adjacent properties to the highway. A bridge structure was also a concern as the resulting channel would be steep, resulting in high flow velocities with the potential to scour the downstream channel.

A 1950mm diameter precast concrete culvert complete with velocity reducing baffles was therefore selected as the preferred hydraulic structure for Cotton Creek. Figure 3 shows a plan view of the new highway and the key physical components of the design. It also illustrates the relative distances between Moyie Lake, the railway and the highway.

Environmental Design Optimization for Cotton Creek Culvert:

It was recognized that the passage of anadromous fish species to Cotton Creek upstream of the highway was neither possible nor appropriate given the presence of natural fish barriers and lack of suitable habitat above the road. However, there was modest amount of habitat in Cotton Creek that was under utilized between the CP Railway and the highway. The goal was to incorporate a number of features into the design of the Cotton Creek culvert that would enhance this habitat and make it accessible to fish. Elimination of the CP Rail culvert barrier would be a prerequisite to this objective.

A number of opportunities for habitat compensation works were identified including meandering side channels next to Cotton Creek, and biofiltration swales to improve the water quality of surface runoff.

Channel Downstream of Highway with Headwall in Background

Natural Cave Inlet Upstream of Highway

FIGURE 3 – PLAN VIEW OF COTTON CREEK CULVERT DESIGN

A hydraulic assessment was performed on the culvert retrofit located under the CP Rail tracks. It was found that the concrete box culvert alone could adequately carry design discharge flows for Cotton Creek without adversely effecting downstream habitat. The twin corrugated steel culverts were removed and the lower reach of Cotton Creek was restored to a stable state that would facilitate fish passage.

The final design issue focused on the habitat and terrain that was available between the CP Railway and the outlet for the Cotton Creek Culvert. Several environment features were integrated into the design of the culvert to allow the proposed fish habitat to flourish. Figure 4 shows a detailed plan view of the culvert outlet illustrating the key environmental enhancement features of the design including:

- Perforated Embankment Sub Drains and Low Flow Diversion Pipes;
- Creation of Plunge Pools and Spawning Channels;
- Concrete Energy Dissipaters and Flood Containment Walls; and
- Boulder Weir Structures.

Diversion pipes were connected to natural rock fissures and installed in the culvert headwall directing creek flow to the newly created spawning channels and plunge pools. Perforated drainage pipes were installed in the embankment fill and directed to the spawning channel as well, further supplementing the baseline flow. These features provide a consistent, regular flow as regulated by the capacity of the rock opening upstream of the highway, the runoff in the creek, and the water intercepted from the embankment. The low flow diversion pipes were sized to provide an oxygenated water source for the spawning channels.

The energy dissipaters and concrete flood containment walls ensured that the resulting flood discharge would not cause undue erosion to the downstream sections of Cotton Creek or damage the installed fish habitat.

Boulder weir structures were incorporated into the channel rehabilitation downstream of the culvert and also within the spawning channels to regulate flow and provide gradient differentials that could be navigated by the resident fish species in Moyie Lake.

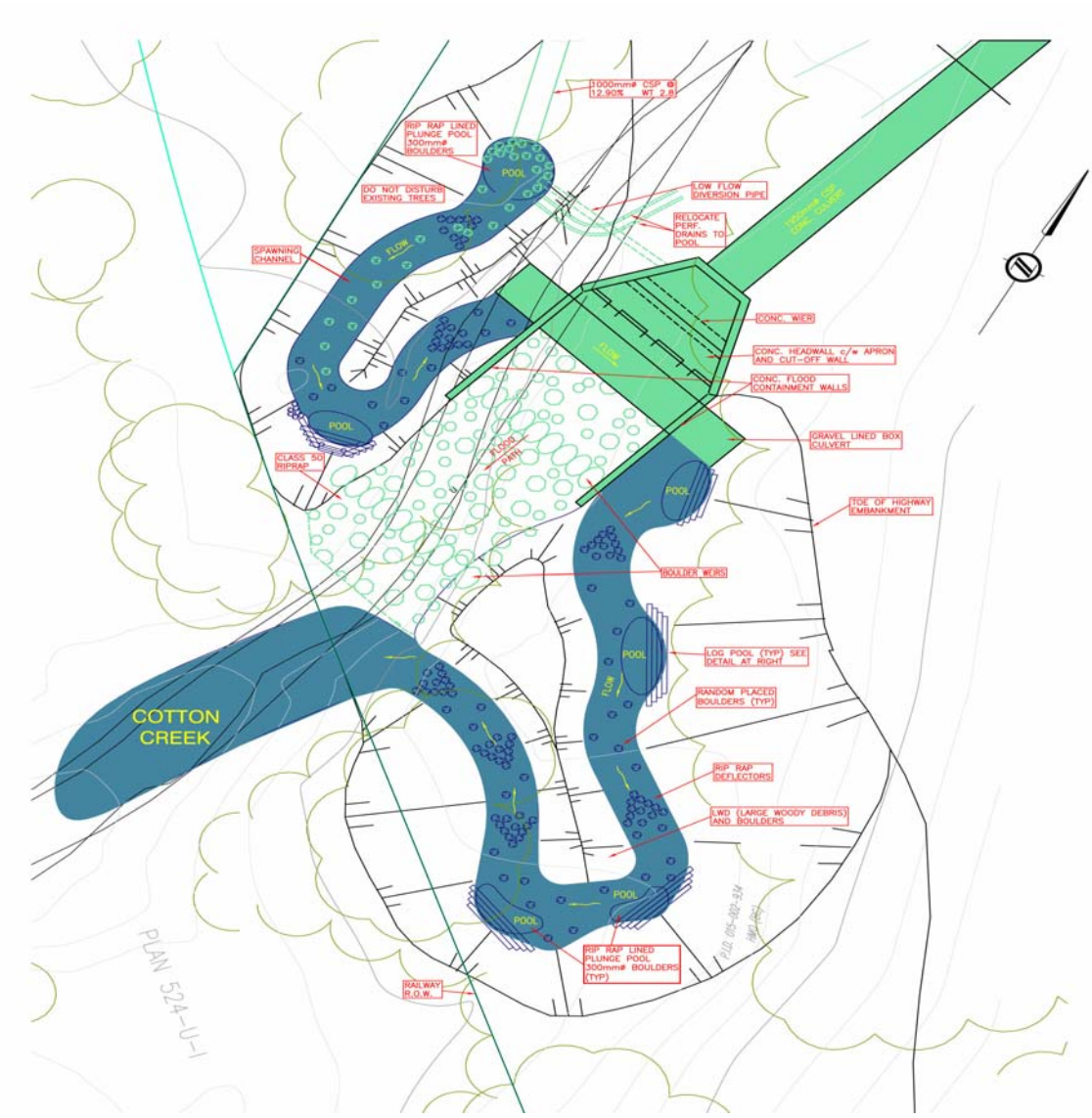

FIGURE 4 – ENVIRONMENTAL ENAHNCEMENT DETAILS

Notable environmental features of the Cotton Creek enhancement project included:

- A combined outlet headwall with construction of a box culvert under the apron separated flows protecting the spawning channel from erosion (see Photo 2);
- Embedded box culvert provides good shade during summer and is an excellent wintering location for fish;
- Construction of 75 m of spawning channel habitat that includes a mixture of pools, riffles, runs and overhangs;
- Planting of indigenous tree and shrub species on both banks of the new spawning channel to provide shade and overhead cover;

- Removal of two culverts under their railway tracks at Cotton Creek, restoring fish passage and habitat; and
- Discharge of ground water from the engineered fill is directed to the spawning channel to assist with periods of low flow.

These features were all implemented at a lower cost than traditional plunge pool or back channel construction and resulted in the creation of more quality habitat.

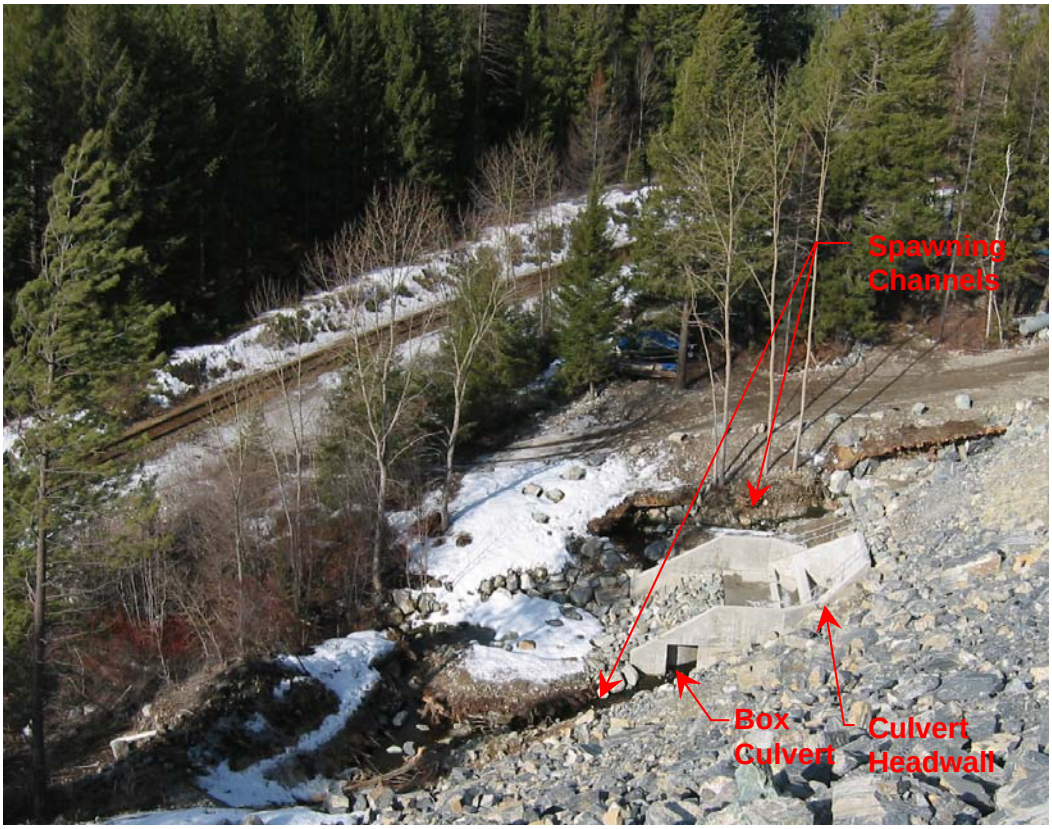

PHOTO 1 – SPAWNING CHANNELS AND CULVERT OUTLET

PUBLIC OPINION SWAYED FOLLOWING IMPLEMENTATION OF DESIGN

Newspapers and the media initially viewed the project in a negative light focusing on the impact to the environment. The facts of the project and the environmental features of the design were presented to the media in response. The public was supportive of the project once made aware of the environmental enhancement features of the design.

PHOTO 2 – OVERFLOW OUTLET PROTECTION FOR SPAWNING CHANNEL

PROJECT SUCCESS MEASURED BY NUMBER OF FISH

Prior to construction, the habitat above the railway culvert in Cotton Creek was marginal for spawning consisting of large cobble material and scoured step pools. The new habitat provides suitable substrate in a stable environment that supports excellent feeding and spawning habitat for the various fish species resident to Moyie Lake. The innovative design protects the channel from the potentially destructive force of high flows, yet through low flow design consideration prevents dry-ups during drought. This was accomplished for a lower capital cost than traditional rehabilitation alternatives.

Photo 3 shows the East Kootenay MLA and MoT Representative enjoying a photo opportunity at Cotton Creek with hundreds of spawning Kokanee Salmon. This is a sight not seen in recent history at Cotton Creek.

PHOTO 3 – KOKANEE SALMON RETURN COTTON CREEK TO LIFE

Through innovative environmental engineering the spawning habitat at Cotton Creek was restored. Flow is maintained during times of drought while the habitat is protected from erosion during flood events, a key concern for any spawning channel. Providing a flood path that is physically separated from the spawning channel ensures protection of the investment for future generations.

The design principles integrated with the culvert outlet structure are readily transferable to other sites. The construction techniques presented in this submission have produced substantial benefits for Cotton Creek that could be realized in other locations where fish habitat and passage is desired. These design techniques could also serve as a retrofit solution for existing culvert or habitat enhancement projects.

Financially, this project was completed for a lower capital cost than comparable alternatives and will require virtually no maintenance beyond that expected for a 'non-fish bearing culvert'. This project demonstrates how sound environmental principles can be adapted to most situations in a cost effective, responsible manner.